Apex Exam Guidebook

Physics

Year 12 QCE

Queensland Curriculum

2026 Edition

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Apex Exam Guidebook
Physics
Year 12 QCE

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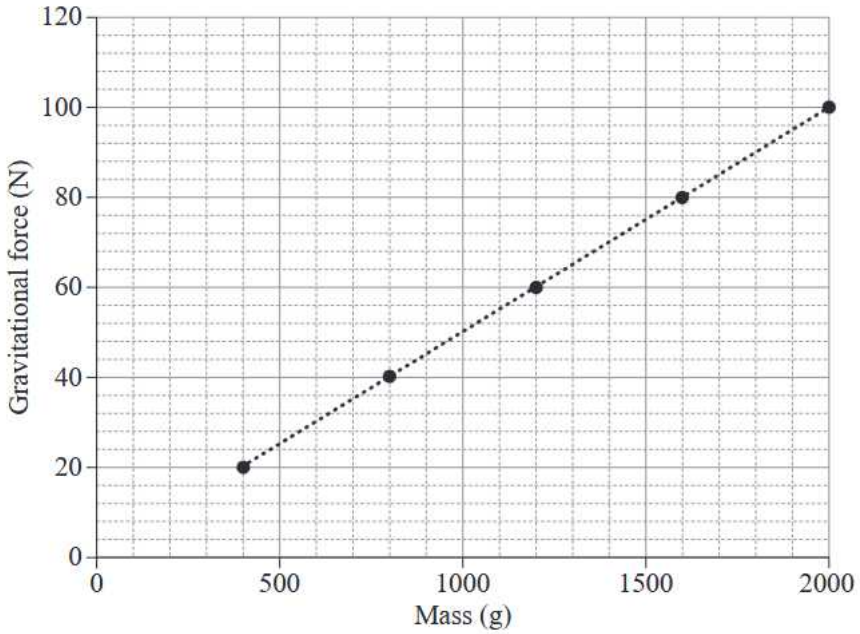
Contents

Unit 3 Gravity and electromagnetism

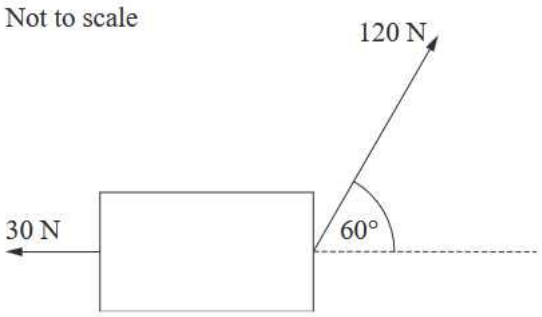
Unit 3 – Topic 1: Gravity and motion

Paper 1 Section 1

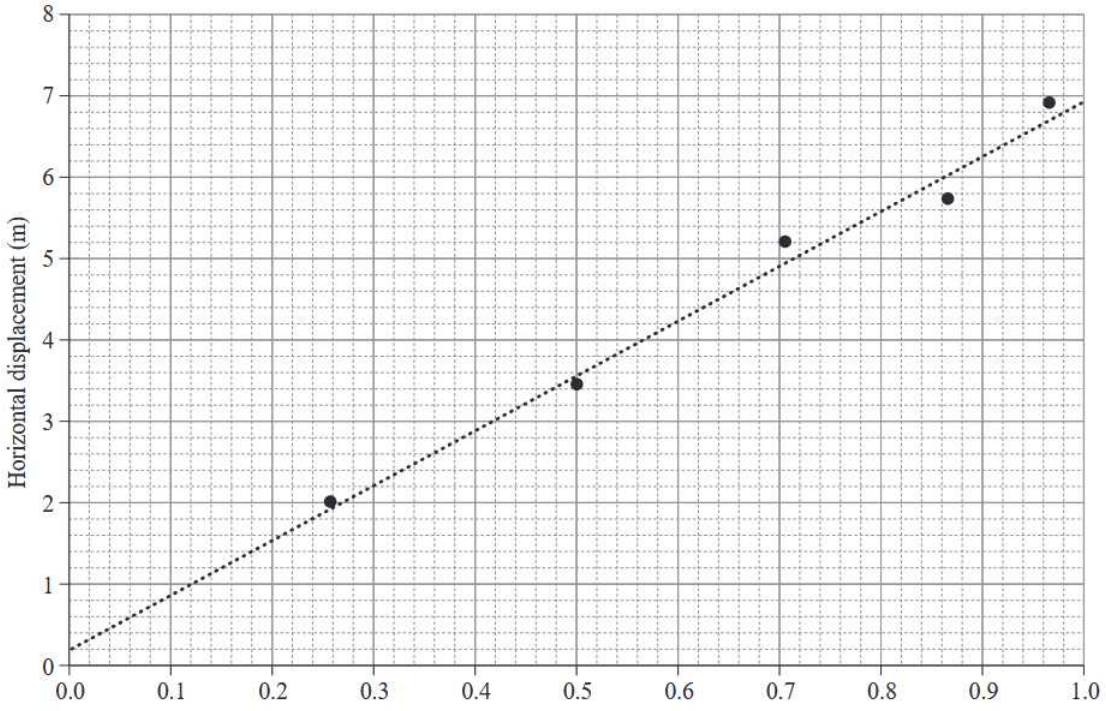
2024 Paper 1 Section 1 Question 3 Gravity and motion	Two objects with masses 65.0 kg and 75.0 kg respectively are separated by 1.50 m. What is the gravitational force of attraction between them? (A) 3.08×10^{-14} N (B) 3.25×10^{-7} N (C) 2.17×10^{-7} N (D) 1.45×10^{-7} N

2024 Paper 1 Section 1 Question 6 Gravity and motion	The graph shows the relationship between the masses of different objects and the gravitational force they experience on an unknown planet's surface.  Determine the gravitational field strength for an object at the planet's surface. (A) 0.02 m s^{-2} (B) 0.05 m s^{-2} (C) 20 m s^{-2} (D) 50 m s^{-2}

2024 Paper 1 Section 1 Question 7 Gravity and motion	An object experiencing a gravitational force of 50.0 N moves down a frictionless incline of 40.0° to the horizontal. Calculate the net force acting on the object. (A) 32.1 N (B) 37.3 N (C) 38.3 N (D) 42.0 N

2024 Paper 1 Section 1 Question 8 Gravity and motion	An object is pulled in two different directions as shown.  What is the magnitude of the net horizontal force acting on the object? (A) 100 N (B) 90 N (C) 70 N (D) 30 N

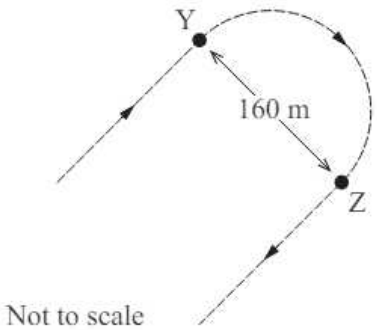
2024 Paper 1 Section 1 Question 11 Gravity and motion	A planet orbiting a star has an orbital radius of 6.4×10^{14} m and completes a full revolution every 1.5 Earth years. What is the mass of the star? (A) 2.0×10^{17} kg (B) 8.0×10^{18} kg (C) 6.9×10^{40} kg (D) 3.3×10^{48} kg

2024 **Paper 1** **Section 1** **Question 12** **Gravity and motion**	The horizontal displacement of an object experiencing projectile motion was measured and recorded against the cosine of the launch angle (i.e. the angle up from the horizontal). The initial velocity was kept constant.  What launch angle would cause the object to land 1.0 m from its starting position? (A) 0.12° (B) 1.0° (C) 6.9° (D) 83°

2024 **Paper 1** **Section 1** **Question 15** **Gravity and motion**	In which direction does the centripetal force act? (A) towards the centre of motion (B) away from the centre of motion (C) opposite to the object's direction of motion (D) tangentially to the object's direction of motion

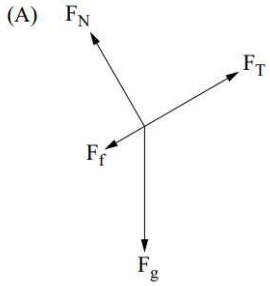
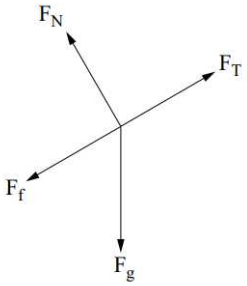
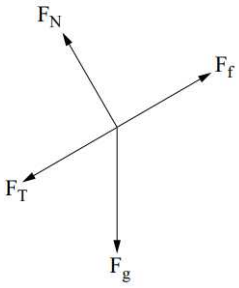
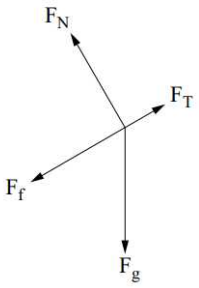
2024 **Paper 1** **Section 1** **Question 19** **Gravity and motion**	A 7 μC charge requires 1.5×10^{-8} J of energy to be moved between two points in an electric field. What is the order of magnitude of the potential difference between the two points? (A) 10^{-2} V (B) 10^{-3} V (C) 10^{-9} V (D) 10^{-13} V

2023 **Paper 1** **Section 1** **Question 4** **Gravity and motion**	Kepler's third law (A) describes the elliptical orbit of planets. (B) combines Newton's first law of motion with uniform circular motion. (C) equates the area of the arc sweep of a planet to the time taken to complete it. (D) describes the relationship between uniform circular motion and the Law of Universal Gravitation.

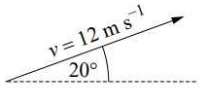
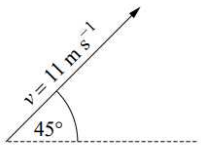
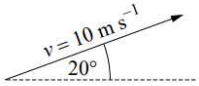
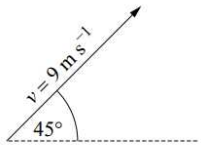
2023 Paper 1 Section 1 Question 6 Gravity and motion	An object of mass 6.0×10^2 kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.  Calculate the centripetal force experienced by the object as it moves from Y to Z. (A) 3.0×10^3 N (B) 7.6×10^2 N (C) 3.8×10^2 N (D) 7.6×10^1 N

2023 Paper 1 Section 1 Question 15 Gravity and motion	Two objects experience a gravitational force, F, between them. Calculate the magnitude of the force acting between the two objects if the distance between them was doubled and the mass of one object was doubled. (A) $\frac{1}{4}F$ (B) $\frac{1}{2}F$ (C) $1\,F$ (D) $2\,F$

2023 Paper 1 Section 1 Question 18 Gravity and motion	A 20 kg object is placed on an inclined plane with a slope of 35°. If the object experiences a frictional force of 40 N and no additional applied force, calculate its acceleration down the inclined plane. (A) 3.6 m s^{-2} (B) 5.6 m s^{-2} (C) 6.0 m s^{-2} (D) 7.6 m s^{-2}

2022 Paper 1 Section 1 Question 3 Gravity and motion	Which free body diagram best represents an object being pulled at a constant speed up an inclined plane? (A)  (B)  (C)  (D) 

2022 Paper 1 Section 1 Question 4 Gravity and motion	An object orbiting Earth has an orbital period of 5.6×10^3 s. What is the object's orbital radius? (A) 3.8×10^5 m (B) 6.8×10^6 m (C) 1.8×10^{10} m (D) 1.3×10^{12} m

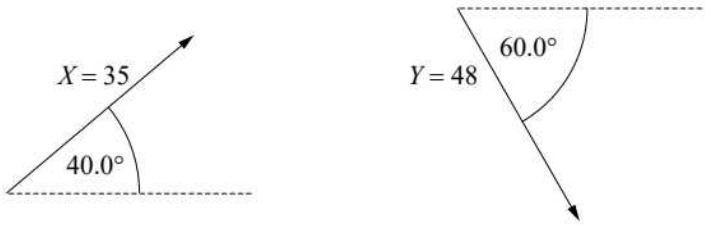
2022 Paper 1 Section 1 Question 9 Gravity and motion	Which diagram would result in the furthest horizontal distance travelled? (A)  (B)  (C)  (D)  Not to scale

2022 Paper 1 Section 1 Question 12 Gravity and motion	An object experiencing uniform circular motion in a horizontal plane travels at an average speed of 8.0 m s^{-1}. Calculate the radius of the object's path if it takes 0.3 s to complete a full rotation. (A) 3.8×10^{-1} m (B) 2.6×10^0 m (C) 1.5×10^1 m (D) 1.7×10^2 m

2022 Paper 1 Section 1 Question 16

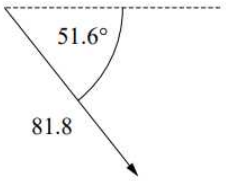
Gravity and motion

Two vectors are shown.

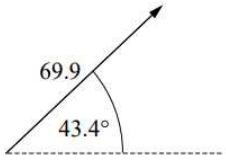


Which option represents the resultant vector of $X + Y$?

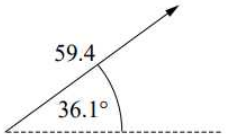
(A)



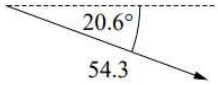
(B)



(C)



(D)



Not to scale

2022 Paper 1 Section 1 Question 17

Gravity and motion

An object is in orbit 400 km above the surface of the Earth. The Earth has a radius of 6.4×10^6 m.

What is the magnitude of the gravitational field strength experienced by the object?

(A) 8.6×10^0 m s^{-2}
(B) 9.7×10^0 m s^{-2}
(C) 2.5×10^3 m s^{-2}
(D) 5.9×10^7 m s^{-2}

2021 Paper 1 Section 1 Question 2

Gravity and motion

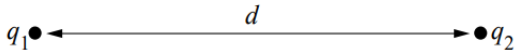
Calculate the initial horizontal velocity of a projectile with an initial velocity of 38 m s^{-1} at an angle of 42° up from the horizontal.

(A) 25 m s^{-1}
(B) 28 m s^{-1}
(C) 34 m s^{-1}
(D) 40 m s^{-1}

2021 Paper 1 Section 1 Question 4

Gravity and motion

The diagram shows two charges (q_1 and q_2) separated by a distance (d).

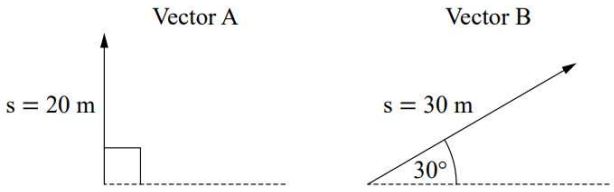


There is a force, F, acting between the two charges.

Calculate the magnitude of the force acting between the two charges if d is halved and the charge of q_2 is doubled.

(A) 1F
(B) 2F
(C) 4F
(D) 8F

2021 **Paper 1** **Section 1** **Question 7** **Gravity and motion**	*Normal force* is the force acting along an imaginary line (A) parallel to the surface. (B) perpendicular to the surface. (C) opposite to the gravitational force. (D) in the same direction as the gravitational force.

2021 **Paper 1** **Section 1** **Question 8** **Gravity and motion**	The diagram shows two displacement vectors.  Calculate the resultant vector above the horizontal axis when Vector A is added to Vector B. (A) 43.6 m at 36.6° (B) 43.6 m at 53.4° (C) 48.4 m at 18.1° (D) 48.4 m at 71.9°

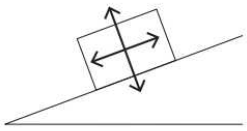
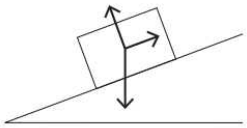
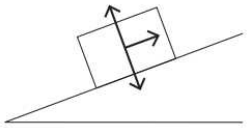
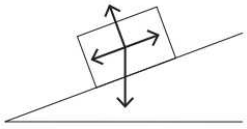
2021 **Paper 1** **Section 1** **Question 11** **Gravity and motion**	Uniform circular motion occurs when an object is travelling in a circle at a constant (A) speed, due to a force of constant magnitude acting in a parallel direction to its velocity. (B) velocity, due to a force of constant magnitude acting in a parallel direction to its speed. (C) speed, due to a force of constant magnitude acting in a perpendicular direction to its velocity. (D) velocity, due to a force of constant magnitude acting in a perpendicular direction to its speed.

2021 **Paper 1** **Section 1** **Question 12** **Gravity and motion**	Calculate the maximum height reached by a projectile with an initial velocity of 15 m s^{-1} at an angle of 30° up from the horizontal. (A) 2.87 m (B) 3.83 m (C) 8.61 m (D) 11.5 m

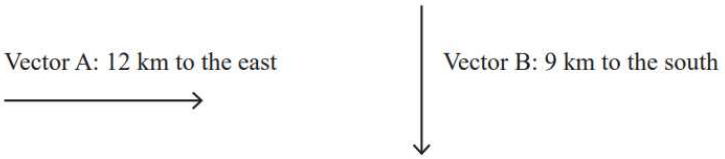
2021 **Paper 1** **Section 1** **Question 13** **Gravity and motion**	Calculate the orbital period of a satellite travelling around the Earth with a radius of 4.00×10^8 m. (A) 3.49×10^{-2} hours (B) 3.94×10^2 hours (C) 6.99×10^2 hours (D) 1.76×10^9 hours

2021 **Paper 1** **Section 1** **Question 16** **Gravity and motion**	The weight of a 5 kg object on Earth is (A) 0.49 N (B) 0.51 N (C) 49 N (D) 51 N

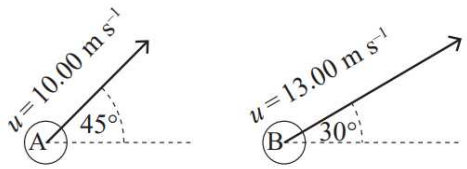
2021 **Paper 1** **Section 1** **Question 18** **Gravity and motion**	A gravitational field is the (A) net gravitational force per unit mass at a particular point in space. (B) energy stored in an object as a result of its position relative to another object. (C) region of space surrounding a body in which another body experiences a force of gravitational attraction. (D) position in space where objects experience a force or acquire potential energy as they are 'worked' into that position.

2020 **Paper 1** **Section 1** **Question 1** **Gravity and motion**	Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane? (A)  (B)  (C)  (D) 

2020 **Paper 1** **Section 1** **Question 2** **Gravity and motion**	The definition of *average speed* is the rate of change of (A) velocity. (B) distance. (C) acceleration. (D) displacement.

2020 **Paper 1** **Section 1** **Question 3** **Gravity and motion**	The diagram shows two vectors.  Calculate the magnitude of the resultant vector when Vector A is added to Vector B. (A) 15 km (B) 16.5 km (C) 21 km (D) 108 km

2020 **Paper 1** **Section 1** **Question 8** **Gravity and motion**	An object 46 m above the ground is projected horizontally, with an initial velocity of 25 m s^{-1}. Calculate the horizontal displacement of the object at the time it reaches the ground. (A) 77 m (B) 120 m (C) 190 m (D) 240 m

2020 **Paper 1** **Section 1** **Question 11** **Gravity and motion**	The diagram shows object A and object B being projected at different velocities.  Which of the following statements is true? (A) Object A has a shorter flight time than object B. (B) Object A has a smaller maximum height than object B. (C) Object A has a larger horizontal velocity than object B. (D) Object A has a smaller horizontal displacement than object B.

2020 **Paper 1** **Section 1** **Question 12** **Gravity and motion**	Which of the following is one of Kepler's laws of planetary motion? (A) The laws of physics are the same in all inertial frames of reference. (B) All planets move about the Sun in elliptical orbits, having the Sun as one of the foci. (C) The speed of light in a vacuum has the same value, c, in all inertial frames of reference. (D) The force of attraction between each pair of point particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

2020 **Paper 1** **Section 1** **Question 15** **Gravity and motion**	Calculate the orbital period of a satellite travelling on a 3.00×10^8 m radius orbit around the Earth. (A) 1.44×10^{-2} hours (B) 4.54×10^{2} hours (C) 1.64×10^{6} hours (D) 7.44×10^{8} hours

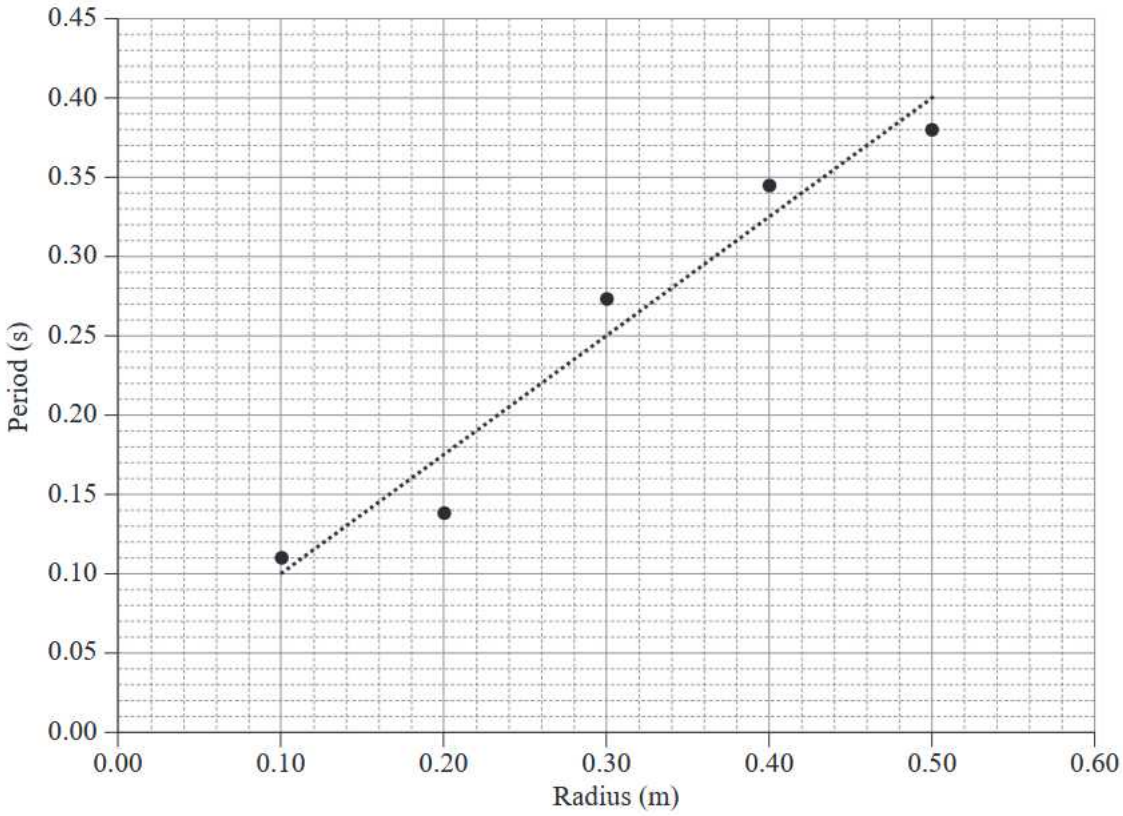
2020 **Paper 1** **Section 1** **Question 18** **Gravity and motion**	Calculate the initial vertical velocity of a projectile with an initial velocity of 68 m s^{-1} at an angle of 51° up from the horizontal. (A) 43 m s^{-1} (B) 51 m s^{-1} (C) 53 m s^{-1} (D) 68 m s^{-1}

2024
Paper 1
Section 2
Question 23

Gravity and motion

An experiment was conducted to study an object undergoing circular motion, with the radius of motion acting as the independent variable and the speed kept constant.

The data comparing the period and radius of motion is shown. [4 marks]



a) Identify the period expected for a 25 cm radius of motion. [1 mark]

Period = _____ s

b) Determine the constant speed of the object. Show your working. [3 marks]

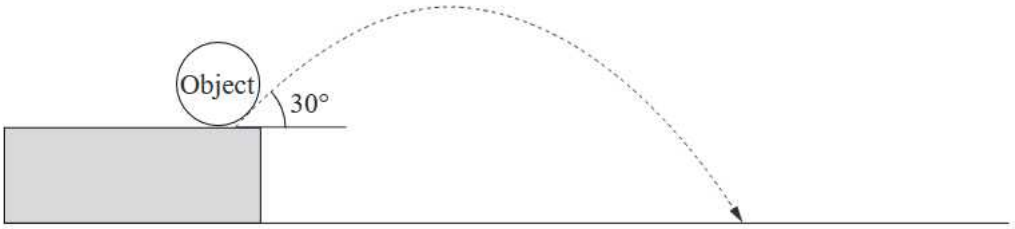
Speed = _____ m s^{-1}

2024
Paper 1
Section 2
Question 27

Gravity and motion

On another planet, an object was projected upwards from an initial height and took 0.71 s to land.

Not to scale



The relationship between vertical displacement (m) and time (s) is $s_y = -5.18t^2 + 3.5t$.

Determine the horizontal displacement of the object when it lands.

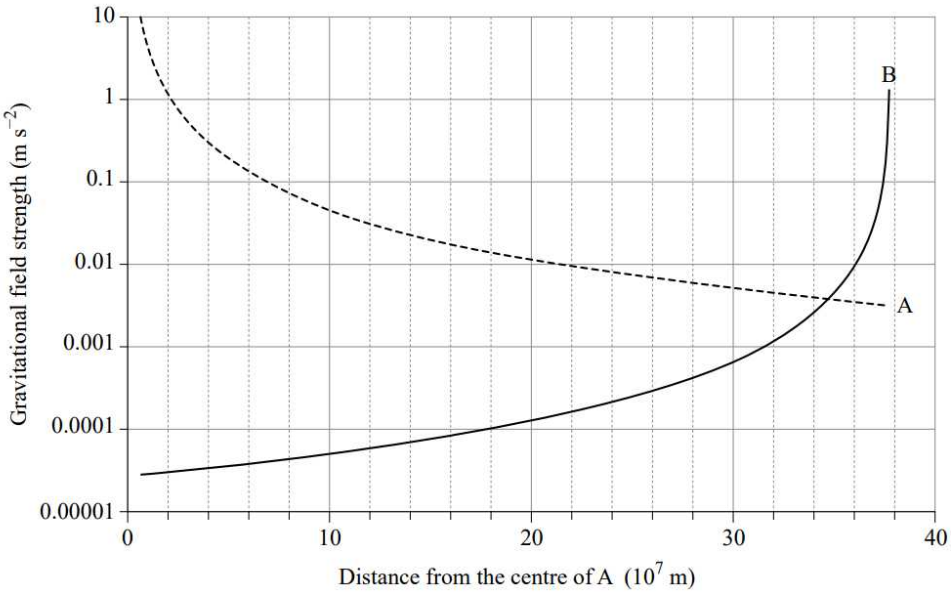
Horizontal displacement = _____ m

2023 **Paper 1** **Section 2** **Question 27** **Gravity and motion**	A satellite orbits a planet of mass 6.42×10^{23} kg at a height of 5000 km from the surface. The planet has a diameter of 6780 km. Determine the speed required for the satellite to maintain its orbit. Show your working. (5 marks) Speed = _____ m s^{-1} (to two significant figures)

2022
Paper 1
Section 2
Question 27

Gravity and motion

Object A is five times the mass of object B. The graph shows the contribution of each object towards the strength of the net gravitational field between them.

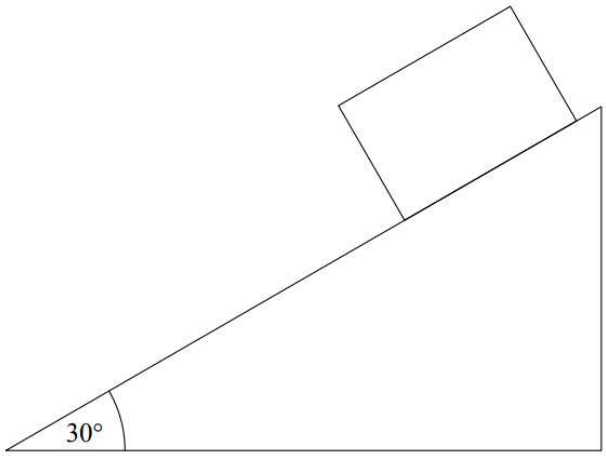


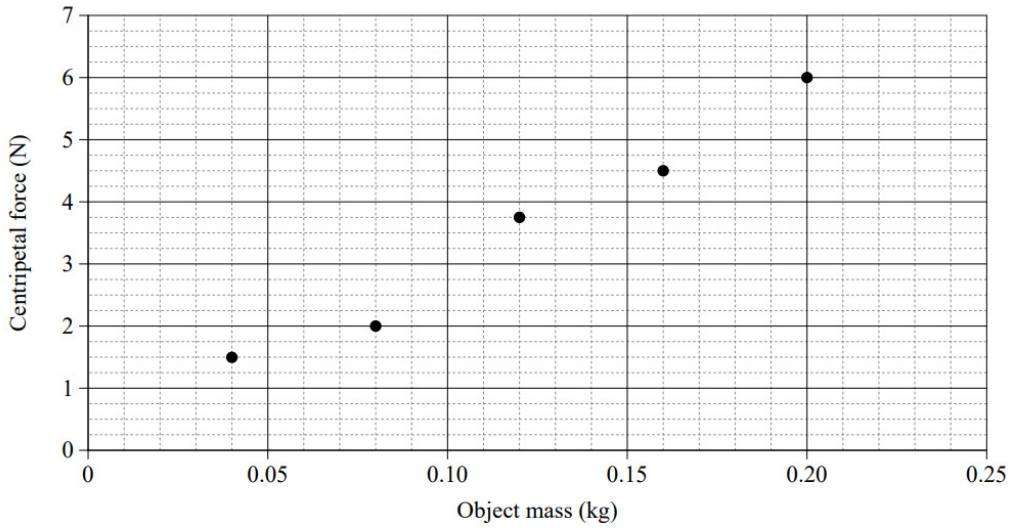
Determine the total distance between the centre of the two objects. Show your working. [5 marks]

Total distance = _____ m (to two significant figures)

2022 **Paper 1** **Section 2** **Question 28** **Gravity and motion**	An object of mass 200 g moves in a uniform circular path with a radius of 25 cm. The time taken for 10 revolutions is 3.0s. a) Calculate the distance travelled by the object after 3.9 s. Show your working. [2 marks] Distance = _____ m (to two significant figures) b) Calculate the centripetal force acting on the object. Show your working. [5 marks] Centripetal force = _____ N (to two significant figures)

2021 **Paper 1** **Section 2** **Question 22** **Gravity and motion**	A planet is orbiting a 3.38×10^{31} kg star. The radius of the orbit is 4.23×10^{8} km. Calculate the average speed of the planet. [3 marks] Average speed = _____ m s^{-1} (to the nearest whole number)

2021 **Paper 1** **Section 2** **Question 24** **Gravity and motion**	The diagram shows a 1.5 kg object on an inclined plane with an angle of 30° up from the horizontal.  Not to scale The object experiences a frictional force of 4.5 N. Calculate the magnitude of the net force acting on the object. [3 marks] Magnitude of net force = _____ N (to 1 decimal place)

2021 Paper 1 Section 2 Question 25 Gravity and motion	The graph shows the centripetal forces required to keep objects with different mass in uniform circular motion with a constant speed and constant radius of 20 cm.  Determine the speed of the objects. [4 marks] Speed = _____ m s^{-1} (to 1 decimal place)

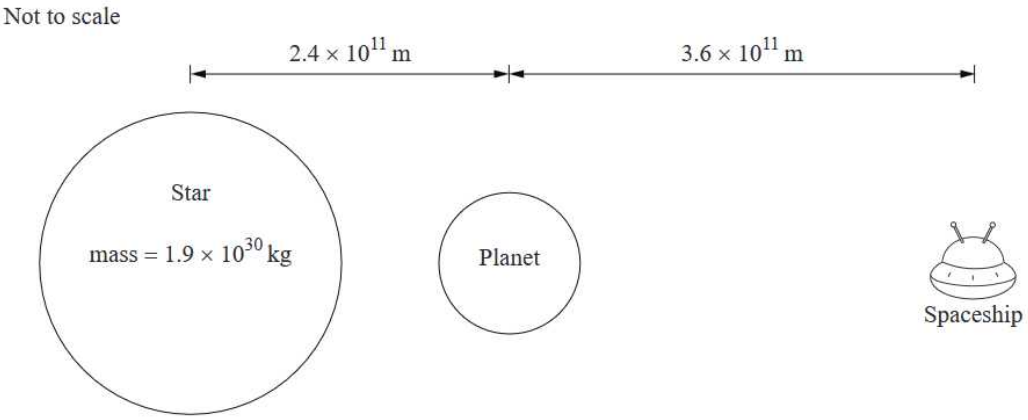
2020 Paper 1 Section 2 Question 21 Gravity and motion	An object that is 7.12 × 6 10 m from the centre of the Earth experiences a gravitational force of 2.84 kN. Calculate the mass of the object. [3 marks] Mass = _____ kg (to the nearest whole number)

2020 Paper 1 Section 2 Question 25 Gravity and motion	Mars has an average orbital radius of approximately 1.5 times the average orbital radius of Earth. Calculate the time it takes Mars to orbit the Sun. [3 marks] Time = _____ days (to the nearest whole number)

2024 Paper 2 Section 1 Question 2

Gravity and motion

In a distant solar system, a star, planet and spaceship are aligned as shown.



a) Calculate the strength of the star's gravitational field experienced by the spaceship.
Show your working. [3 marks]

Gravitational field strength = _____ m s^{-2}

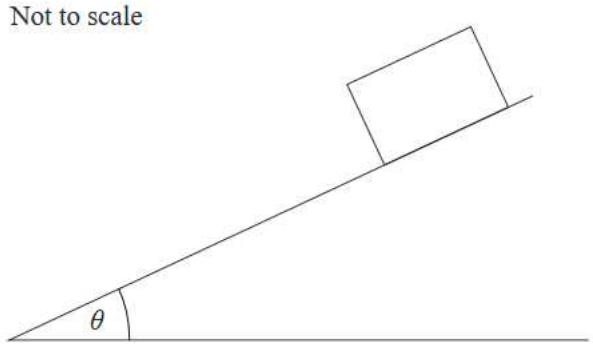
b) An observer on the planet measures the spaceship to be travelling directly towards the star at a speed of 1.9×10^8 m s–1. Calculate the distance between the spaceship and the star from the perspective of an astronaut on the spaceship. Show your working. [3 marks]

Distance = _____ m

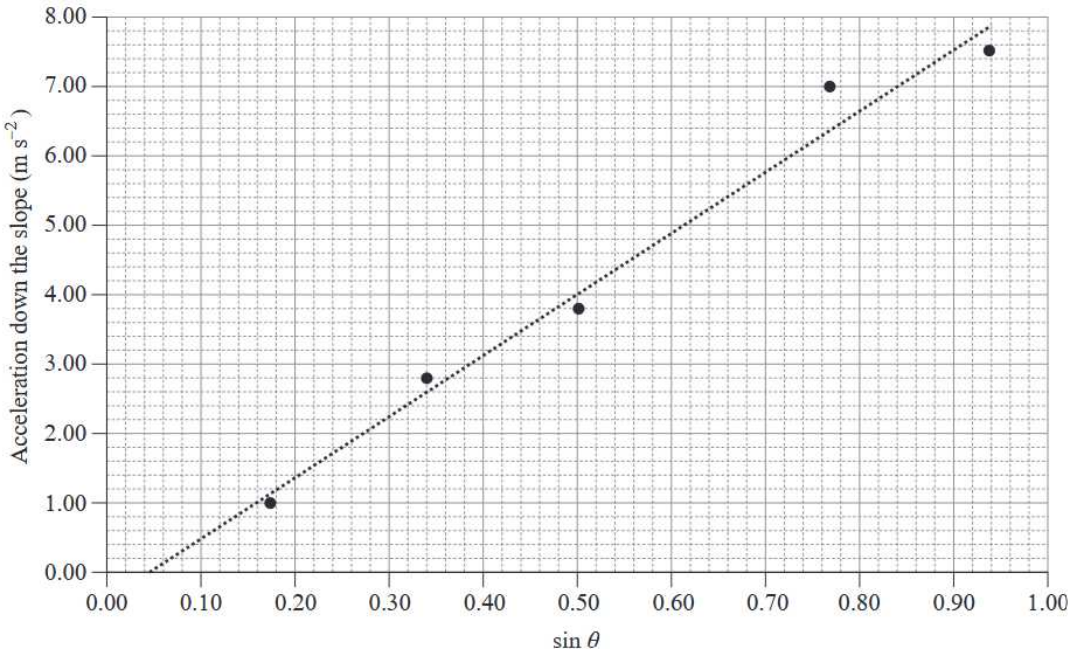
2024
Paper 2
Section 1
Question 3

Gravity and motion

A student conducted an experiment to address the following research question: What is the relationship between the angle of inclination and the acceleration from rest down a 2.4 m slope of a 0.050 kg object?



Data from the experiment was processed to produce the following graph.



a) Determine the magnitude of the frictional force acting on the object when the angle of inclination is 45°. Use the graph and show your working. [5 marks]

Magnitude of frictional force = _____ N

b) Calculate the final velocity of the object when the angle of inclination is 45°.
Show your working. [3 marks]

Final velocity = _____ m s^{-1}

2024
Paper 2
Section 1
Question 4

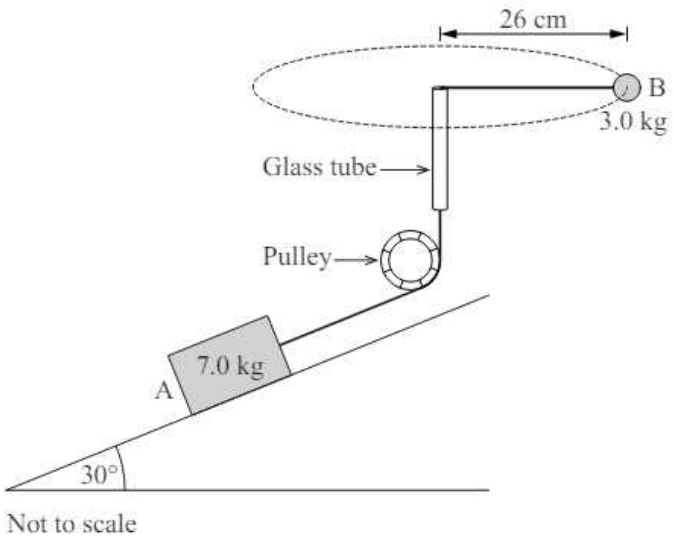
Gravity and motion

Explain how a satellite can be accelerating yet maintain a constant speed in a circular orbit around a planet. [4 marks]

2023
Paper 2
Section 1
Question 2

Gravity and motion

In a frictionless system, object A rests on an inclined plane and object B undergoes horizontal circular motion. The two objects are connected by a length of string as shown.



Not to scale

Determine the speed of object B needed for object A to remain stationary. Show your working. (5 marks)

Speed = _____ m s^{-1} (to two significant figures)

2023 Paper 2 Section 1 Question 4

Gravity and motion

Two objects on different planets experience different accelerations due to gravity.

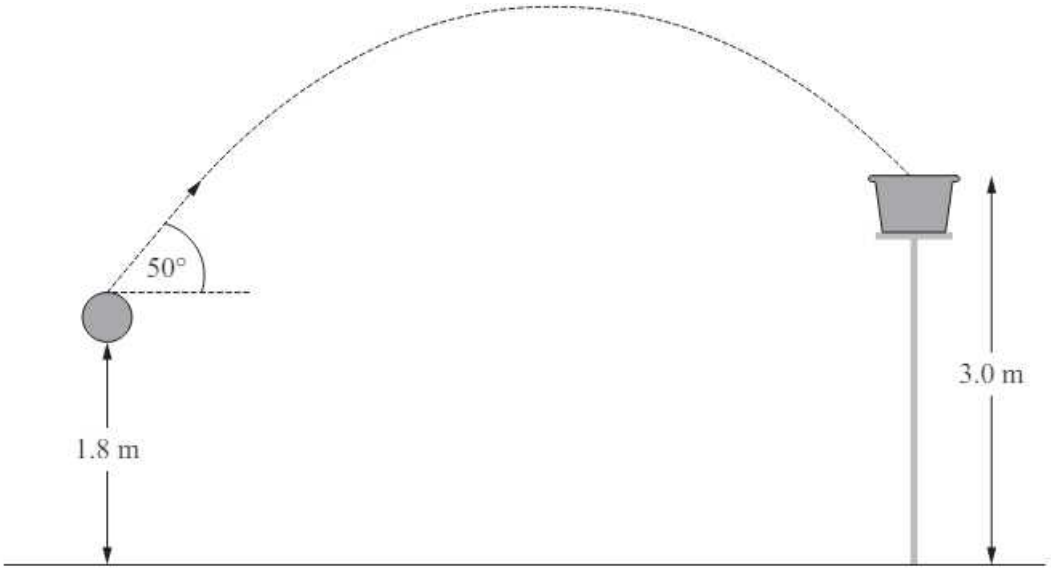
Object	Mass (kg)	Acceleration due to gravity (m s^{-2})
A	79	1.6
B	32	3.7

Determine which object has the greatest force acting on it. Show your working. (3 marks)

2023 Paper 2 Section 1 Question 6

Gravity and motion

A ball is thrown with an initial velocity of 8.0 m s^{-1} into a bucket as shown.



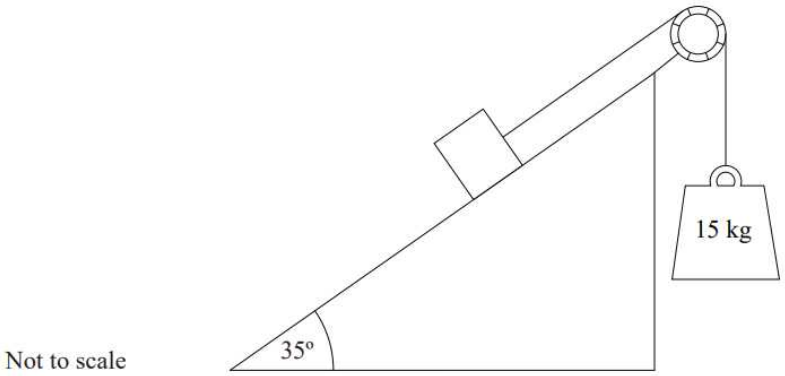
Not to scale

a) Calculate the time taken for the ball to reach its maximum height. Show your working. [4 marks]

Time = _____ s (to two significant figures)

b) Calculate the magnitude of the ball's final velocity when it enters the bucket. Show your working. [6 marks]

Final velocity = _____ m s^{-1} (to two significant figures)

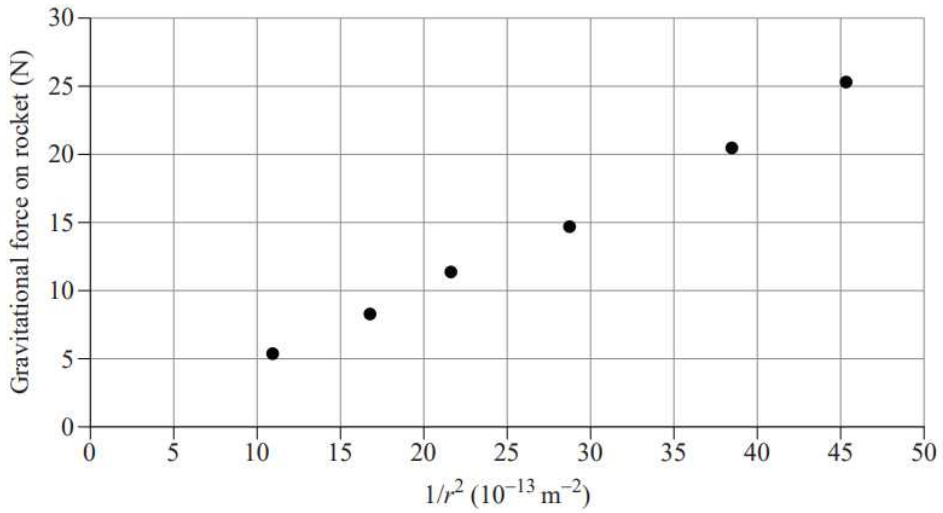
2022 Paper 2 Section 1 Question 4 Gravity and motion	A stationary object on a frictionless inclined plane is connected to a 15 kg weight as shown.  Not to scale Calculate the mass of the object on the inclined plane. [5 marks] Mass = _____ kg (to two significant figures)

2022 Paper 2 Section 1 Question 7 Gravity and motion	Two asteroids experience a gravitational force of 3.3×10^3 N between them. Their masses are 2.7×10^{17} kg and 6.1×10^{15} kg. Calculate the distance between the two asteroids. Show your working. [3 marks] Distance = _____ m (to two significant figures)

2022
Paper 2
Section 1
Question 8

Gravity and motion

The graph shows the gravitational force experienced by a rocket of mass 750 kg as it approaches an asteroid.



Determine the mass of the asteroid. Show your working. [4 marks]

Mass = _____ kg (to two significant figures)

2022 Paper 2 Section 1 Question 9

Gravity and motion

A person spins an object 4.3 m above the ground in a horizontal circular path of radius 0.8 m. They release the object horizontally, allowing it to travel to the ground.

a) Calculate the centripetal acceleration of the object before it is released, given it takes 5 s for the object to complete 12 revolutions. Show your working. [4 marks]

Centripetal acceleration = _____ m s^{-2} (to two significant figures)

b) Calculate the total horizontal displacement for the object after it is released. Show your working. [5 marks]

Total horizontal displacement = _____ m (to two significant figures)

2021 Paper 2 Section 1 Question 3 Gravity and motion	An object undergoes uniform circular motion in a path with a radius of *r*. Determine the effect on the radius if the mass of the object is doubled, but the centripetal force and velocity remain unchanged. [3 marks]

2021 Paper 2 Section 1 Question 4 Gravity and motion	A spacecraft is located between two large asteroids, Asteroid A and Asteroid B, that are 120 km apart. Asteroid A's mass is approximately four times the mass of Asteroid B. Determine the distance of the spacecraft from Asteroid B if it experiences no net gravitational force from the two asteroids. [4 marks]

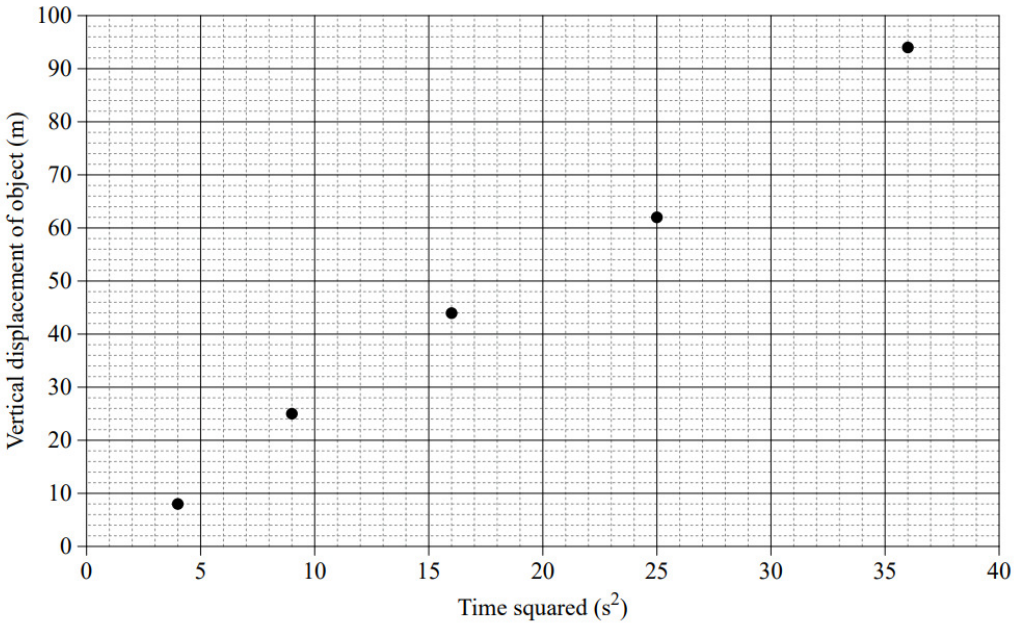
Distance from Asteroid B = _____ km (to the nearest whole number)

2021 Paper 2 Section 1 Question 7

Gravity and motion

An object on a planet is launched horizontally from a cliff. Its vertical displacement is measured over 6 seconds.

The graph shows the object's vertical displacement with respect to time squared.



a) Determine the mathematical relationship between vertical displacement (s) and time (t). [3 marks]

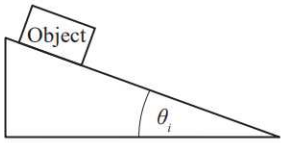
b) Calculate the acceleration due to gravity on the planet. [3 marks]

Acceleration = _____ m s^{-2} (to 2 significant figures)

2020 Paper 2 Section 1 Question 8

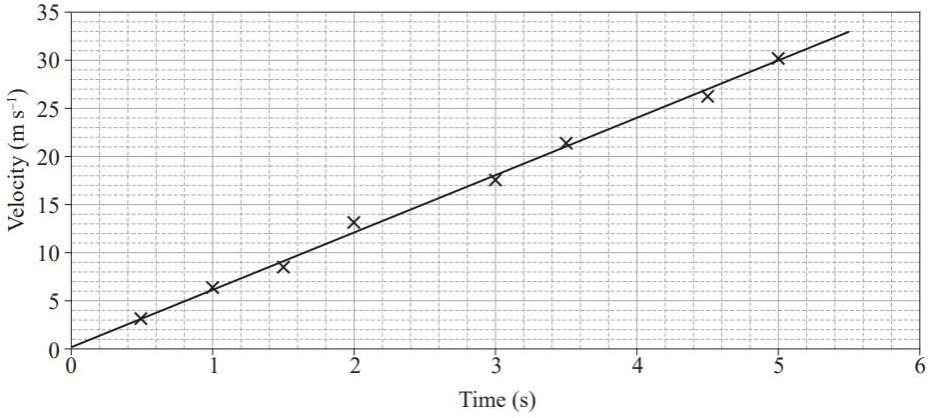
Gravity and motion

The diagram shows an object sliding down a frictionless inclined plane.



Not drawn to scale

The graph shows the velocity of the object measured at various times.



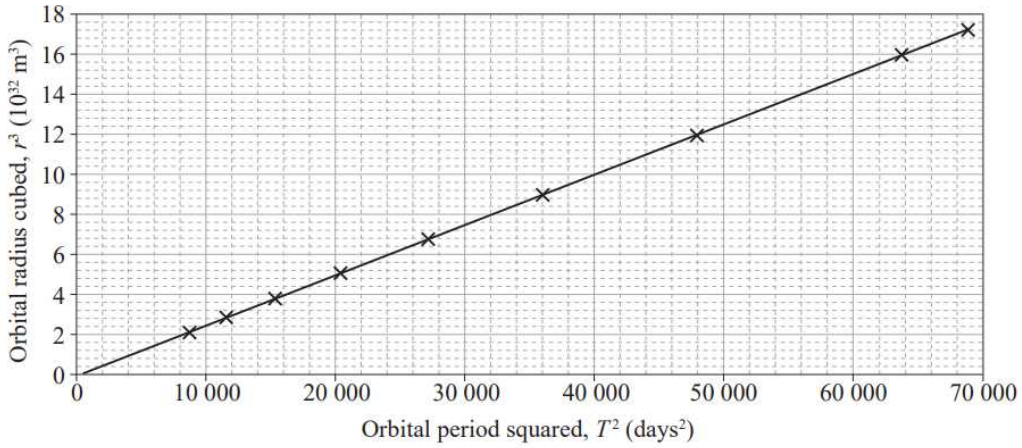
Determine the angle of incline, θ_i, of the inclined plane. Show your working

$\theta_i =$ _____ °

2020
Paper 2
Section 1
Question 9

Gravity and motion

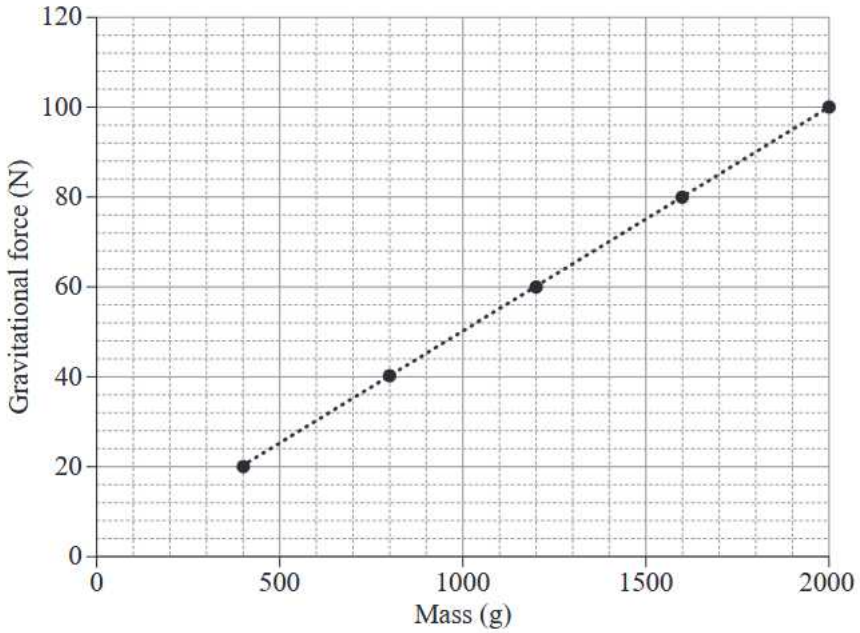
Nine planets orbit the same star. The orbital radius and orbital period of each planet was measured. The graph shows the cube of the orbital radius of each planet, r^3, compared to its orbital period squared, T^2.



Determine the mass of the star. Show your working. [5 marks]

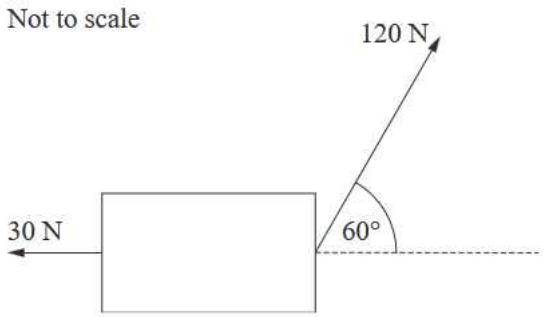
	Mass = _____ kg (to 1 decimal place)

2024 Paper 1 Section 1 Question 3 Gravity and motion	Two objects with masses 65.0 kg and 75.0 kg respectively are separated by 1.50 m. What is the gravitational force of attraction between them? (A) 3.08×10^{-14} N (B) 3.25×10^{-7} N (C) 2.17×10^{-7} N (D) 1.45×10^{-7} N **Answer is D.**

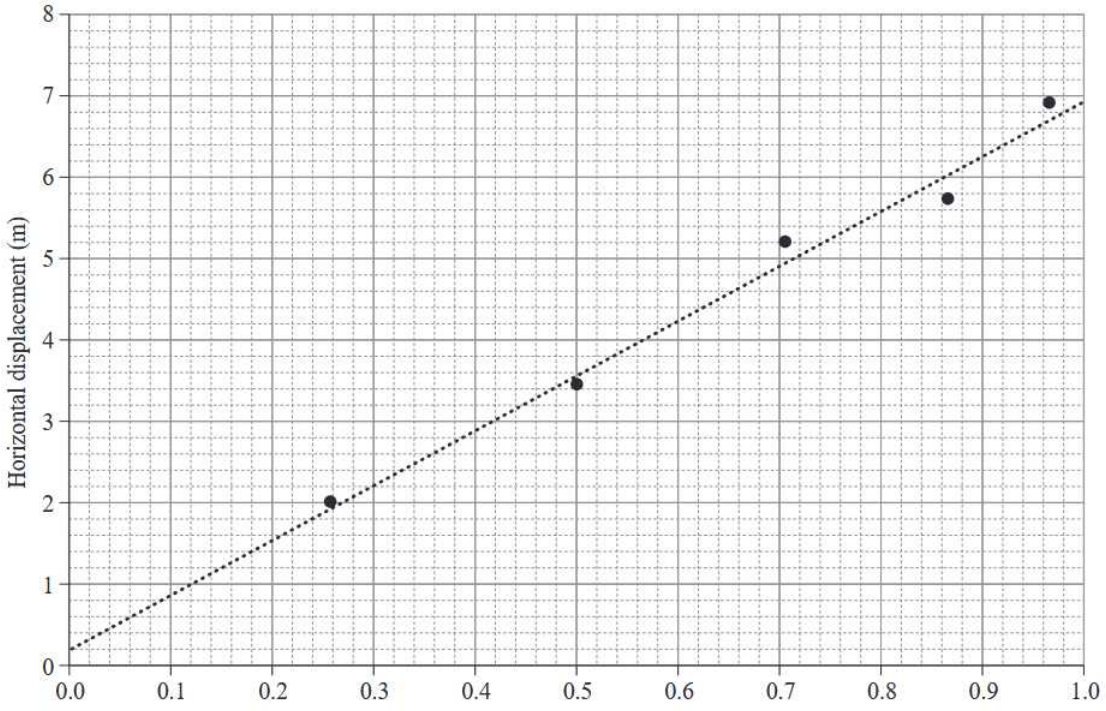
2024 Paper 1 Section 1 Question 6 Gravity and motion	The graph shows the relationship between the masses of different objects and the gravitational force they experience on an unknown planet's surface.  Determine the gravitational field strength for an object at the planet's surface. (A) 0.02 m s^{-2} (B) 0.05 m s^{-2} (C) 20 m s^{-2} (D) 50 m s^{-2} **Answer is D.**

2024 Paper 1 Section 1 Question 7 Gravity and motion	An object experiencing a gravitational force of 50.0 N moves down a frictionless incline of 40.0° to the horizontal. Calculate the net force acting on the object. **(A) 32.1 N – Answer** (B) 37.3 N (C) 38.3 N (D) 42.0 N

2024	An object is pulled in two different directions as shown.

Paper 1 Section 1 Question 8 Gravity and motion	 What is the magnitude of the net horizontal force acting on the object? (A) 100 N (B) 90 N (C) 70 N **(D) 30 N – Answer**

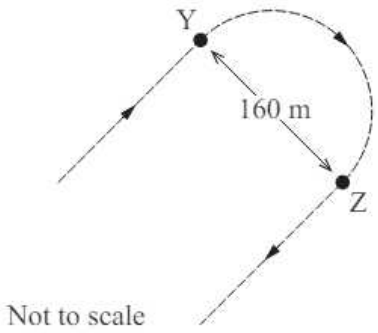
2024 Paper 1 Section 1 Question 11 Gravity and motion	A planet orbiting a star has an orbital radius of 6.4×10^{14} m and completes a full revolution every 1.5 Earth years. What is the mass of the star? (A) 2.0×10^{17} kg (B) 8.0×10^{18} kg (C) 6.9×10^{40} kg (D) 3.3×10^{48} kg **Answer is C.**

2024 Paper 1 Section 1 Question 12 Gravity and motion	The horizontal displacement of an object experiencing projectile motion was measured and recorded against the cosine of the launch angle (i.e. the angle up from the horizontal). The initial velocity was kept constant.  What launch angle would cause the object to land 1.0 m from its starting position? (A) 0.12° (B) 1.0° (C) 6.9° **(D) 83° – Answer**

2024 Paper 1 Section 1 Question 15 Gravity and motion	In which direction does the centripetal force act? **(A) towards the centre of motion – Answer** (B) away from the centre of motion (C) opposite to the object's direction of motion (D) tangentially to the object's direction of motion

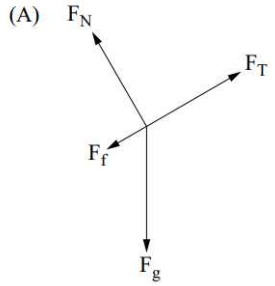
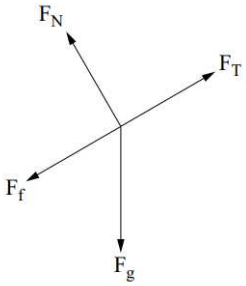
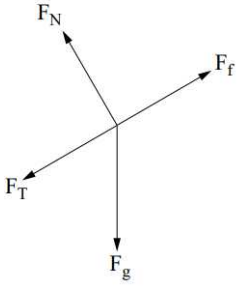
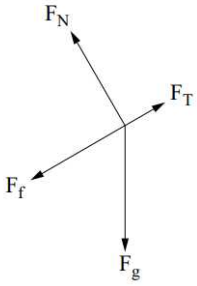
2024 Paper 1 Section 1 Question 19 Gravity and motion	A 7 μC charge requires 1.5×10^{-8} J of energy to be moved between two points in an electric field. What is the order of magnitude of the potential difference between the two points? (A) 10^{-2} V (B) 10^{-3} V (C) 10^{-9} V (D) 10^{-13} V **Answer is B.**

2023 Paper 1 Section 1 Question 4 Gravity and motion	Kepler's third law (A) describes the elliptical orbit of planets. (B) combines Newton's first law of motion with uniform circular motion. (C) equates the area of the arc sweep of a planet to the time taken to complete it. **(D) describes the relationship between uniform circular motion and the Law of Universal Gravitation. – Answer**

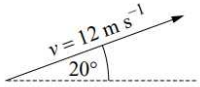
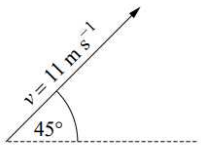
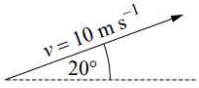
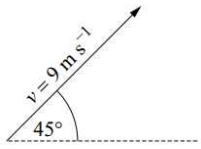
2023 Paper 1 Section 1 Question 6 Gravity and motion	An object of mass 6.0×10^2 kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.  Calculate the centripetal force experienced by the object as it moves from Y to Z. (A) 3.0×10^3 N **(B) 7.6×10^2 N – Answer** (C) 3.8×10^2 N (D) 7.6×10^1 N

2023 Paper 1 Section 1 Question 15 Gravity and motion	Two objects experience a gravitational force, F, between them. Calculate the magnitude of the force acting between the two objects if the distance between them was doubled and the mass of one object was doubled. (A) $\frac{1}{4}F$ (B) $\frac{1}{2}F$ (C) $1\,F$ (D) $2\,F$ **Answer is B.**

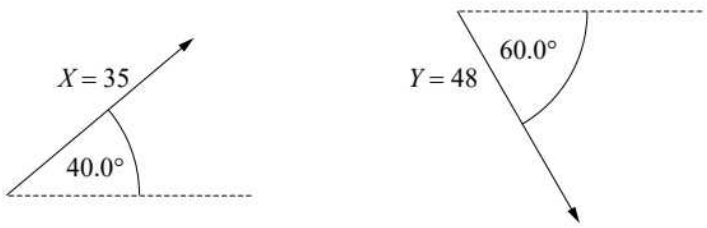
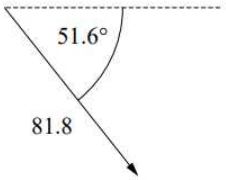
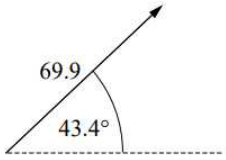
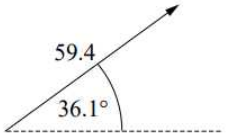
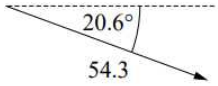
2023 Paper 1 Section 1 Question 18 Gravity and motion	A 20 kg object is placed on an inclined plane with a slope of 35°. If the object experiences a frictional force of 40 N and no additional applied force, calculate its acceleration down the inclined plane. **(A) 3.6 m s^{-2} – Answer** (B) 5.6 m s^{-2} (C) 6.0 m s^{-2} (D) 7.6 m s^{-2}

2022 Paper 1 Section 1 Question 3 Gravity and motion	Which free body diagram best represents an object being pulled at a constant speed up an inclined plane? (A)  (B)  (C)  (D)  **Answer is A.**

2022 Paper 1 Section 1 Question 4 Gravity and motion	An object orbiting Earth has an orbital period of 5.6×10^3 s. What is the object's orbital radius? (A) 3.8×10^5 m **(B) 6.8×10^6 m – Answer** (C) 1.8×10^{10} m (D) 1.3×10^{12} m

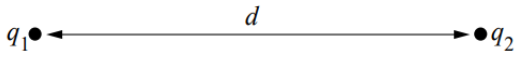
2022 Paper 1 Section 1 Question 9 Gravity and motion	Which diagram would result in the furthest horizontal distance travelled? (A)  (B)  (C)  (D)  Not to scale **Answer is B.**

2022 **Paper 1** **Section 1** **Question 12** **Gravity and motion**	An object experiencing uniform circular motion in a horizontal plane travels at an average speed of 8.0 m s^{-1} . Calculate the radius of the object's path if it takes 0.3 s to complete a full rotation. **(A) 3.8 × 10^{-1} m – Answer** (B) 2.6 × 10^{0} m (C) 1.5 × 10^{1} m (D) 1.7 × 10^{2} m

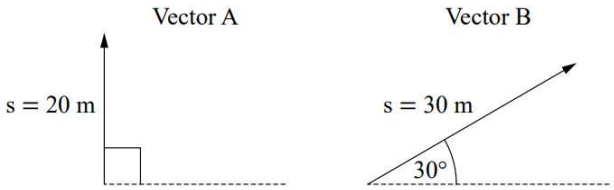
2022 **Paper 1** **Section 1** **Question 16** **Gravity and motion**	Two vectors are shown.  Which option represents the resultant vector of $X + Y$? (A)  (B)  (C)  (D)  Not to scale **Answer is D.**

2022 **Paper 1** **Section 1** **Question 17** **Gravity and motion**	An object is in orbit 400 km above the surface of the Earth. The Earth has a radius of 6.4 × 10^{6} m. What is the magnitude of the gravitational field strength experienced by the object? **(A) 8.6 × 10^{0} m s^{-2} – Answer** (B) 9.7 × 10^{0} m s^{-2} (C) 2.5 × 10^{3} m s^{-2} (D) 5.9 × 10^{7} m s^{-2}

2021 **Paper 1** **Section 1** **Question 2** **Gravity and motion**	Calculate the initial horizontal velocity of a projectile with an initial velocity of 38 m s^{-1} at an angle of 42° up from the horizontal. (A) 25 m s^{-1} **(B) 28 m s^{-1} – Answer** (C) 34 m s^{-1} (D) 40 m s^{-1}

2021 Paper 1 Section 1 Question 4 Gravity and motion	The diagram shows two charges (q_1 and q_2) separated by a distance (d).  There is a force, F, acting between the two charges. Calculate the magnitude of the force acting between the two charges if d is halved and the charge of q_2 is doubled. (A) 1F (B) 2F (C) 4F **(D) 8F – Answer**

2021 Paper 1 Section 1 Question 7 Gravity and motion	*Normal force* is the force acting along an imaginary line (A) parallel to the surface. **(B) perpendicular to the surface. – Answer** (C) opposite to the gravitational force. (D) in the same direction as the gravitational force.

2021 Paper 1 Section 1 Question 8 Gravity and motion	The diagram shows two displacement vectors.  Calculate the resultant vector above the horizontal axis when Vector A is added to Vector B. (A) 43.6 m at 36.6° **(B) 43.6 m at 53.4° – Answer** (C) 48.4 m at 18.1° (D) 48.4 m at 71.9°

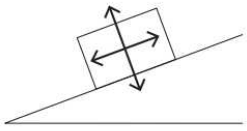
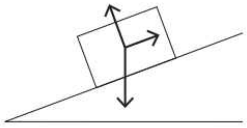
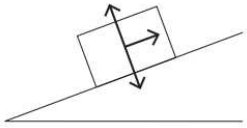
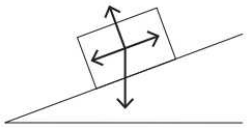
2021 Paper 1 Section 1 Question 11 Gravity and motion	Uniform circular motion occurs when an object is travelling in a circle at a constant (A) speed, due to a force of constant magnitude acting in a parallel direction to its velocity. (B) velocity, due to a force of constant magnitude acting in a parallel direction to its speed. **(C) speed, due to a force of constant magnitude acting in a perpendicular direction to its velocity. – Answer** (D) velocity, due to a force of constant magnitude acting in a perpendicular direction to its speed.

2021 Paper 1 Section 1 Question 12 Gravity and motion	Calculate the maximum height reached by a projectile with an initial velocity of 15 m s^{-1} at an angle of 30° up from the horizontal. **(A) 2.87 m – Answer** (B) 3.83 m (C) 8.61 m (D) 11.5 m

2021 **Paper 1** **Section 1** **Question 13** **Gravity and motion**	Calculate the orbital period of a satellite travelling around the Earth with a radius of 4.00×10^8 m. (A) 3.49×10^{-2} hours (B) 3.94×10^2 hours **(C) 6.99×10^2 hours – Answer** (D) 1.76×10^9 hours

2021 **Paper 1** **Section 1** **Question 16** **Gravity and motion**	The weight of a 5 kg object on Earth is (A) 0.49 N (B) 0.51 N **(C) 49 N – Answer** (D) 51 N

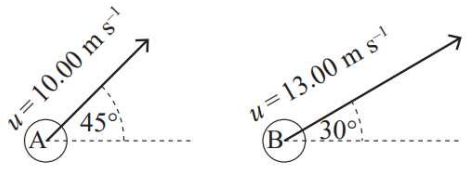
2021 **Paper 1** **Section 1** **Question 18** **Gravity and motion**	A gravitational field is the (A) net gravitational force per unit mass at a particular point in space. (B) energy stored in an object as a result of its position relative to another object. **(C) region of space surrounding a body in which another body experiences a force of gravitational attraction. – Answer** (D) position in space where objects experience a force or acquire potential energy as they are 'worked' into that position.

2020 **Paper 1** **Section 1** **Question 1** **Gravity and motion**	Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane? (A)  (B)  (C)  (D)  **Answer is B.**

2020 **Paper 1** **Section 1** **Question 2** **Gravity and motion**	The definition of *average speed* is the rate of change of (A) velocity. **(B) distance. – Answer** (C) acceleration. (D) displacement.

2020 Paper 1 Section 1 Question 3 Gravity and motion	The diagram shows two vectors.  Calculate the magnitude of the resultant vector when Vector A is added to Vector B. **(A) 15 km – Answer** (B) 16.5 km (C) 21 km (D) 108 km

2020 Paper 1 Section 1 Question 8 Gravity and motion	An object 46 m above the ground is projected horizontally, with an initial velocity of 25 m s^{-1}. Calculate the horizontal displacement of the object at the time it reaches the ground. **(A) 77 m – Answer** (B) 120 m (C) 190 m (D) 240 m

2020 Paper 1 Section 1 Question 11 Gravity and motion	The diagram shows object A and object B being projected at different velocities.  Which of the following statements is true? (A) Object A has a shorter flight time than object B. (B) Object A has a smaller maximum height than object B. (C) Object A has a larger horizontal velocity than object B. **(D) Object A has a smaller horizontal displacement than object B. – Answer**

2020 Paper 1 Section 1 Question 12 Gravity and motion	Which of the following is one of Kepler's laws of planetary motion? (A) The laws of physics are the same in all inertial frames of reference. **(B) All planets move about the Sun in elliptical orbits, having the Sun as one of the foci. – Answer** (C) The speed of light in a vacuum has the same value, c, in all inertial frames of reference. (D) The force of attraction between each pair of point particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

2020 Paper 1 Section 1 Question 15 Gravity and motion	Calculate the orbital period of a satellite travelling on a 3.00×10^8 m radius orbit around the Earth. (A) 1.44×10^{-2} hours **(B) 4.54×10^2 hours – Answer** (C) 1.64×10^6 hours (D) 7.44×10^8 hours

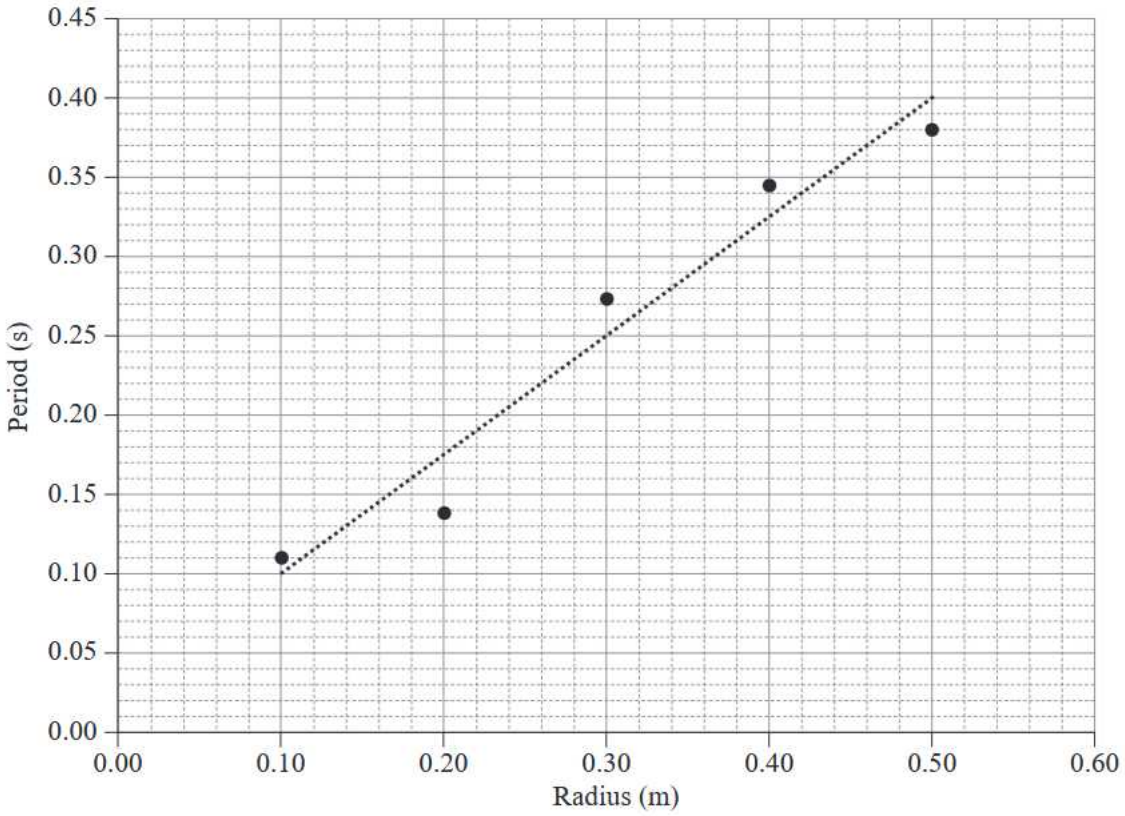
2020 Paper 1 Section 1 Question 18 Gravity and motion	Calculate the initial vertical velocity of a projectile with an initial velocity of 68 m s^{-1} at an angle of 51° up from the horizontal. (A) 43 m s^{-1} (B) 51 m s^{-1} **(C) 53 m s^{-1} – Answer** (D) 68 m s^{-1}

2024 Paper 1 Section 2 Question 23

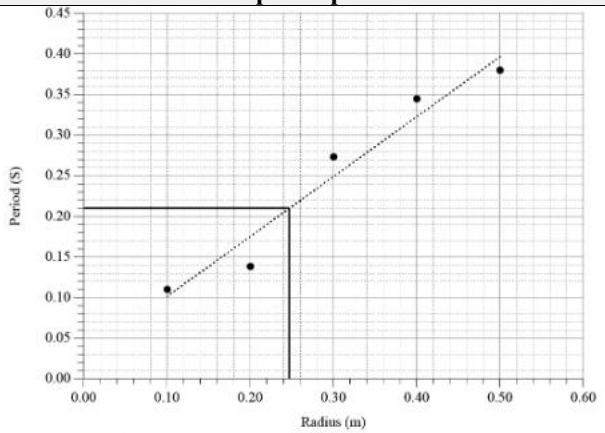
Gravity and motion

An experiment was conducted to study an object undergoing circular motion, with the radius of motion acting as the independent variable and the speed kept constant.

The data comparing the period and radius of motion is shown. [4 marks]



a) Identify the period expected for a 25 cm radius of motion. [1 mark]

Sample response	The response
 Period = 0.21 s	• identifies the period **[1 mark]**

b) Determine the constant speed of the object. Show your working. [3 marks]

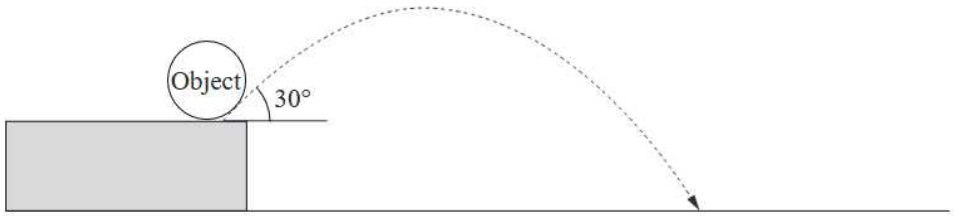
Sample response	The response
$\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{0.40 - 0.10}{0.50 - 0.10}$ $= \frac{0.30}{0.40}$ $= 0.75 \text{ s m}^{-1}$ (to two significant figures) Since $v = \frac{2\pi r}{T}$, then $T = \frac{2\pi r}{v}$, therefore gradient $= \frac{2\pi}{v}$ $0.75 = \frac{2\pi}{v}$ $v = 8.38$ Speed = 8.38 m s^{-1}	• calculates gradient **[1 mark]** • recognises the relationship between gradient and average speed (i.e. $m = \frac{2\pi}{v}$) **[1 mark]** • determines the constant speed of the object **[1 mark]**

2024 Paper 1 Section 2 Question 27

Gravity and motion

On another planet, an object was projected upwards from an initial height and took 0.71 s to land.

Not to scale



The relationship between vertical displacement (m) and time (s) is $s_y = -5.18t^2 + 3.5t$.

Determine the horizontal displacement of the object when it lands.

Sample response	The response
$s = ut + \frac{1}{2}at^2$ $s = 3.5t - 5.18t^2$ $u_x = \frac{3.5}{\tan 30}$ $= 6.06 \text{ m s}^{-1}$ right Since $a_x = 0 \text{ ms}^{-2}$, u_x = constant $s_x = u_x t$ $= 6.06 \times 0.71$ $= 4.3026$ $= 4.3$ m Range = 4.3 m	• recognises trigonometric relationship between initial velocity and horizontal component **[1 mark]** • calculates the horizontal component of the initial velocity to be 6.06 m s^{-1} **[1 mark]** • recognises that horizontal acceleration is zero **[1 mark]** • determines the range (horizontal displacement) to be 4.3 m **[1 mark]**

2023 Paper 1 Section 2 Question 27

Gravity and motion

A satellite orbits a planet of mass 6.42×10^{23} kg at a height of 5000 km from the surface. The planet has a diameter of 6780 km.

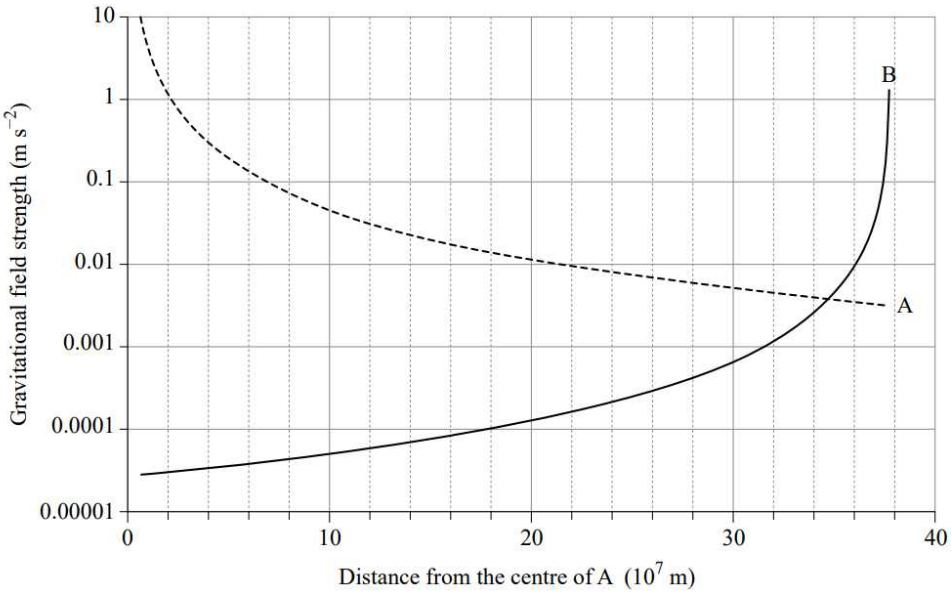
Determine the speed required for the satellite to maintain its orbit. Show your working. (5 marks)

Sample response	The response
$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$ $\frac{T^2}{(3390\times10^3 + 5000\times10^3)^3} = \frac{4\pi^2}{6.67\times10^{-11}\times6.42\times10^{23}}$ $T = \sqrt{\frac{4\pi^2 \times 5.91\times10^{20}}{6.67\times10^{-11}\times6.42\times10^{23}}}$ $= 2.33\times10^4 \text{ s}$ $v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 8.39\times10^6}{2.33\times10^4}$ $= 2.3\times10^3 \text{ m s}^{-1}$ Speed = 2.3×10^3 m s^{-1} (to two significant figures)	• recognises the scenario relates to – orbital mechanics **[1 mark]** – circular motion **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • demonstrates correct substitution **[1 mark]** • calculates the speed **[1 mark]**

2022
Paper 1
Section 2
Question 27

Gravity and motion

Object A is five times the mass of object B. The graph shows the contribution of each object towards the strength of the net gravitational field between them.



Determine the total distance between the centre of the two objects. Show your working. [5 marks]

Sample Response	The response
Point where lines intersect indicates distance from centre of A where net gravitational field strength is equal to zero. $r_A = 35; r_B = x - 35$ $g_A - g_B = 0$ $g_A = g_B$ $\frac{\cancel{G}M_A}{r_A^2} = \frac{\cancel{G}M_B}{r_B^2}$ $\frac{5\cancel{M}_B}{35^2} = \frac{\cancel{M}_B}{(x-35)^2}$ $\frac{35^2}{5} = (x-35)^2$ $\sqrt{\frac{35^2}{5}} = x - 35$ $x = \frac{35}{\sqrt{5}} + 35$ $= 50.7$ Total distance = 51×10^7 m (to two significant figures)	• recognises the scenario relates to gravitational field strength [1 mark] • identifies distance from A where net gravitational field strength is zero [1 mark] • constructs an equation that can be solved for the distance between the objects [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the distance between the centre of the two objects [1 mark]

2022 Paper 1 Section 2 Question 28

Gravity and motion

An object of mass 200 g moves in a uniform circular path with a radius of 25 cm. The time taken for 10 revolutions is 3.0s.

a) Calculate the distance travelled by the object after 3.9 s. Show your working. [2 marks]

Sample Response	The response
distance = $2\pi r \times$ number of revolutions $= 2\pi \times 0.25 \times \frac{3.9}{0.3}$ $= 20.4\ m$ Distance travelled = 20 m (to two significant figures)	• recognises the scenario relates to the circumference of circular motion [1 mark] • calculates total distance travelled [1 mark]

b) Calculate the centripetal force acting on the object. Show your working. [5 marks]

Sample Response	The response
$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.25}{0.3}$ $= 5.236...\ \text{m s}^{-1}$ $F_{net} = \frac{mv^2}{r}$ $= \frac{0.2 \times 5.236^2}{0.25}$ $= 21.93\ N$ Centripetal force = 22 N (to two significant figures)	• recognises the scenario relates to velocity in circular motion [1 mark] centripetal motion [1 mark] • provides appropriate mathematical reasoning [1 mark] • demonstrates correct substitution [1 mark] • calculates centripetal force of object [1 mark]

2021 Paper 1 Section 2 Question 22

Gravity and motion

A planet is orbiting a 3.38×10^{31} kg star. The radius of the orbit is 4.23×10^{8} km.

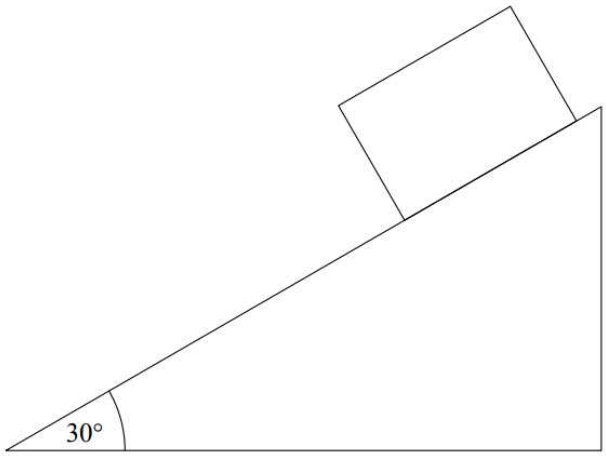
Calculate the average speed of the planet. [3 marks]

Sample Response	The response	Notes
Assume the planet is undergoing uniform circular motion. $F = \frac{mv^2}{r}$ This is equal to the force of gravity. $F = \frac{GMm}{r^2}$ Equating these two equations and rearranging for velocity gives: $v = \sqrt{\frac{GM}{r}}$ $v = \sqrt{\frac{6.67 \times 10^{-11} \times 3.38 \times 10^{31}}{4.23 \times 10^{11}}}$ v = 73 km s^{-1} or 73 005 m s^{-1} Average speed = 73 005 m s^{-1} (to the nearest whole number)	• recognises the scenario relates to uniform circular motion and universal gravitation [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the average speed [1 mark]	Allow FT error from incorrect substitution. Do not penalise for incorrect decimal places/significant figures.

2021
Paper 1
Section 2
Question 24

Gravity and motion

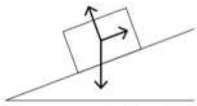
The diagram shows a 1.5 kg object on an inclined plane with an angle of 30° up from the horizontal.



Not to scale

The object experiences a frictional force of 4.5 N.

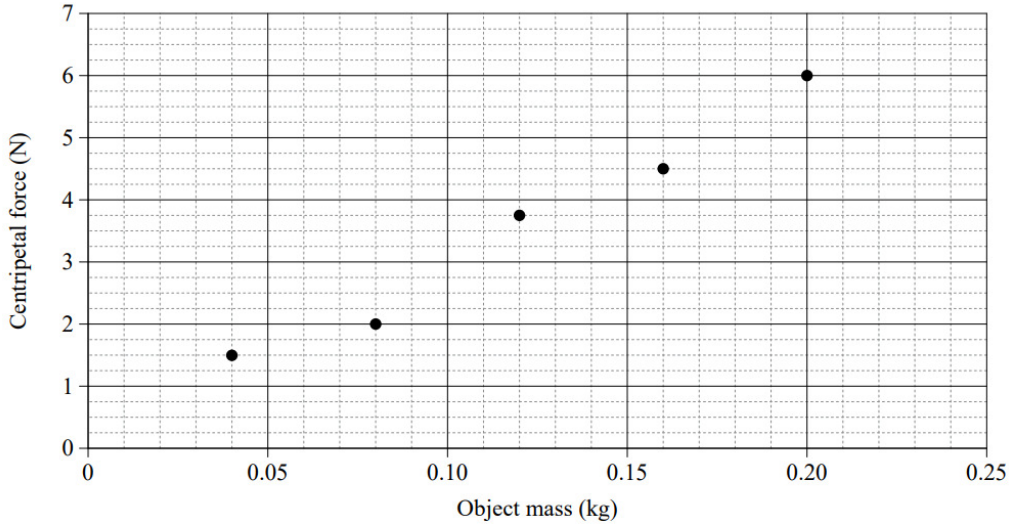
Calculate the magnitude of the net force acting on the object. [3 marks]

Sample Response	The response	Notes
 $F_{g,x} = mg\sin\theta = 1.5 \times 9.8 \times \sin 30 = 7.4$ N $F_{net} = F_{g,x} - F_f = 7.4 - 4.5 = 2.9$ N Magnitude of net force = 2.9 N (to 1 decimal place)	• identifies the forces acting on the object [1 mark] • calculates the component of the gravitational force acting down the slope [1 mark] • calculates the magnitude of the net force [1 mark]	Allow FT error for the magnitude of the net force. Do not penalise for incorrect decimal places/significant figures.

2021 Paper 1 Section 2 Question 25

Gravity and motion

The graph shows the centripetal forces required to keep objects with different mass in uniform circular motion with a constant speed and constant radius of 20 cm.



Determine the speed of the objects. [4 marks]

Sample Response	The response	Notes
$F = \frac{mv^2}{r}$ gradient = $\frac{v^2}{r}$ gradient = $\frac{6.0-0.0}{0.2-0.0} = 30$ $v = \sqrt{0.2 \times \text{gradient}}$ $v = \sqrt{0.2 \times 30}$ $v = 2.4\ \text{m s}^{-1}$ Speed = 2.4 m s^{-1} (to 1 decimal place)	• recognises how the scenario relates to $F = \frac{mv^2}{r}$ [1 mark] • identifies line of best fit [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the speed [1 mark]	Appropriate mathematical reasoning may include: - determining the gradient - substituting the gradient into a formula for v - or other suitable response consistent with a reasonable understanding. Allow FT error from the line of best fit (LOBF). LOBF may be identified by: - line drawn on graph - appropriate values derived from graph used in calculations. Accept reasonable variations in the LOBF. Do not penalise for incorrect decimal places/significant figures.

2020 Paper 1 Section 2 Question 21

Gravity and motion

An object that is 7.12 × 6 10 m from the centre of the Earth experiences a gravitational force of 2.84 kN. Calculate the mass of the object. [3 marks]

Sample Response	The response	Notes
$F = \frac{GMm}{r^2}$ $m = \frac{Fr^2}{GM}$ $m = \frac{2.84 \times 10^3 \times (7.12 \times 10^6)^2}{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}$ Mass = 362 kg	• indicates an understanding of the physical scenario in relation to Newton's law of universal gravitation or other relevant physical concept/s [1 mark] • provides pertinent mathematical operation/s correctly performed [1 mark] • determines the mass [1 mark]	Accept answers inclusive between 361.5 kg and 362 kg. Allow FT error for the mass Do not penalise for incorrect decimal places/significant figures.

2020 Paper 1 Section 2 Question 25

Gravity and motion

Mars has an average orbital radius of approximately 1.5 times the average orbital radius of Earth.

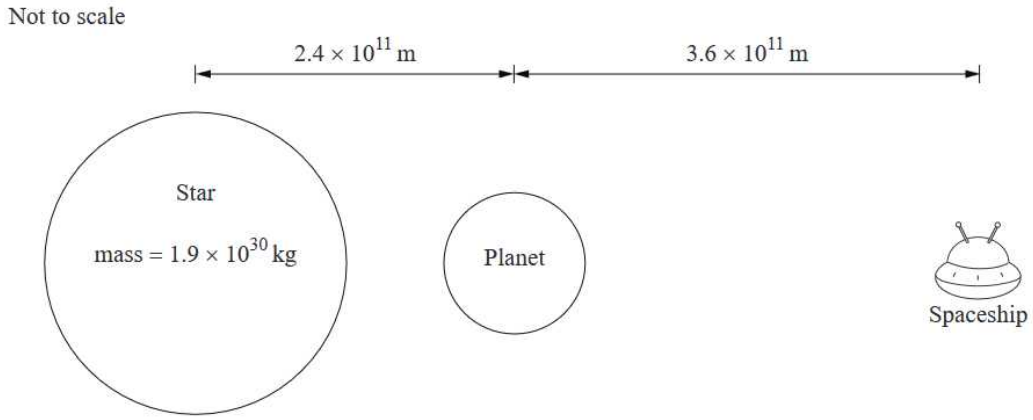
Calculate the time it takes Mars to orbit the Sun. [3 marks]

Sample Response	The response	Notes
$\frac{T_{Mars}^2}{r_{Mars}^3} = \frac{4\pi^2}{Gm}$ $T = \sqrt{\frac{4\pi^2}{Gm} r^3}$ $T_{Mars} = \sqrt{\frac{4\pi^2}{Gm}(1.5 \times r_{Earth})^3}$ Therefore $T_{Mars} = \sqrt{1.5^3} T_{Earth}$ $T_{Mars} = 1.8371 \times 365$ days $T_{Mars} = 670.5$ days Time = 671 days	• indicates an understanding of the physical scenario in relation to Kepler's Law or other relevant physical concept/s [1 mark] • provides pertinent mathematical operation/s correctly performed [1 mark] • determines the time [1 mark]	Accept answers between: • 1.83 and 1.84 years inclusive • 670 days and 671 days inclusive • 16 080 and 16 107 hours inclusive • 57 888 000 seconds and 57 974 400 seconds inclusive. Allow FT error for the time. Do not penalise for incorrect decimal places/significant figures.

2024 Paper 2 Section 1 Question 2

Gravity and motion

In a distant solar system, a star, planet and spaceship are aligned as shown.



a) Calculate the strength of the star's gravitational field experienced by the spaceship.
Show your working. [3 marks]

Sample response	The response
$g = \frac{GM}{r^2}$ $= \frac{6.67\times10^{-11}\times1.9\times10^{30}}{(2.4\times10^{11}+3.6\times10^{11})^2}$ $= \frac{1.27\times10^{20}}{(6.0\times10^{11})^2}$ $= 3.5\times10^{-4}$ Gravitational field strength = 3.5×10^{-4} m s^{-2}	• shows mathematical reasoning that relates to strength of a gravitational field $g = \frac{GM}{r^2}$ **[1 mark]** • recognises the distance is from centre of star to centre of the spaceship **[1 mark]** • calculates the gravitational field strength **[1 mark]**

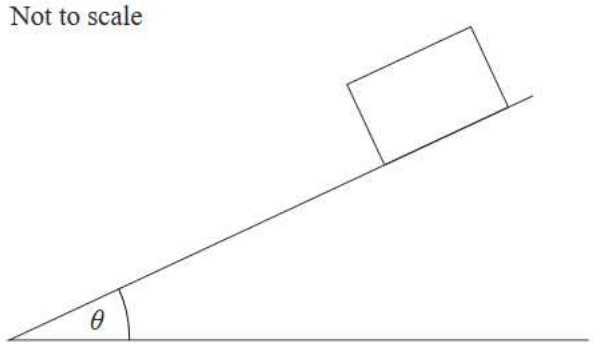
b) An observer on the planet measures the spaceship to be travelling directly towards the star at a speed of 1.9 × 10^8 m s–1. Calculate the distance between the spaceship and the star from the perspective of an astronaut on the spaceship. Show your working. [3 marks]

Sample response	The response
$L = L_0\sqrt{1-\frac{v^2}{c^2}}$ $= 6.0\times10^{11}\times\sqrt{1-\frac{(1.9\times10^8)^2}{(3.0\times10^8)^2}}$ Distance = 4.6×10^{11} m	• recognises the scenario relates to length contraction **[1 mark]** • identifies proper length **[1 mark]** • calculates the distance from the spaceship's frame of reference **[1 mark]**

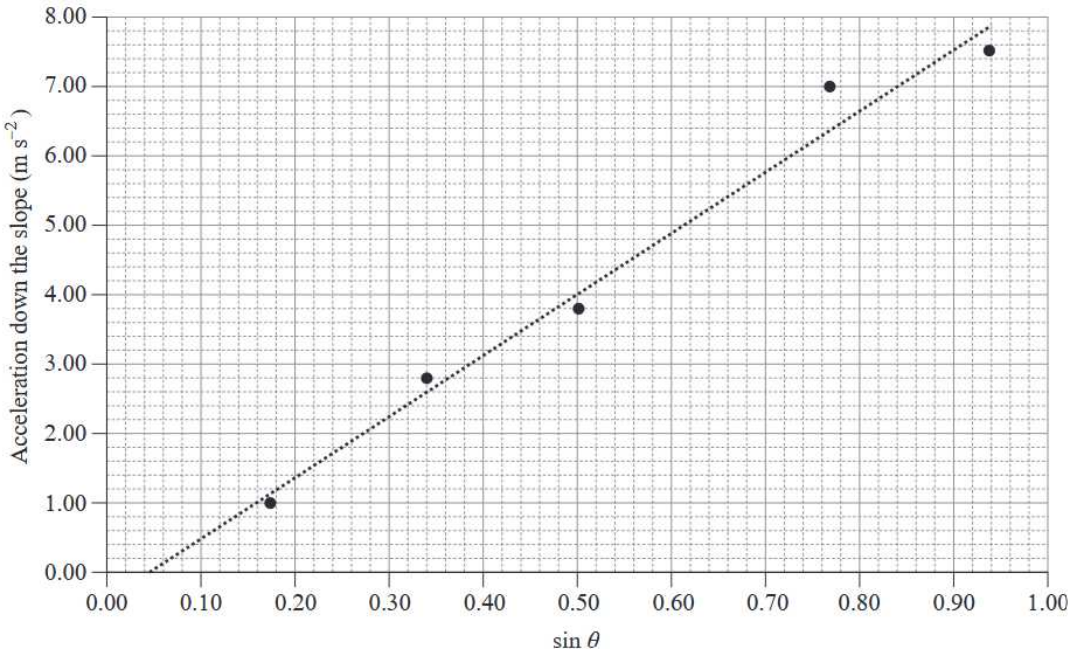
2024
Paper 2
Section 1
Question 3

Gravity and motion

A student conducted an experiment to address the following research question: What is the relationship between the angle of inclination and the acceleration from rest down a 2.4 m slope of a 0.050 kg object?



Data from the experiment was processed to produce the following graph.



a) Determine the magnitude of the frictional force acting on the object when the angle of inclination is 45°. Use the graph and show your working. [5 marks]

Sample response	The response
$F_{net} = F_g - F_f$ $ma = mg\sin\theta - F_f$ $a = g\sin\theta - \frac{F_f}{m}$	• recognises the scenario relates to forces on an inclined plane **[1 mark]** • determines the component of weight down the inclined plane **[1 mark]**
At sin 45°, on graph a = 5.85 ms^{-2} $5.85 = 9.8 \times 0.707 - \frac{F_f}{0.050}$ $F_f = \left[(9.8 \times 0.707) - 5.85\right] \times 0.050$ $= 0.0539$	• identifies from graph the acceleration at sin 45° **[1 mark]** • shows appropriate mathematical reasoning **[1 mark]**
Magnitude of frictional force = 0.054 N	• determines the frictional force **[1 mark]**

b) Calculate the final velocity of the object when the angle of inclination is 45°.
Show your working. [3 marks]

Sample response	The response
$v^2 = u^2 + 2as$ $v^2 = 0 + 2 \times 5.85 \times 2.4$ $v = 5.30$ Final velocity = 5.3 m s^{-1}	• selects appropriate equation/s of motion **[1 mark]** • performs correct substitution **[1 mark]** • calculates final velocity of the object **[1 mark]**

2024
Paper 2
Section 1
Question 4

Gravity and motion

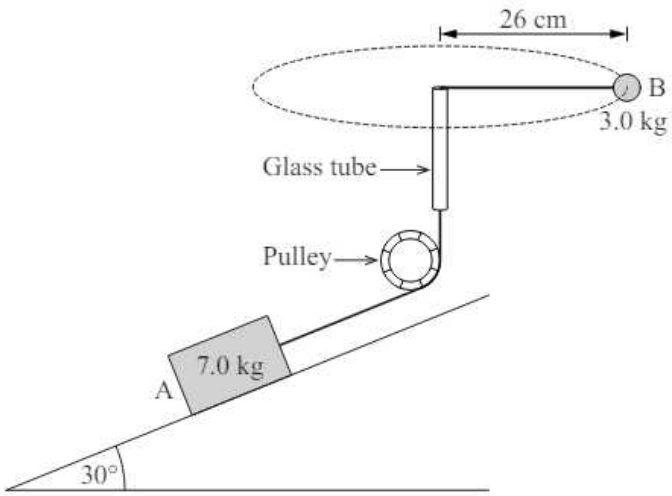
Explain how a satellite can be accelerating yet maintain a constant speed in a circular orbit around a planet. [4 marks]

Sample response	The response
The satellite has inertia and, in the absence of the planet, would continue in a straight line with the same speed until acted upon by an unbalanced force. When the planet's gravitational force pulls the satellite towards it (perpendicular to the satellite's motion), the satellite changes direction and thus accelerates towards the planet, but its speed does not change. As a result, the satellite continues to move 'forward', but the planet's gravitational force pulls the satellite towards it. So the resultant motion is that the satellite has a constant speed (not velocity as direction is changing) travelling in a circle around the planet.	• describes inertia of satellite **[1 mark]** • identifies that planet provides a centripetal force **[1 mark]** • identifies that the centripetal force is perpendicular to the satellites motion **[1 mark]** • explains that changing direction means change in velocity which is acceleration **[1 mark]**

2023 Paper 2 Section 1 Question 2

Gravity and motion

In a frictionless system, object A rests on an inclined plane and object B undergoes horizontal circular motion. The two objects are connected by a length of string as shown.



Not to scale

Determine the speed of object B needed for object A to remain stationary. Show your working. (5 marks)

Sample response	The response
For object A to remain stationary, $F_{g,parallel} = F_T$ and $F_T = F_c$ $F_{g,parallel} = 7 \times 9.8 \times \sin 30 = 34.3 = F_c$ $F = \frac{mv^2}{r}$ $34.3 = \frac{7.0 \times v^2}{0.26}$ $v = \sqrt{\frac{34.3 \times 0.26}{3.0}}$ $= 1.7 \text{ m s}^{-1}$ Speed = 1.7 m s^{-1} (to two significant figures)	• identifies the equivalence of the parallel component of force due to gravity and centripetal force **[1 mark]** • calculates the parallel component of force due to gravity **[1 mark]** • recognises the scenario relates to centripetal force acting on an object **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the speed of object B **[1 mark]**

2023 Paper 2 Section 1 Question 4

Gravity and motion

Two objects on different planets experience different accelerations due to gravity.

Object	Mass (kg)	Acceleration due to gravity ($m\ s^{-2}$)
A	79	1.6
B	32	3.7

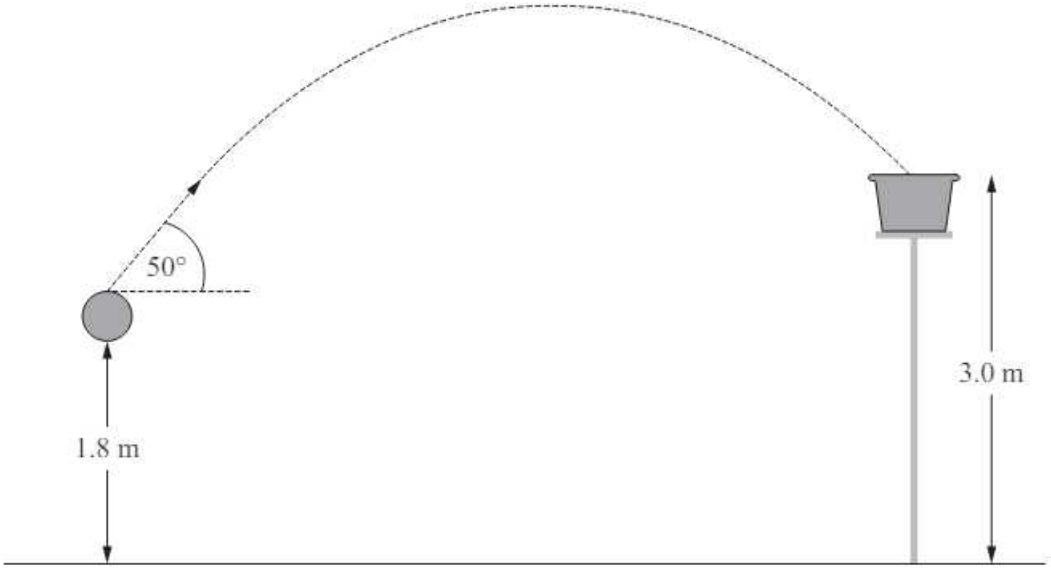
Determine which object has the greatest force acting on it. Show your working. (3 marks)

Sample response	The response
Force on object A $= mg = 79 \times 1.6 = 126.4$ N $\approx$ 130 N down Force on object B $= mg = 32 \times 3.7 = 118$ N $\approx$ 120 N down Object A experiences the greatest force.	• recognises the scenario relates to relationship between the force due to gravity and mass **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • identifies the object experiencing the greatest force acting on it **[1 mark]**

2023 Paper 2 Section 1 Question 6

Gravity and motion

A ball is thrown with an initial velocity of 8.0 m s^{-1} into a bucket as shown.

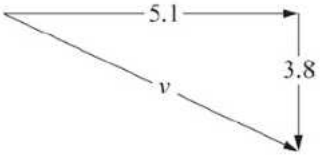


Not to scale

a) Calculate the time taken for the ball to reach its maximum height. Show your working. [4 marks]

Sample response	The response
$u_y = 8.0 \sin 50 = 6.13$ m s^{-1} $v_y = gt + u_y$ $0 = -9.8t + 6.13$ $t = 0.63$ s Time = 0.63 s (to two significant figures)	• recognises the scenario relates to an object undergoing projectile motion **[1 mark]** • calculates the initial vertical velocity **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates time taken to reach maximum height **[1 mark]**

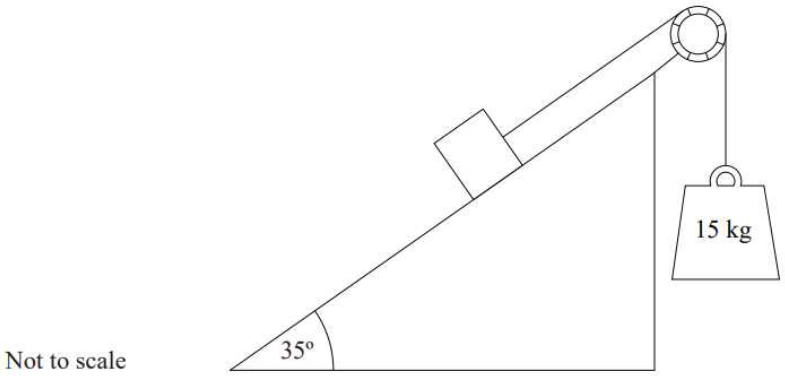
b) Calculate the magnitude of the ball's final velocity when it enters the bucket. Show your working. [6 marks]

Sample response	The response
Method 1: Vector solution Impact velocity equal to the vector sum of v_x and v_y $v_y^2 = 2gs_y + u_y^2$ $= 2 \times -9.8 \times 1.2 + 6.13^2$ $= 14.1$ $v_y = 3.7 \text{ m s}^{-1}$ $v_x = u_x = 8.0 \cos 50 = 5.1 \text{ m s}^{-1}$  $v = \sqrt{5.1^2 + 3.7^2} = 6.3 \text{ m s}^{-1}$ Final velocity = 6.3 m s^{-1} (to two significant figures)	• recognises the scenario relates to the relationship between initial and final velocities – vertically **[1 mark]** – horizontally **[1 mark]** • calculates final – vertical velocity **[1 mark]** – horizontal velocity **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the final velocity **[1 mark]**
Method 2: Energy solution $\sum E_i = \sum E_f$ $KE_i = KE_f + GPE$ $\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$ $\frac{1}{2} \times 8^2 = \frac{1}{2}v^2 + 9.8 \times 1.2$ $v^2 = 40.48$ $v = 6.36 \text{ m s}^{-1}$ Final velocity = 6.4 m s^{-1} (to two significant figures)	• recognises the scenario relates to – conservation of energy **[1 mark]** – kinetic energy **[1 mark]** – gravitational potential energy **[1 mark]** • demonstrates correct substitution **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the final velocity **[1 mark]**

2022 Paper 2 Section 1 Question 4

Gravity and motion

A stationary object on a frictionless inclined plane is connected to a 15 kg weight as shown.



Calculate the mass of the object on the inclined plane. [5 marks]

Sample Response	The response
$F_A = F_B$ $m_A g \sin\theta = m_B g$ $m_A \times 9.8 \times \sin 35° = 15 \times 9.8$ $5.62 m_A = 147$ $m_A = 26$ Mass of object = **26** kg (to two significant figures)	• identifies equivalent forces acting parallel to the plane [1 mark] • recognises the scenario relates to tensile force acting on the object on an inclined plane [1 mark] the component of force on the object acting down the plane [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the mass of the object [1 mark]

2022 Paper 2 Section 1 Question 7

Gravity and motion

Two asteroids experience a gravitational force of 3.3×10^3 N between them. Their masses are 2.7×10^{17} kg and 6.1×10^{15} kg.

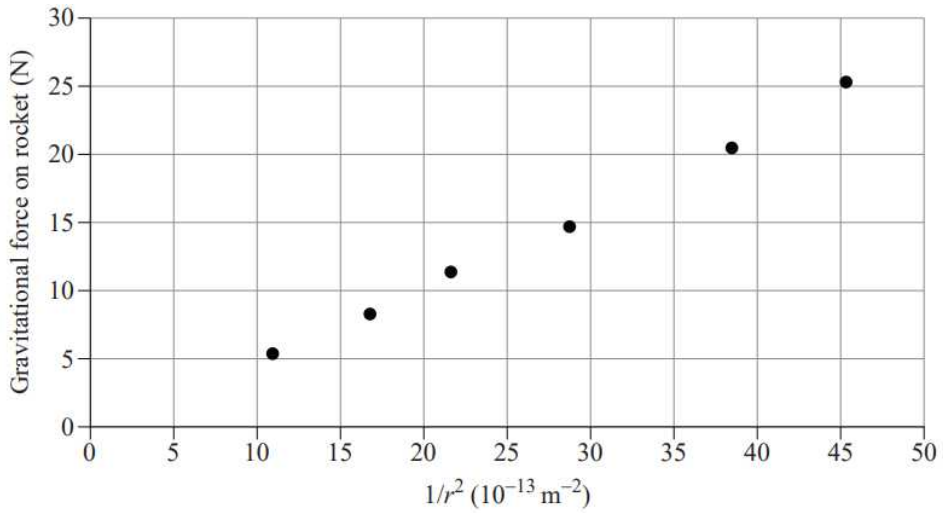
Calculate the distance between the two asteroids. Show your working. [3 marks]

Sample Response	The response
$F = \frac{GMm}{r^2}$ $3.3 \times 10^3 = \frac{6.67 \times 10^{-11} \times 2.7 \times 10^{17} \times 6.1 \times 10^{15}}{r^2}$ $r = \sqrt{\frac{6.67 \times 10^{-11} \times 2.7 \times 10^{17} \times 6.1 \times 10^{15}}{3.3 \times 10^3}}$ $= 5.8 \times 10^9$ m Distance between asteroids = **5.8 × 10⁹** m (to two significant figures)	• recognises the scenario relates to Newton's Law of Universal Gravitation [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the distance between the asteroids [1 mark]

2022 Paper 2 Section 1 Question 8

Gravity and motion

The graph shows the gravitational force experienced by a rocket of mass 750 kg as it approaches an asteroid.



Determine the mass of the asteroid. Show your working. [4 marks]

Sample Response	The response
Given $F = \frac{GMm}{r^2}$, $gradient = GMm$ $gradient = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{24 - 8}{44 \times 10^{-13} - 16 \times 10^{-13}}$ $= 5.71 \times 10^{12}$ $gradient = GMm$ $5.71 \times 10^{12} = 6.67 \times 10^{-11} \times 750M$ $M = \frac{5.71 \times 10^{12}}{6.67 \times 10^{-11} \times 750}$ $= 1.1 \times 10^{20}\ kg$ Mass of asteroid = 1.1×10^{20} kg (to two significant figures)	• recognises the scenario relates to Newton's Law of Universal Gravitation [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the gradient [1 mark] • determines the mass of the asteroid [1 mark]

2022 Paper 2 Section 1 Question 9

Gravity and motion

A person spins an object 4.3 m above the ground in a horizontal circular path of radius 0.8 m. They release the object horizontally, allowing it to travel to the ground.

a) Calculate the centripetal acceleration of the object before it is released, given it takes 5 s for the object to complete 12 revolutions. Show your working. [4 marks]

Sample Response	The response
$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.8}{5 \div 12}$ $= 12.1\, m\, s^{-1}$ $a_c = \frac{v^2}{r}$ $= \frac{12.1^2}{0.8}$ $= 180\ \text{m s}^{-2}$ Centripetal acceleration = 180 m s^{-2} (to two significant figures)	• recognises the scenario relates to velocity in circular motion [1 mark] centripetal acceleration [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the centripetal acceleration of the object [1 mark]

b) Calculate the total horizontal displacement for the object after it is released. Show your working. [5 marks]

Sample Response	The response
$s_y = u_y t + \frac{1}{2}at^2$ $4.3 = 0 + \frac{1}{2} \times 9.8t^2$ $t = \sqrt{\frac{4.3}{4.9}}$ $= 0.94\ s$ $s_x = u_x t + \frac{1}{2}at^2$ $= 12.1 \times 0.94 + \frac{1}{2} \times 0 \times 0.94^2$ $= 11.4\ m$ Horizontal displacement = 11 m (to two significant figures)	• recognises the scenario relates to vertical component of projectile motion [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the time of flight [1 mark] • recognises the scenario relates to the horizontal component of projectile motion [1 mark] • calculates the total horizontal displacement [1 mark]

2021 Paper 2 Section 1 Question 3

Gravity and motion

An object undergoes uniform circular motion in a path with a radius of *r*.

Determine the effect on the radius if the mass of the object is doubled, but the centripetal force and velocity remain unchanged. [3 marks]

Sample Response	The response
$F = \frac{mv^2}{r}$ Let R be the radius of the new path $\frac{Mv^2}{r} = \frac{2Mv^2}{R}$ $\frac{1}{r} = \frac{2}{R}$ $R = 2r$ The radius will double.	• recognises the scenario relates to uniform circular motion [1 mark] • provides correct reasoning [1 mark] • indicates that the radius will double [1 mark]

2021 Paper 2 Section 1 Question 4

Gravity and motion

A spacecraft is located between two large asteroids, Asteroid A and Asteroid B, that are 120 km apart. Asteroid A's mass is approximately four times the mass of Asteroid B.

Determine the distance of the spacecraft from Asteroid B if it experiences no net gravitational force from the two asteroids. [4 marks]

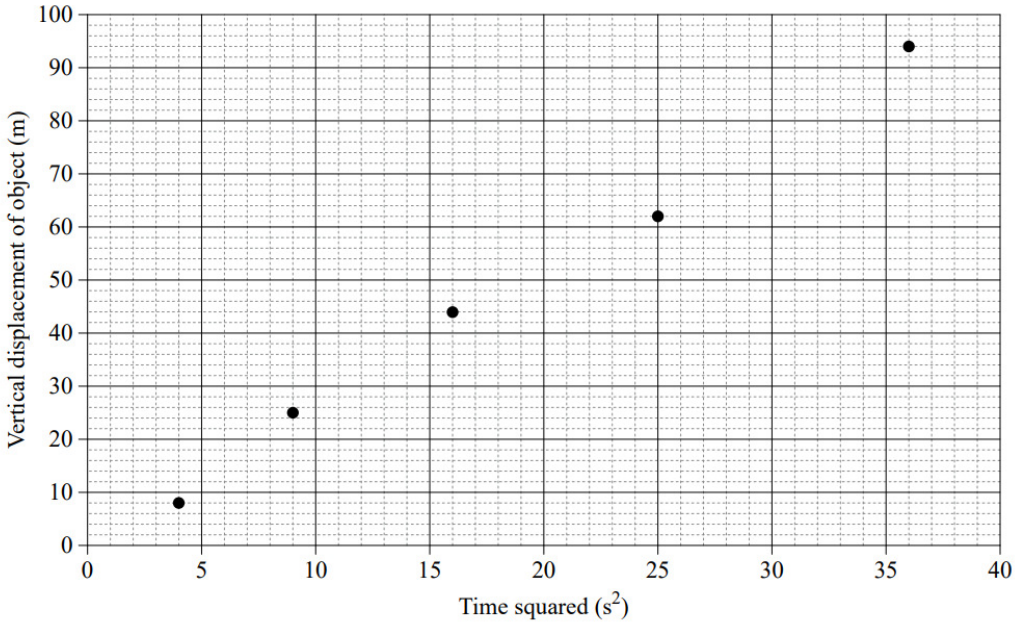
Sample Response	The response	Notes
$F_{g,net} = 0$ Therefore $\lvert F_{g,A} \rvert = \lvert F_{g,B} \rvert$ $G\frac{m_s M_A}{r_A^2} = G\frac{m_s M_B}{r_B^2}$ $\frac{4M_B}{r_A^2} = \frac{M_B}{r_B^2}$ $4M_B \times r_B^2 = r_A^2 \times M_B$ $\frac{4M_B \times r_B^2}{M_B} = r_A^2$ $r_A^2 = 4r_B^2$ $r_A = 2r_B$ $120 = r_A + r_B$ $120 = 3r_B$ $r_B = 40$ Distance from Asteroid B = 40 km (to the nearest whole number).	• recognises the scenario relates to Newton's law of universal gravitation [1 mark] • recognises that no net force occurs when the forces are equivalent [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines distance from the asteroid [1 mark]	Appropriate mathematical reasoning may also be demonstrated by other suitable means, e.g. use of quadratic equations. Do not penalise for incorrect decimal places/significant figures.

2021 Paper 2 Section 1 Question 7

Gravity and motion

An object on a planet is launched horizontally from a cliff. Its vertical displacement is measured over 6 seconds.

The graph shows the object's vertical displacement with respect to time squared.



a) Determine the mathematical relationship between vertical displacement (s) and time (t). [3 marks]

Sample Response	The response	Notes
The mathematical proportionality is $s \propto t^2$ intercept $= 0$ gradient $= \frac{y_2 - y_1}{x_2 - x_1}$ gradient $= \frac{94 - 0}{36 - 0}$ gradient $= 2.6$ $s = 2.6t^2$	• identifies the y-intercept [1 mark] • determines the gradient of the graph [1 mark] • identifies a mathematical relationship [1 mark]	For the gradient, accept between 2.5 and 2.7 inclusive.

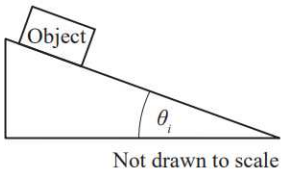
b) Calculate the acceleration due to gravity on the planet. [3 marks]

Sample Response	The response	Notes
$s = ut + \frac{1}{2}at^2$ Therefore $2.6t^2 = \frac{1}{2}at^2$ This means that $\frac{1}{2}a = 2.6$ $a = 2 \times 2.6$ $a = 5.2$ m s^{-2} Acceleration = 5.2 m s^{-2} (to 2 significant figures)	• recognises the gradient can be used to find acceleration due to gravity [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the acceleration due to gravity [1 mark]	Allow FT error from Question 7a). Do not penalise for incorrect decimal places/significant figures.

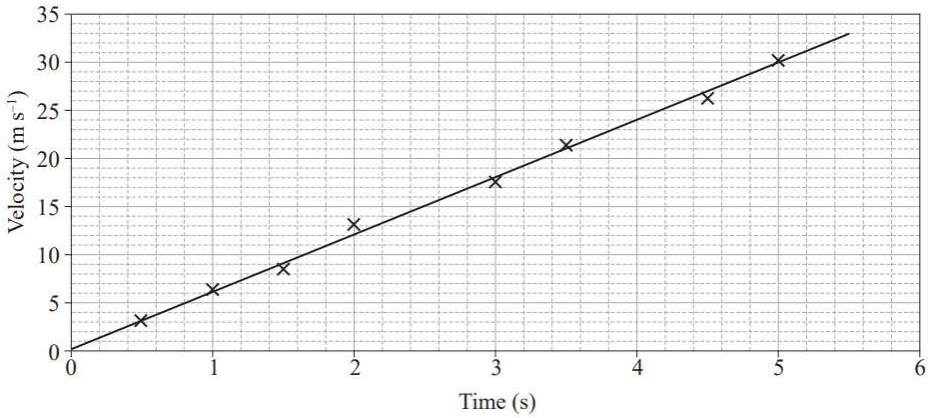
2020
Paper 2
Section 1
Question 8

Gravity and motion

The diagram shows an object sliding down a frictionless inclined plane.



The graph shows the velocity of the object measured at various times.



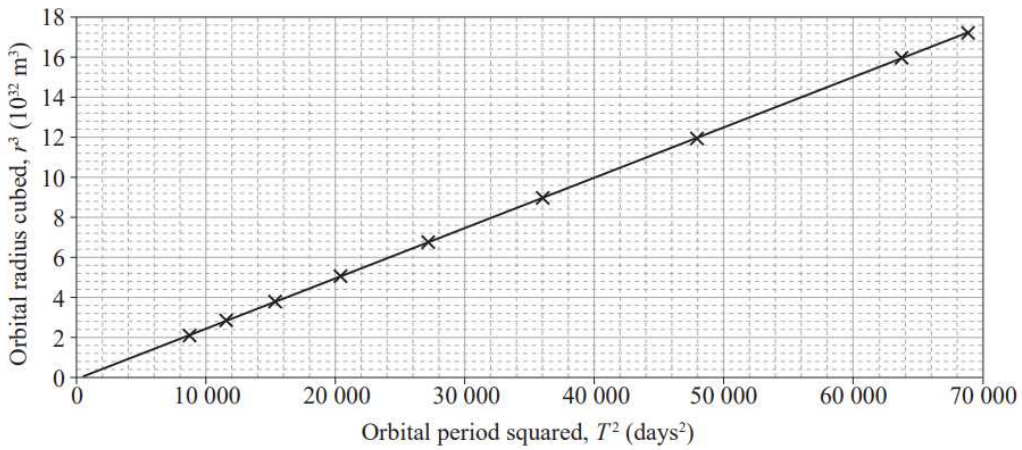
Determine the angle of incline, θ_i, of the inclined plane. Show your working

Sample Response	The response	Notes
Gradient of the graph = 6 m s^{-2} = acceleration The component of the acceleration due to gravity down the inclined plane is $g\sin\theta$ Therefore $g\sin\theta = 6$ $\theta_i = \sin^{-1}(6/9.8) = 38^\circ$	• arrives at a value for the gradient [1 mark] • indicates an understanding of how the acceleration of the object is represented by the gradient of the graph [1 mark] • provides pertinent mathematical operation/s correctly performed using the gradient value [1 mark] • determines angle [1 mark]	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept values inclusive between 37o and 38o for the angle. Allow FT error from the gradient value calculated.

2020 Paper 2 Section 1 Question 9

Gravity and motion

Nine planets orbit the same star. The orbital radius and orbital period of each planet was measured. The graph shows the cube of the orbital radius of each planet, r^3, compared to its orbital period squared, T^2.



Determine the mass of the star. Show your working. [5 marks]

Sample Response	The response	Notes
The gradient of the graph can be used to find $\frac{GM}{4\pi^2}$. The gradient of the graph can be found using the following two points: (0,0) and (40 000, 12). First, the x values will be converted to seconds^2 (0,0) and (2.985984 x10^{14}, 12 x 10^{32}). The gradient = 4.02 x 10^{18} Let the gradient be represented by the pronumeral V. $V = \frac{GM}{4\pi^2}$ $M = \frac{V4\pi^2}{G}$ Mass = 2.4×10^{30} kg (to 1 decimal place) The gradient of the graph can be used to find $\frac{GM}{4\pi^2}$. The gradient of the graph can be found using the following two points: (0,0) and (40 000, 12). First, the x values will be converted to seconds^2 (0,0) and (2.985984 x10^{14}, 12 x 10^{32}). The gradient = 4.02 x 10^{18} Let the gradient be represented by the pronumeral V. $V = \frac{GM}{4\pi^2}$ $M = \frac{V4\pi^2}{G}$ Mass = 2.4×10^{30} kg (to 1 decimal place)	• indicates an understanding that the gradient represents $\frac{GM}{4\pi^2}$ [1 mark] • provides pertinent mathematical operation/s correctly performed to convert days^2 into seconds^2 [1 mark] • arrives at a value for the gradient [1 mark] • provides pertinent mathematical operation/s correctly performed using the gradient [1 mark] • determines the mass [1 mark]	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table or expressed to a greater precision than done in the sample response. In this case: Accept values for the gradient inclusive between 3.6 x 10^{18} and 4.1 x 10^{18}. Accept values for the mass inclusive between 2.2 x 10^{30} kg and 2.4 x 10^{30} kg. Allow FT error for the mass.

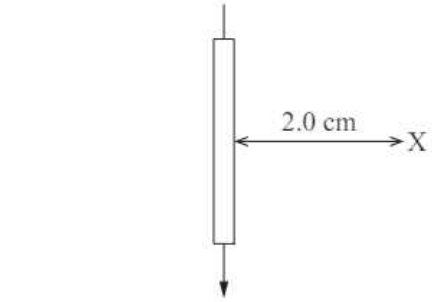
Unit 3 – Topic 2: Electromagnetism

Paper 1 Section 1

2024 Paper 1 Section 1 Question 5 Electromag.	The magnitude of the electrostatic force between two positively charged particles (A) is inversely proportional to the square of the distance between the particles. (B) increases as the square of the distance between the particles increases. (C) is proportional to the square of the distance between the particles. (D) is unrelated to the square of the distance between the particles.

2024 Paper 1 Section 1 Question 10 Electromag.	An experiment was conducted to determine the force experienced by an 85 cm wire with a 2.4 A current flowing through it in an external magnetic field. It was rotated through varying angles within the magnetic field such that data analysis identified the relationship $F = 0.0306 \sin\theta$. What is the order of magnitude of the strength of the external magnetic field? (A) 10^{-4} T (B) 10^{-2} T (C) 10^{2} T (D) 10^{4} T

2024 Paper 1 Section 1 Question 14 Electromag.	Magnetic flux density is a quantity related to the (A) rate of change of field lines moving through a given area. (B) number of magnetic field lines per unit area. (C) volume occupied by a magnetic field. (D) mass–charge ratio of a magnet.

2023 Paper 1 Section 1 Question 3 Electromag.	A current-carrying wire is shown.  Not to scale $I = 0.5$ A Determine the magnetic field strength at X. (A) 5×10^{-6} T out of the page (B) 5×10^{-6} T into the page (C) 5×10^{-8} T out of the page (D) 5×10^{-8} T into the page

2023 Paper 1 Section 1 Question 9 Electromag.	A magnet is passed through a solenoid comprising five turns and a cross-sectional area of 0.60 m2 to produce an EMF of 0.75 V. Calculate the EMF if the same magnet passes through another solenoid with three times as many turns and half the cross-sectional area at the same rate. (A) 0.89 V (B) 1.1 V (C) 4.0 V (D) 4.5 V

2023 **Paper 1** **Section 1** **Question 11** **Electromag.**	Coulomb's law describes the observation that (A) an electromotive force in a circuit may be induced through changes in the magnetic flux. (B) charged particles moving across magnetic field lines experience a force. (C) a change in the electromotive force is opposed. (D) like electric charges repel one another.

2023 **Paper 1** **Section 1** **Question 13** **Electromag.**	A magnet moving through a coil of wire will induce a current with a magnetic field (A) parallel to the electric field. (B) opposite in direction to the change in flux. (C) inversely proportional to the electromotive force. (D) that will continue to fluctuate once the magnet is removed.

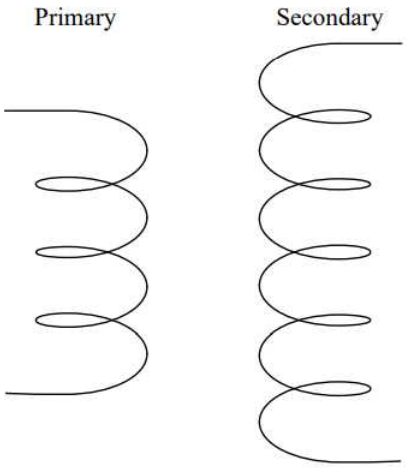
2023 **Paper 1** **Section 1** **Question 19** **Electromag.**	Calculate the electric field strength experienced at a distance of 2.8×10^{-11} m from the centre of a helium nucleus. (A) 1.0×10^{2} N C^{-1} (B) 2.0×10^{2} N C^{-1} (C) 3.7×10^{12} N C^{-1} (D) 7.3×10^{12} N C^{-1}

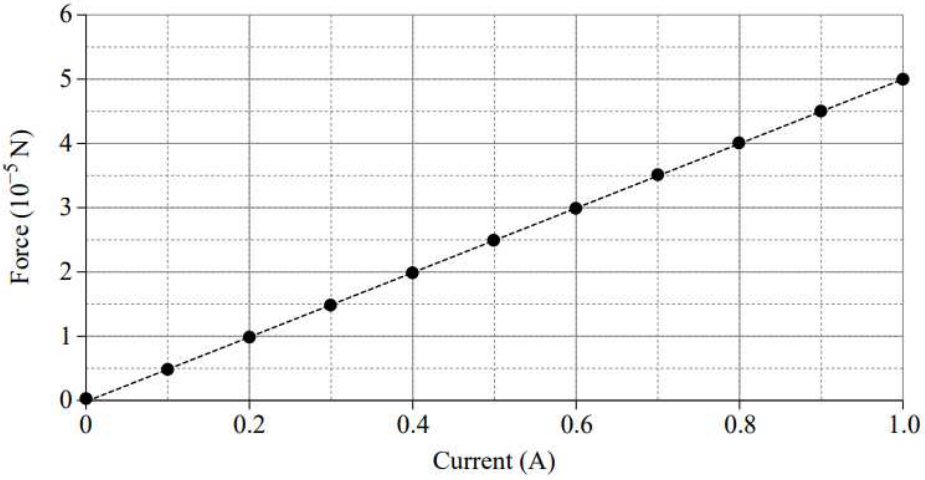
2022 **Paper 1** **Section 1** **Question 1** **Electromag.**	*Electromotive force* is (A) the production of voltage across an electrical conductor due to its dynamic interaction with a magnetic field. (B) a difference in potential that tends to give rise to an electric current. (C) the repulsion experienced by two negatively charged particles. (D) one of the four fundamental forces

2022 **Paper 1** **Section 1** **Question 7** **Electromag.**	Which change would produce the greatest increase in magnetic field strength inside a current-carrying solenoid? (A) decreasing the thickness of the wire (B) increasing the length of the solenoid (C) adding more turns of wire to the solenoid (D) using an alternating current instead of a direct current

2022 **Paper 1** **Section 1** **Question 10** **Electromag.**	*Electric field strength* refers to the (A) intensity of an electric field at a particular location. (B) change in electrical potential energy between two defined points. (C) sum of electrically charged particles passing a point in a given time. (D) physical property of an object experiencing a force in an electromagnetic field.

2022 **Paper 1** **Section 1** **Question 13** **Electromag.**	A rectangular coil of 3000 turns and dimensions 0.1 m × 0.2 m is rotated in a uniform magnetic field of 2 mT. Calculate the minimum number of revolutions per second required to produce an average EMF of 6 V. (A) 1 (B) 3 (C) 13 (D) 50

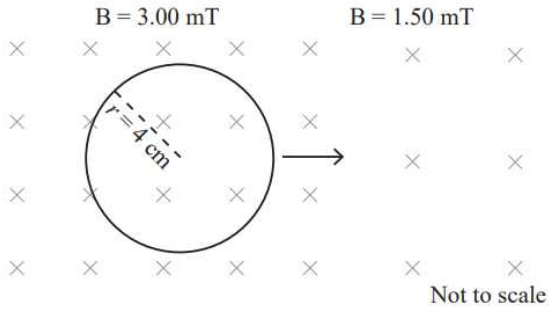
2022 **Paper 1** **Section 1** **Question 18** **Electromag.**	The primary and secondary coils from a lossless transformer are shown.  Compared to the primary coil, the secondary coil will experience decreased (A) power. (B) current. (C) voltage. (D) resistance.

2022 **Paper 1** **Section 1** **Question 19** **Electromag.**	A current-carrying wire is placed perpendicular to two magnets. As the current in the wire is changed, the force acting on it is recorded. The gradient of the line of best fit is proportional to the  (A) potential difference. (B) electromotive force. (C) resistance of the wire. (D) magnetic field strength.

2021 **Paper 1** **Section 1** **Question 6** **Electromag.**	Electromagnetic radiation is (A) extremely high-frequency radiation emitted from the nucleus of some radionuclides. (B) the emission of energy as waves or particles, especially high-energy particles, that causes ionisation. (C) a wave of energy produced by an oscillating electric charge, resulting in mutually perpendicular electric and magnetic fields. (D) radiant energy consisting of synchronised oscillations of electric and magnetic fields, or electromagnetic waves, propagated at the speed of light in a vacuum.

2021 **Paper 1** **Section 1** **Question 14** **Electromag.**	Moving electric charges in a magnetic field experience (A) a decrease in charge. (B) an increase in charge. (C) a force parallel to the direction of the magnetic field. (D) a force perpendicular to the direction of the magnetic field.

2021 **Paper 1** **Section 1** **Question 17** **Electromag.**	Electrical potential energy is the (A) intensity of an electric field at a particular location. (B) difference in potential that tends to give rise to an electric current. (C) capacity of electric charge carriers to do work due to their position in an electric circuit. (D) work done on an electron in accelerating it through an electrical potential difference of one volt.

2020 **Paper 1** **Section 1** **Question 4** **Electromag.**	The diagram shows a current-carrying loop moving from one magnetic field to another magnetic field in 0.600 seconds.  Calculate the magnitude of the EMF produced in the current-carrying loop. (A) 1.26×10^{-6} V (B) 1.26×10^{-5} V (C) 1.26×10^{-1} V (D) 1.26×10^{2} V

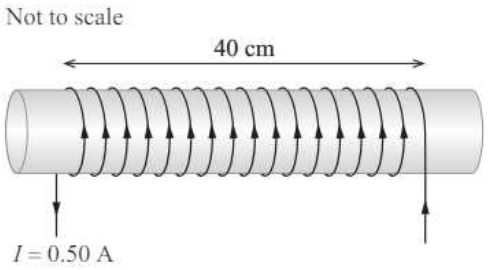
2020 **Paper 1** **Section 1** **Question 5** **Electromag.**	Which of the following is Lenz's Law? (A) The total electric charge of an isolated system remains constant regardless of changes within the system. (B) The magnetic flux around a current-carrying wire changes in proportion to the rate of change of the current. (C) The direction of an induced electric current always opposes the change in the circuit or magnetic field that produces it. (D) The ratio of the sines of the angles of incidence and refraction of a wave is constant when the wave passes between two given media.

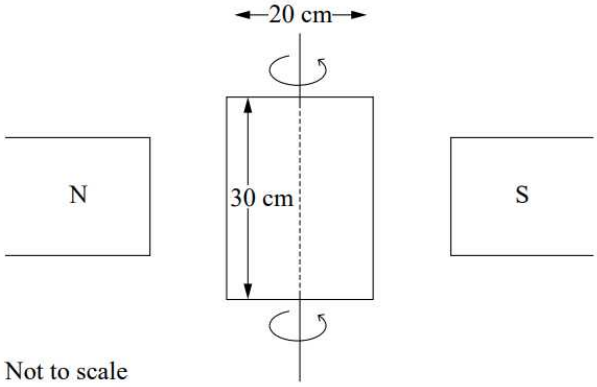
2020 **Paper 1** **Section 1** **Question 17** **Electromag.**	The definition of *magnetic field* is (A) a region of space through which the total magnetic flux is measured. (B) a region of space surrounding a body in which another body experiences a force of attraction. (C) a region of space around an electrically charged particle or object within which a force would be exerted on other electrically charged particles or objects. (D) a region of space near a magnet, electric current or moving electrically charged particle in which a magnetic force acts on any other magnet, electric current or moving electrically charged particle.

2020 **Paper 1** **Section 1** **Question 19** **Electromag.**	A solenoid with 24 loops of wire produces an EMF of 36 V during a magnetic flux change of 0.3 Wb. Calculate the period during which the magnetic flux varied. (A) 0.2 s (B) 0.5 s (C) 2.2 s (D) 5.0 s

2024 **Paper 1** **Section 2** **Question 25** **Electromag.**	A transformer with a turns ratio of 48:1 is set up to reduce a 240 V input. a) Explain how a transformer works in terms of Faraday's Law and electromagnetic induction. [3 marks] b) Determine the output voltage. [1 mark] Voltage = _____ V

2024 **Paper 1** **Section 2** **Question 26** **Electromag.**	The centres of two small equally positively charged metallic spheres are separated by a distance of 0.30 m and experience a force of 0.025 N between them. Calculate the charge on each of the metallic spheres. Show your working. Charge = _____ C

2023 **Paper 1** **Section 2** **Question 24** **Electromag.**	A solenoid consisting of 1240 turns is shown.  Determine the magnitude and direction of the magnetic field inside the solenoid. Show your working. (4 marks) Magnitude = _____ T (to two significant figures) Direction = _____

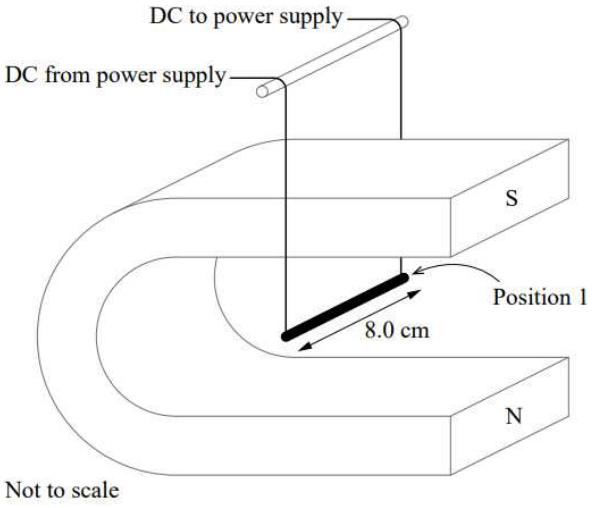
2022 Paper 1 Section 2 Question 24 Electromag.	A rectangular loop is placed in a uniform magnetic field of 5 mT.  Calculate the change in flux through the loop when it is rotated 60° around the vertical axis. Show your working. [3 marks] Change in flux = _____ Wb (to two significant figures)
2022 Paper 1 Section 2 Question 25 Electromag.	Describe how electromagnetic radiation is propagated by the interaction between electric and magnetic fields. [2 marks]

2021 **Paper 1** **Section 2** **Question 21** **Electromag.**	Explain how transformers work in terms of Faraday's law and electromagnetic induction. [3 marks]

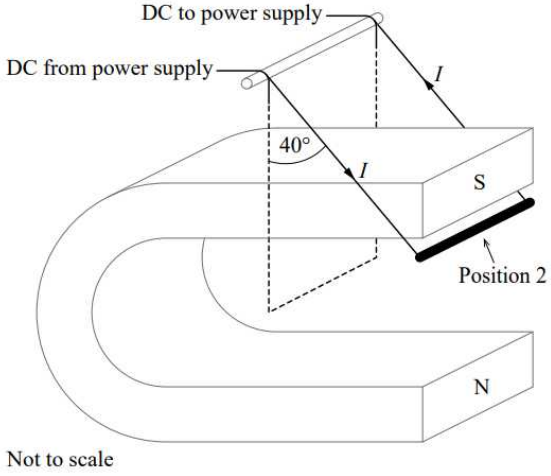
2021
Paper 1
Section 2
Question 23

Electromag.

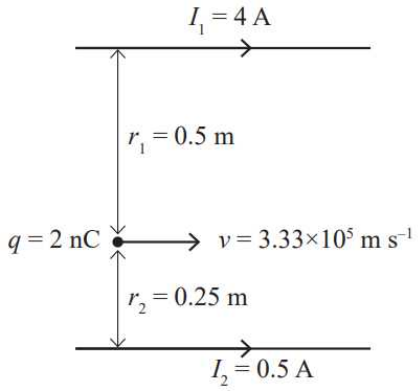
The diagram shows a metal rod with a mass of 10.0 g and a length of 8.0 cm suspended in a uniform magnetic field of 0.50 T. There is no electric current through the metal rod when it is in Position 1.



When a current (I) is passed through the metal rod it moves to Position 2, with an angle of 40° to the vertical.



Determine the magnitude of the current required to move the metal rod into Position 2. [5 marks]

2020 **Paper 1** **Section 2** **Question 28** **Electromag.**	The diagram shows a charged particle moving between two current-carrying wires.  Calculate the magnitude of the magnetic force acting on the charged particle. [4 marks]

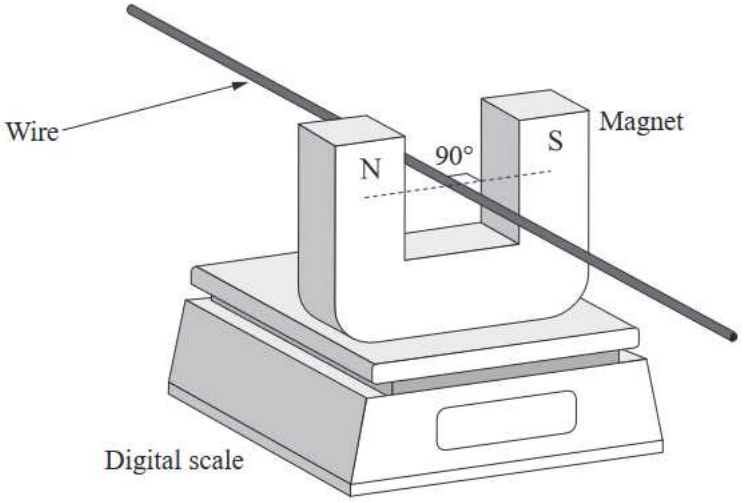
Magnetic force = _____ N (to 2 decimal places)

2024 **Paper 2** **Section 1** **Question 1** **Electromag.**	A coil of wire with 100 turns and a radius of 1.4 cm is placed perpendicular to a magnetic field of strength 0.510 T. The magnetic field strength is then changed to 0.030 T in 0.020 s. Calculate the magnitude of electromotive force (emf) induced in the coil. Show your working. [4 marks] Magnitude of emf = _____ V

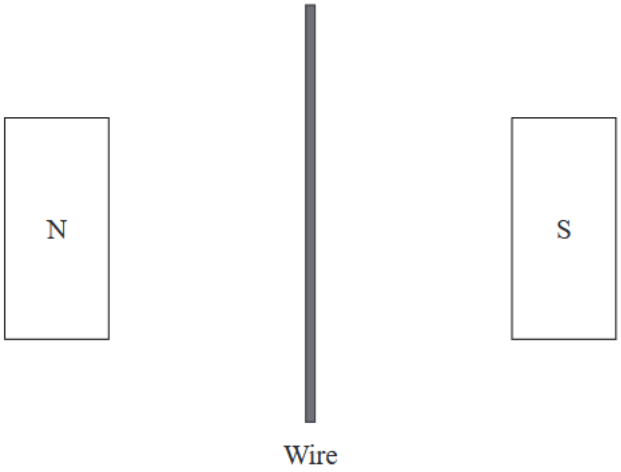
2024
Paper 2
Section 1
Question 8

Electromag.

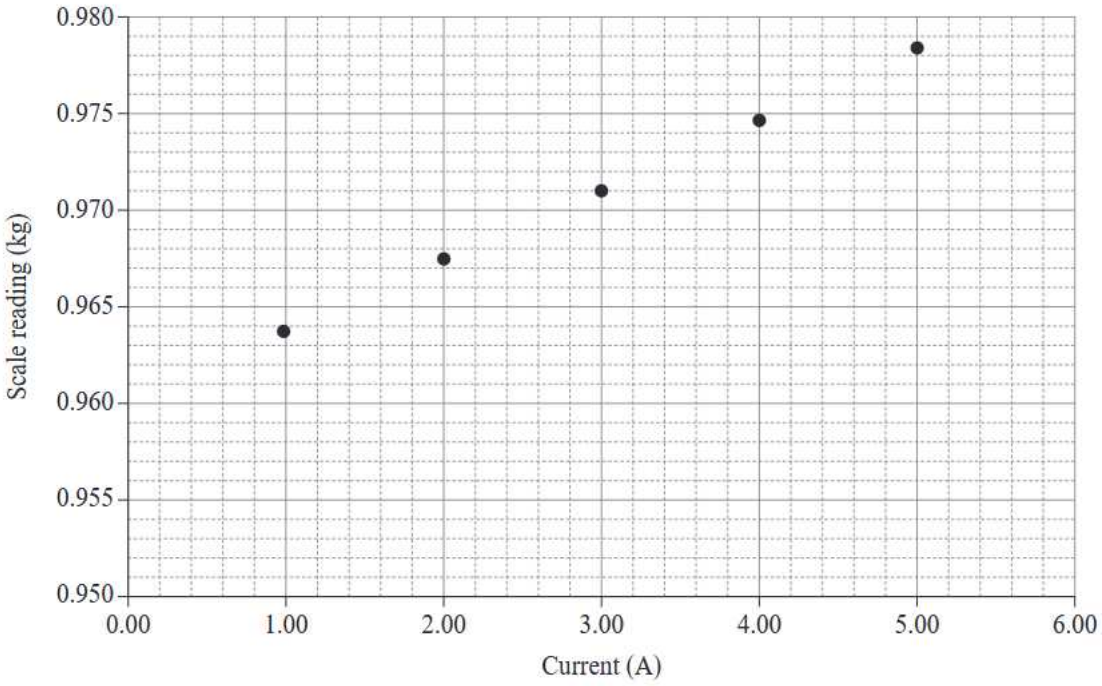
A U-shaped magnet was placed on a digital scale. A current-carrying wire was connected to a variable power supply and passed through the space between the poles of the magnet. The length of wire within the magnetic field was 0.08 m, and the wire did not touch the magnet.



a) Sketch the magnetic field between the north and south poles of the magnet when there is no current in the wire. [1 mark]



The power supply was switched on. Readings from the digital scale were recorded while the current in the wire was varied to produce the graph shown



b) Identify the mass of the magnet. [1 mark]

Mass = _____ kg

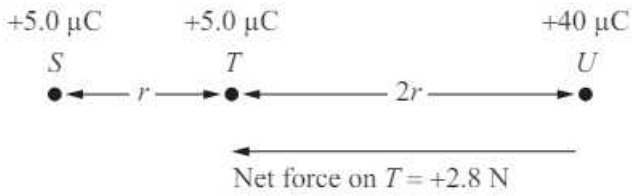
c) Determine the strength of the magnetic field produced by the magnet.
Show your working. [5 marks]

Magnetic field strength = _____ T

2023
Paper 2
Section 1
Question 3

Electromag.

Three charges are in a straight line as shown.



a) Calculate the electric field strength at T. Show your working. [2 marks]

Electric field strength = _____ N C^{-1} (to two significant figures)

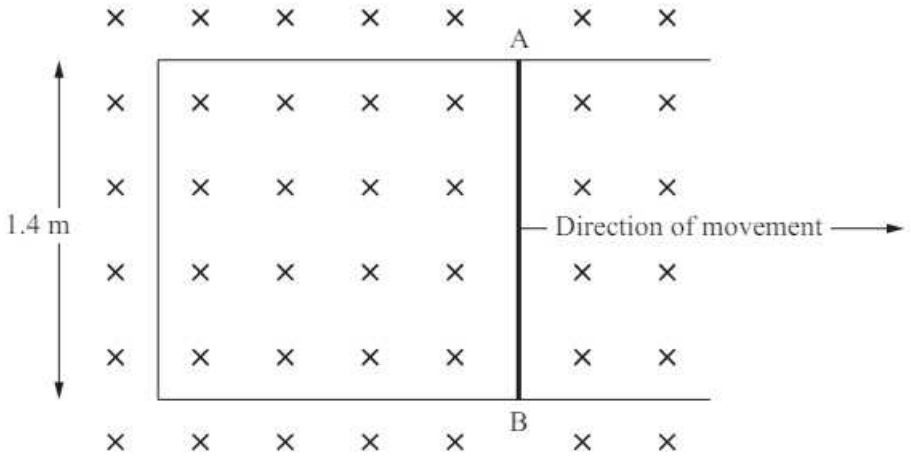
b) Determine the value of *r*. Show your working. [6 marks]

$r =$ _____ m (to two significant figures)

2023
Paper 2
Section 1
Question 8

Electromag.

A length of wire, AB, is placed across an incomplete loop sitting within a magnetic field as shown. Wire AB then moves with a constant velocity of 40 m s^{-1} , creating an induced EMF of 23 µV.



Not to scale

a) Determine the magnitude of the magnetic field strength experienced by the loop. Show your working. [4 marks]

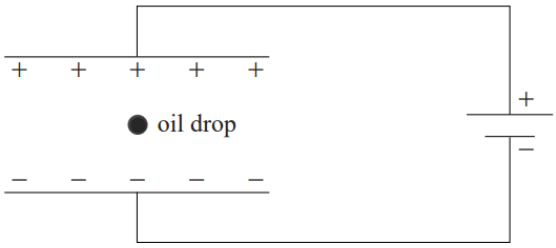
Magnetic field strength = _____ T (to two significant figures)

b) Draw a conclusion about the direction of the induced current within the loop. Justify your reasoning. [2 marks]

2022
Paper 2
Section 1
Question 3

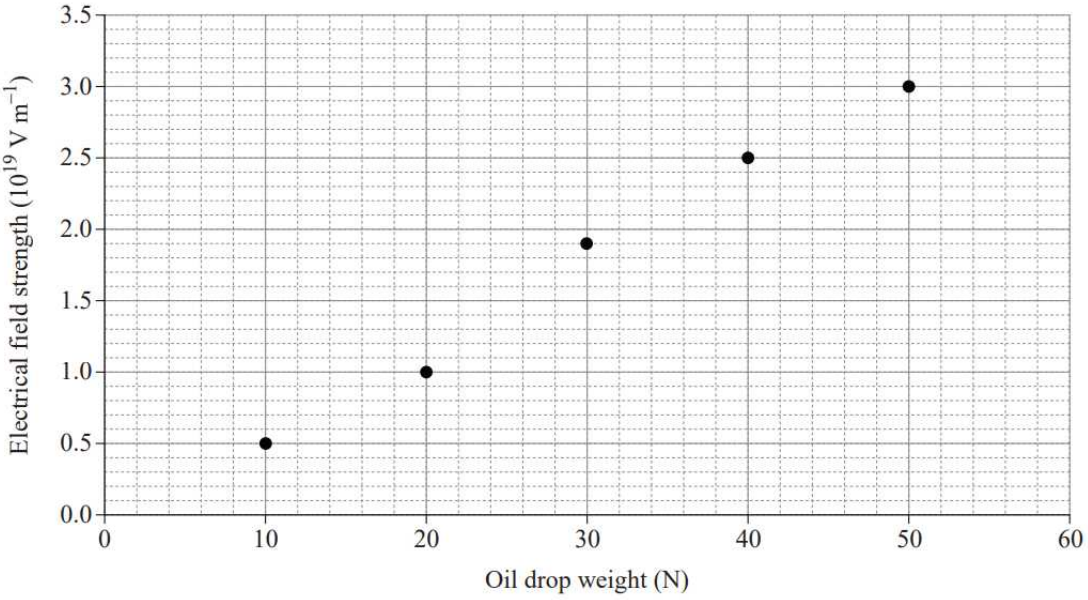
Electromag.

Negatively charged oil drops were placed in a uniform electric field generated by two parallel plates. By altering the applied voltage between the plates, the oil drops were suspended in the air between the plates.



Not to scale

The graph shows the electric field strength required (achieved by altering the applied voltage) to suspend negatively charged oil drops of varying weight.



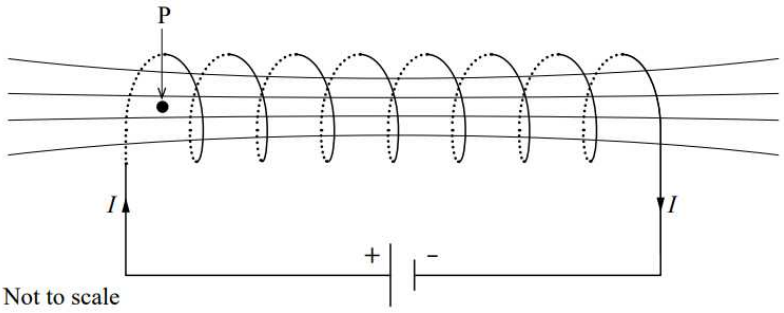
a) Determine the average charge on the oil drops. Show your working. [4 marks]

Average charge = _____ C (to two significant figures)

	Another oil drop was suspended between the plates with an electric field strength of 2.0×10^{19} V m^{-1}. . b) Determine the work done to move this oil drop a distance of 5 mm towards the negatively charged plate. Show your working. [4 marks] Work done = _____ J (to two significant figures)

2021 Paper 2 Section 1 Question 1 Electromag.	A charge of 2.8×10^{-7} C experiences an electrostatic force of 5.2×10^{-1} N when placed near a charge of 3.2×10^{-7} C. Calculate the distance between the two charges. [3 marks] Distance = _____ m (to 2 significant figures)

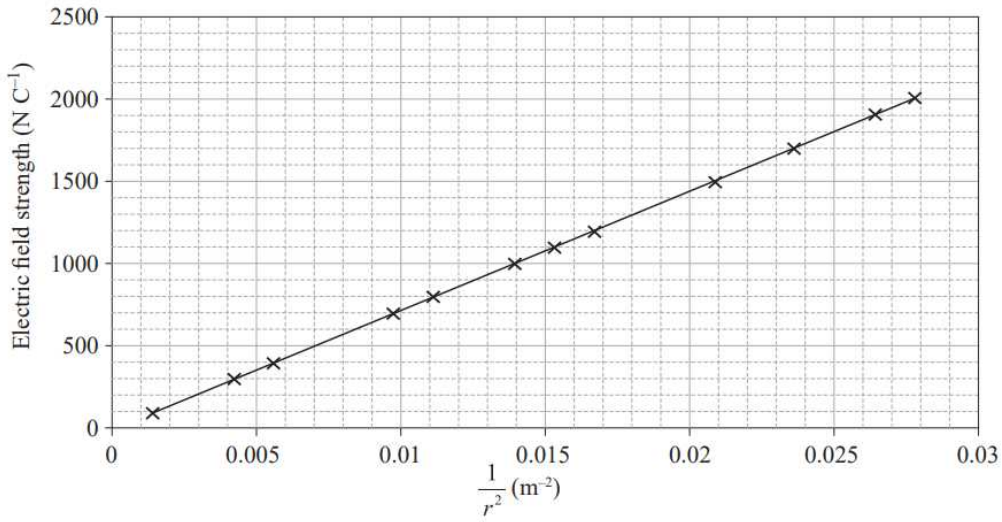
2021 **Paper 2** **Section 1** **Question 5** **Electromag.**	An alpha particle with a charge of $+3.2 \times 10^{-19}$ C moves through an electric field, accelerating from rest through a potential difference of 240 V. Determine the velocity of the particle at the end of its acceleration, expressing your answer in scientific notation. [4 marks] Velocity = _____ m s^{-1} (to 2 significant figures)

2021 **Paper 2** **Section 1** **Question 6** **Electromag.**	The diagram shows the magnetic field lines inside a solenoid carrying a current of 2 A.  a) Calculate the number of turns per metre that would produce a magnetic field strength of 300 μT at Point P. [3 marks] b) Determine the direction of the magnetic field produced by the solenoid. [1 mark]

2020
Paper 2
Section 1
Question 2

Electromag.

A physicist measured the electric field strength at different distances away from a point charge. The data is plotted in the graph.



a) Identify the mathematical relationship between E and $\frac{1}{r^2}$ [3 marks]

b) Use the mathematical relationship identified in 2a) to deduce the magnitude of the charge creating the electric field. [3 marks]

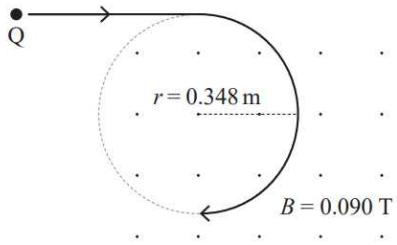
Charge = _____ C (to 1 decimal place)

2020 Paper 2 Section 1 Question 5 Electromag.	An electron is situated halfway between two nuclei that are separated from each other by a distance of 4.5×10^{-10} m. The first nucleus contains two protons. The second nucleus contains three protons. Calculate the magnitude of the overall electromagnetic force experienced by the electron. [4 marks] Force = _____ N (to 1 decimal place)

2020
Paper 2
Section 1
Question 6

Electromag.

The diagram shows a particle, Q, entering a uniform magnetic field of 0.090 T. The particle has a speed of 1.5×10^6 m s^{-1} . Once in the magnetic field, the particle moves in a circular path as shown.



It is suspected that Q is one of the particles listed in the table.

Particle number	Charge, q (C)	Mass, m (kg)
1	-1.60×10^{-19}	9.11×10^{-31}
2	$+1.60 \times 10^{-19}$	9.11×10^{-31}
3	$+1.60 \times 10^{-19}$	1.67×10^{-27}
4	$+1.60 \times 10^{-19}$	3.34×10^{-27}
5	-1.60×10^{-19}	3.34×10^{-27}

Determine which particle Q is most likely to be. [4 marks]

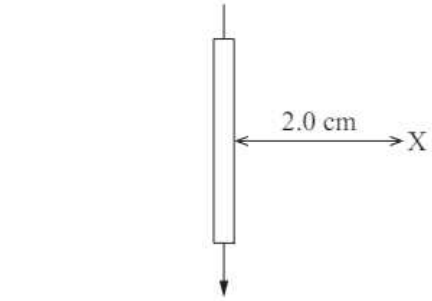
Particle Q = _____

Marking Guide – Paper 1 Section 1

2024 Paper 1 Section 1 Question 5 Electromag.	The magnitude of the electrostatic force between two positively charged particles **(A) is inversely proportional to the square of the distance between the particles. – Answer** (B) increases as the square of the distance between the particles increases. (C) is proportional to the square of the distance between the particles. (D) is unrelated to the square of the distance between the particles.

2024 Paper 1 Section 1 Question 10 Electromag.	An experiment was conducted to determine the force experienced by an 85 cm wire with a 2.4 A current flowing through it in an external magnetic field. It was rotated through varying angles within the magnetic field such that data analysis identified the relationship $F = 0.0306 \sin\theta$. What is the order of magnitude of the strength of the external magnetic field? (A) 10^{-4} T (B) 10^{-2} T (C) 10^{2} T (D) 10^{4} T **Answer is B.**

2024 Paper 1 Section 1 Question 14 Electromag.	Magnetic flux density is a quantity related to the (A) rate of change of field lines moving through a given area. **(B) number of magnetic field lines per unit area. – Answer** (C) volume occupied by a magnetic field. (D) mass–charge ratio of a magnet.

2023 Paper 1 Section 1 Question 3 Electromag.	A current-carrying wire is shown.  Not to scale $I = 0.5$ A Determine the magnetic field strength at X. **(A) 5×10^{-6} T out of the page – Answer** (B) 5×10^{-6} T into the page (C) 5×10^{-8} T out of the page (D) 5×10^{-8} T into the page

2023 Paper 1 Section 1 Question 9 Electromag.	A magnet is passed through a solenoid comprising five turns and a cross-sectional area of 0.60 m2 to produce an EMF of 0.75 V. Calculate the EMF if the same magnet passes through another solenoid with three times as many turns and half the cross-sectional area at the same rate. (A) 0.89 V **(B) 1.1 V – Answer** (C) 4.0 V (D) 4.5 V

2023 **Paper 1** **Section 1** **Question 11** **Electromag.**	Coulomb's law describes the observation that (A) an electromotive force in a circuit may be induced through changes in the magnetic flux. (B) charged particles moving across magnetic field lines experience a force. (C) a change in the electromotive force is opposed. **(D) like electric charges repel one another. – Answer**

2023 **Paper 1** **Section 1** **Question 13** **Electromag.**	A magnet moving through a coil of wire will induce a current with a magnetic field (A) parallel to the electric field. **(B) opposite in direction to the change in flux. – Answer** (C) inversely proportional to the electromotive force. (D) that will continue to fluctuate once the magnet is removed.

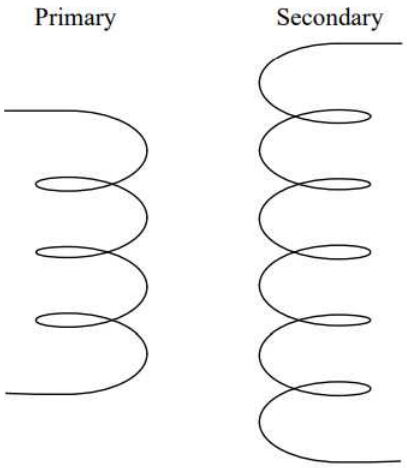
2023 **Paper 1** **Section 1** **Question 19** **Electromag.**	Calculate the electric field strength experienced at a distance of 2.8×10^{-11} m from the centre of a helium nucleus. (A) 1.0×10^{2} N C^{-1} (B) 2.0×10^{2} N C^{-1} **(C) 3.7×10^{12} N C^{-1} – Answer** (D) 7.3×10^{12} N C^{-1}

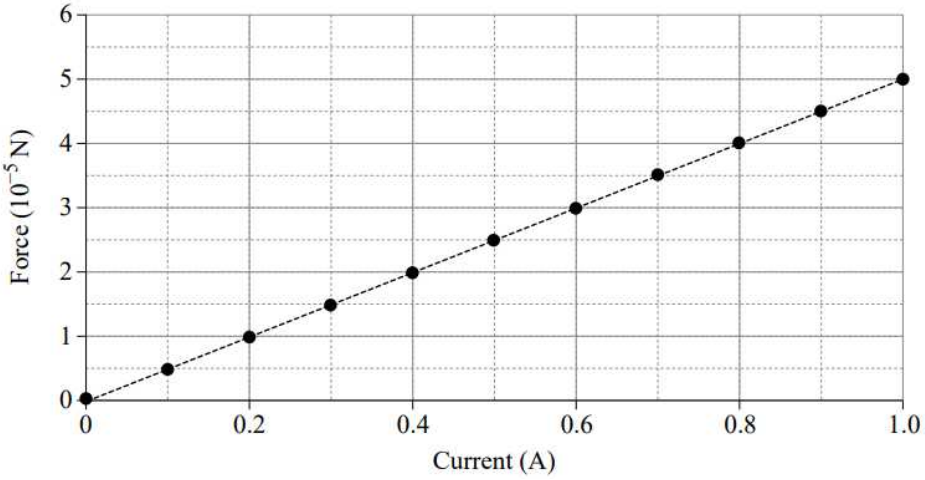
2022 **Paper 1** **Section 1** **Question 1** **Electromag.**	*Electromotive force* is (A) the production of voltage across an electrical conductor due to its dynamic interaction with a magnetic field. **(B) a difference in potential that tends to give rise to an electric current. – Answer** (C) the repulsion experienced by two negatively charged particles. (D) one of the four fundamental forces

2022 **Paper 1** **Section 1** **Question 7** **Electromag.**	Which change would produce the greatest increase in magnetic field strength inside a current-carrying solenoid? (A) decreasing the thickness of the wire (B) increasing the length of the solenoid **(C) adding more turns of wire to the solenoid – Answer** (D) using an alternating current instead of a direct current

2022 **Paper 1** **Section 1** **Question 10** **Electromag.**	*Electric field strength* refers to the **(A) intensity of an electric field at a particular location. – Answer** (B) change in electrical potential energy between two defined points. (C) sum of electrically charged particles passing a point in a given time. (D) physical property of an object experiencing a force in an electromagnetic field.

2022 **Paper 1** **Section 1** **Question 13** **Electromag.**	A rectangular coil of 3000 turns and dimensions 0.1 m × 0.2 m is rotated in a uniform magnetic field of 2 mT. Calculate the minimum number of revolutions per second required to produce an average EMF of 6 V. (A) 1 (B) 3 **(C) 13 – Answer** (D) 50

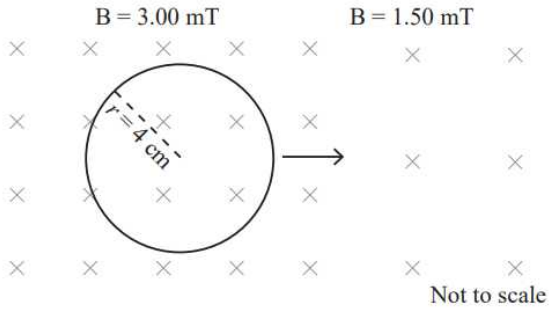
2022 Paper 1 Section 1 Question 18 Electromag.	The primary and secondary coils from a lossless transformer are shown.  Compared to the primary coil, the secondary coil will experience decreased (A) power. **(B) current. – Answer** (C) voltage. (D) resistance.

2022 Paper 1 Section 1 Question 19 Electromag.	A current-carrying wire is placed perpendicular to two magnets. As the current in the wire is changed, the force acting on it is recorded. The gradient of the line of best fit is proportional to the  (A) potential difference. (B) electromotive force. (C) resistance of the wire. **(D) magnetic field strength. – Answer**

2021 Paper 1 Section 1 Question 6 Electromag.	Electromagnetic radiation is (A) extremely high-frequency radiation emitted from the nucleus of some radionuclides. (B) the emission of energy as waves or particles, especially high-energy particles, that causes ionisation. (C) a wave of energy produced by an oscillating electric charge, resulting in mutually perpendicular electric and magnetic fields. **(D) radiant energy consisting of synchronised oscillations of electric and magnetic fields, or electromagnetic waves, propagated at the speed of light in a vacuum. – Answer**

2021 **Paper 1** **Section 1** **Question 14** **Electromag.**	Moving electric charges in a magnetic field experience (A) a decrease in charge. (B) an increase in charge. (C) a force parallel to the direction of the magnetic field. **(D) a force perpendicular to the direction of the magnetic field. – Answer**

2021 **Paper 1** **Section 1** **Question 17** **Electromag.**	Electrical potential energy is the (A) intensity of an electric field at a particular location. (B) difference in potential that tends to give rise to an electric current. **(C) capacity of electric charge carriers to do work due to their position in an electric circuit. – Answer** (D) work done on an electron in accelerating it through an electrical potential difference of one volt.

2020 **Paper 1** **Section 1** **Question 4** **Electromag.**	The diagram shows a current-carrying loop moving from one magnetic field to another magnetic field in 0.600 seconds.  Calculate the magnitude of the EMF produced in the current-carrying loop. (A) 1.26×10^{-6} V **(B) 1.26×10^{-5} V – Answer** (C) 1.26×10^{-1} V (D) 1.26×10^{2} V

2020 **Paper 1** **Section 1** **Question 5** **Electromag.**	Which of the following is Lenz's Law? (A) The total electric charge of an isolated system remains constant regardless of changes within the system. (B) The magnetic flux around a current-carrying wire changes in proportion to the rate of change of the current. **(C) The direction of an induced electric current always opposes the change in the circuit or magnetic field that produces it. – Answer** (D) The ratio of the sines of the angles of incidence and refraction of a wave is constant when the wave passes between two given media.

2020 **Paper 1** **Section 1** **Question 17** **Electromag.**	The definition of *magnetic field* is (A) a region of space through which the total magnetic flux is measured. (B) a region of space surrounding a body in which another body experiences a force of attraction. (C) a region of space around an electrically charged particle or object within which a force would be exerted on other electrically charged particles or objects. **(D) a region of space near a magnet, electric current or moving electrically charged particle in which a magnetic force acts on any other magnet, electric current or moving electrically charged particle. – Answer**

2020 **Paper 1** **Section 1** **Question 19** **Electromag.**	A solenoid with 24 loops of wire produces an EMF of 36 V during a magnetic flux change of 0.3 Wb. Calculate the period during which the magnetic flux varied. **(A) 0.2 s – Answer** (B) 0.5 s (C) 2.2 s (D) 5.0 s

2024 Paper 1 Section 2 Question 25

Electromag.

A transformer with a turns ratio of 48:1 is set up to reduce a 240 V input.

a) Explain how a transformer works in terms of Faraday's Law and electromagnetic induction. [3 marks]

Sample response	The response
According to Faraday's Law, when the magnetic flux linking a circuit changes, an emf is induced in the circuit proportional to the rate of change of the flux linkage. Therefore, in the transformer, the changing voltage in the primary coil will affect the rate of change of the magnetic flux in the second coil. Although the circuits aren't connected, a current will be induced in the secondary circuit.	• describes Faraday's Law **[1 mark]** • explains changing voltage in the primary coil affects rate of change of magnetic flux in secondary coil **[1 mark]** • explains an AC voltage is induced in the secondary coil by electromagnetic induction **[1 mark]**

b) Determine the output voltage. [1 mark]

Sample response	The response
A current will be induced in the second coil generating an AC voltage of: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ $\frac{240}{V_s} = \frac{48}{1}$ $V_s = 5\ \text{V}$	• determines secondary voltage to be 5 V **[1 mark]**

2024 Paper 1 Section 2 Question 26

Electromag.

The centres of two small equally positively charged metallic spheres are separated by a distance of 0.30 m and experience a force of 0.025 N between them.

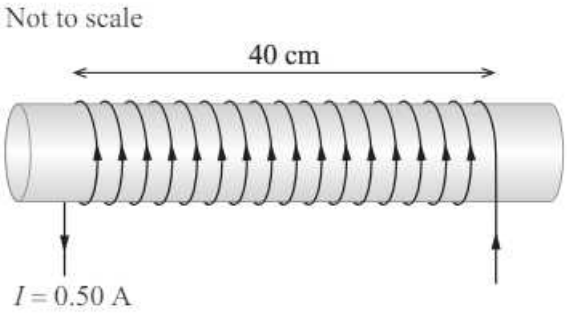
Calculate the charge on each of the metallic spheres. Show your working.

Sample response	The response
$F = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$ $0.025 = \frac{9\times10^9 \times Q^2}{0.30^2}$ $Q = \sqrt{\frac{0.025\times0.30^2}{9\times10^9}}$ $= 5.0\times10^{-7}$ Charge = $5.0\times10^{-7}\,\text{C}$	• recognises the scenario relates to Coulomb's Law **[1 mark]** • recognises the charges have the same value in the equation **[1 mark]** • calculates the charge of the metallic spheres to be $5.0\times10^{-7}\,\text{C}$ **[1 mark]**

2023
Paper 1
Section 2
Question 24

Electromag.

A solenoid consisting of 1240 turns is shown.



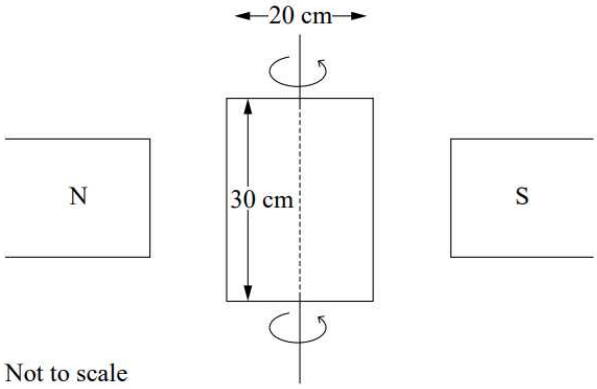
Determine the magnitude and direction of the magnetic field inside the solenoid. Show your working. (4 marks)

Sample response	The response
$n = \frac{1240}{0.4} = 3100\ m^{-1}$ $B = \mu_0 nI$ $= 4\pi \times 10^{-7} \times 3100 \times 0.5$ $= 0.0019$ T Magnitude = 0.0019 T (to two significant figures) Direction = to the left	• recognises the scenario relates to a magnetic field inside a solenoid **[1 mark]** • calculates the number of turns per metre **[1 mark]** • calculates the magnitude of the magnetic field **[1 mark]** • identifies the direction of the magnetic field **[1 mark]**

2022
Paper 1
Section 2
Question 24

Electromag.

A rectangular loop is placed in a uniform magnetic field of 5 mT.



Calculate the change in flux through the loop when it is rotated 60° around the vertical axis. Show your working. [3 marks]

Sample Response	The response
If loop is rotated 60°, angle of the loop perpendicular to the magnetic field is 90° – 60° = 30° $\phi = BA\cos\theta$ $= 5 \times 10^{-3} \times 0.06 \times \cos 30°$ $= 2.6 \times 10^{-4}\ Wb$ Change in flux = 2.6×10^{-4} Wb (to two significant figures)	• identifies the angle of the loop perpendicular to the magnetic field [1 mark] • recognises the scenario relates to the amount of magnetic flux passing through an area [1 mark] • calculates the change in flux [1 mark]

2022 Paper 1 Section 2 Question 25

Electromag.

Describe how electromagnetic radiation is propagated by the interaction between electric and magnetic fields. [2 marks]

Sample Response	The response
Oscillating charged particles induce a magnetic field. This subsequently induces an electric field perpendicular to the magnetic field.	• describes the production of an induced magnetic field [1 mark] • describes formation of an induced electric field, perpendicular to the magnetic field [1 mark]

2021 Paper 1 Section 2 Question 21

Electromag.

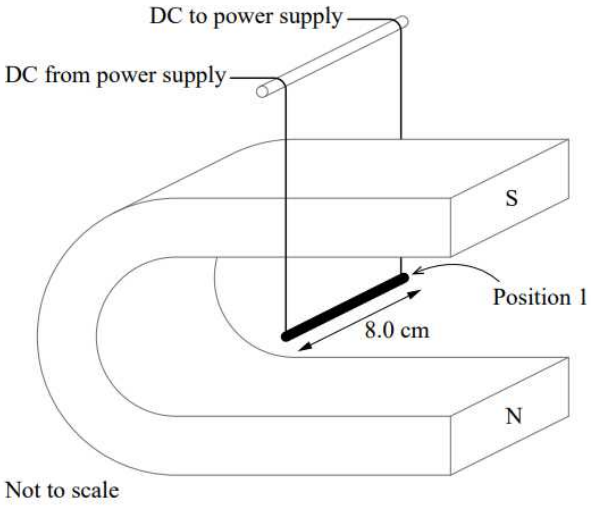
Explain how transformers work in terms of Faraday's law and electromagnetic induction. [3 marks]

Sample Response	The response	Notes
Alternating current passing through the first coil creates a magnetic flux. This magnetic flux induces an EMF in the secondary coil. The induced EMF is proportional to the number of coils and the rate of change of the magnetic flux.	• recognises that alternating current creates a changing magnetic flux [1 mark] • recognises that EMF is induced in the second coil by the changing magnetic flux in the first coil [1 mark] • identifies that the induced EMF is proportional to the number of coils and the rate of change of magnetic flux [1 mark]	For *magnetic flux*, accept *magnetic field* or *electromagnetic field*.

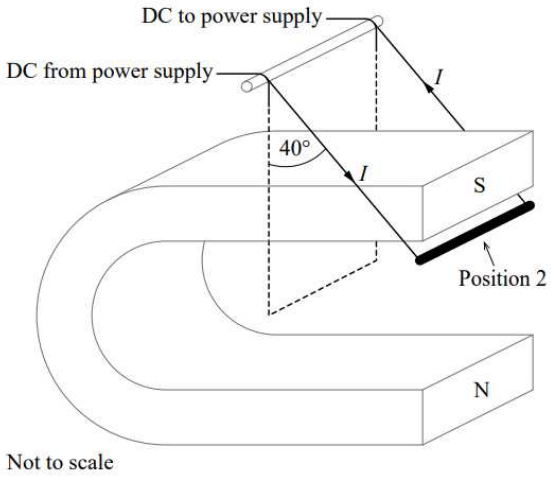
2021
Paper 1
Section 2
Question 23

Electromag.

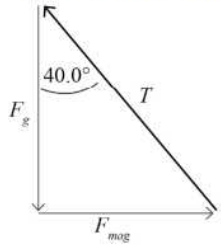
The diagram shows a metal rod with a mass of 10.0 g and a length of 8.0 cm suspended in a uniform magnetic field of 0.50 T. There is no electric current through the metal rod when it is in Position 1.



When a current (I) is passed through the metal rod it moves to Position 2, with an angle of 40° to the vertical.



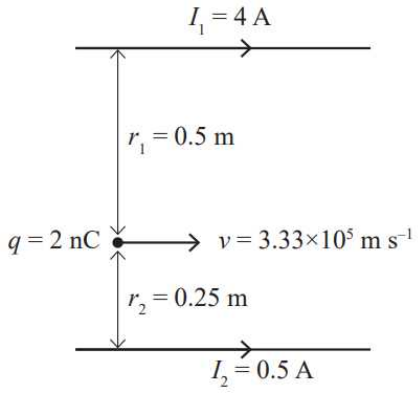
Determine the magnitude of the current required to move the metal rod into Position 2. [5 marks]

Sample Response	The response	Notes
There are three forces acting on the wire and they are balanced, forming a vector triangle.  From the vector triangle: $\tan\theta = \frac{F_{mag}}{F_g}$ Therefore $F_{mag} = F_g \tan\theta$ Therefore $F_{mag} = mg \tan 40^o$ Sub in magnetic force formula on the left-hand side: $BIL \sin\theta = mg \tan 40^o$ The magnetic field is at right angles to the current: $BIL \sin 90^o = mg \tan 40^o$ Since sin 90° = 1, rearranging $I = \frac{mg \tan 40^o}{BL}$ $I = \frac{(0.0100)(9.8)\tan 40^o}{(0.50)(0.080)}$ $I = 2.055\,794 \ldots$ Current = **2.1** A (to 1 decimal place)	• identifies the forces acting on the wire in the magnetic field [1 mark] • recognises that the force of gravity and the force of the magnetic field can be added to determine tension [1 mark] • identifies an equation for the relationship between F_g and F_{mag} [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the magnitude of the current [1 mark]	Allow FT marks due to error/s in prior working. Do not penalise for incorrect decimal places/significant figures.

2020
Paper 1
Section 2
Question 28

Electromag.

The diagram shows a charged particle moving between two current-carrying wires.



Calculate the magnitude of the magnetic force acting on the charged particle. [4 marks]

Sample Response	The response	Notes
$B_1 = \frac{\mu_0 I_1}{2\pi r_1} = 1.6 \times 10^{-6}$ T $\quad B_2 = \frac{\mu_0 I_2}{2\pi r_2} = 4 \times 10^{-7}$ T The magnetic fields are going in different directions, so working out the difference gives an overall magnetic field of B = 1.2×10^{-6} T The force on a moving charge in a magnetic field is given by $F = qvBsin\,\theta$ The velocity is at right angles to the direction of the magnetic field so sin 90 = 1. $F = 2 \times 10^{-9} \times 3.33 \times 10^5 \times 1.2 \times 10^{-6}$ Magnetic force = 7.99×10^{-10} N	• indicates an understanding of the physical scenario in relation to the magnetic field generated by a wire or other relevant physical concept/s [1 mark] • provides pertinent mathematical operation/s correctly performed to determine net magnetic field strength [1 mark] • provides pertinent mathematical operation/s correctly performed [1 mark] • determines the force on the charge [1 mark]	Accept values inclusive between 7.99×10^{-10} N and 8×10^{-10} N. Allow FT error for the magnetic field strength. Do not penalise for incorrect decimal places/significant figures.

2024 Paper 2 Section 1 Question 1

Electromag.

A coil of wire with 100 turns and a radius of 1.4 cm is placed perpendicular to a magnetic field of strength 0.510 T. The magnetic field strength is then changed to 0.030 T in 0.020 s.

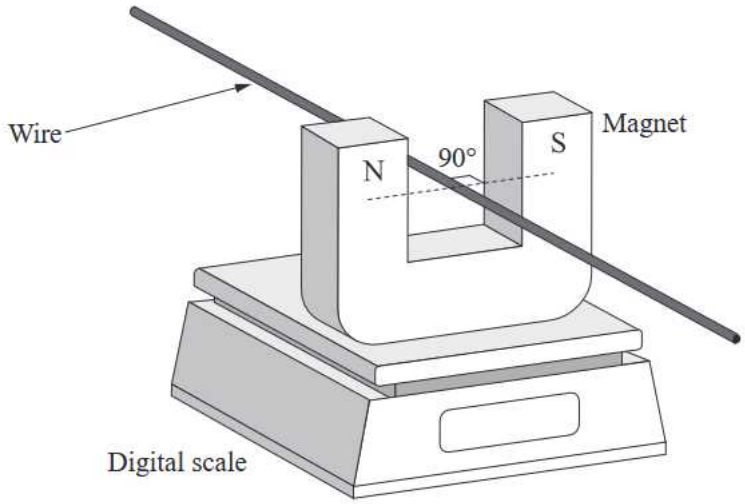
Calculate the magnitude of electromotive force (emf) induced in the coil. Show your working. [4 marks]

Sample response	The response
$r = 1.4 \text{ cm} = 0.014 \text{ m}$ $A = \pi r^2 = \pi \times 0.014^2 \approx 6.16 \times 10^{-4} \text{ m}^2$ $\text{emf} = -\frac{n\Delta(BA_\perp)}{\Delta t}$ $= -\frac{100 \times (0.030 - 0.510) \times (6.16 \times 10^{-4})}{0.020}$ $= 1.48$ Magnitude of emf = 1.5 V	• converts the radius to SI units (from cm to m) **[1 mark]** • determines the area of the coil **[1 mark]** • recognises the scenario relates to induction of an electromotive force by using the equation **[1 mark]** • calculates emf **[1 mark]**

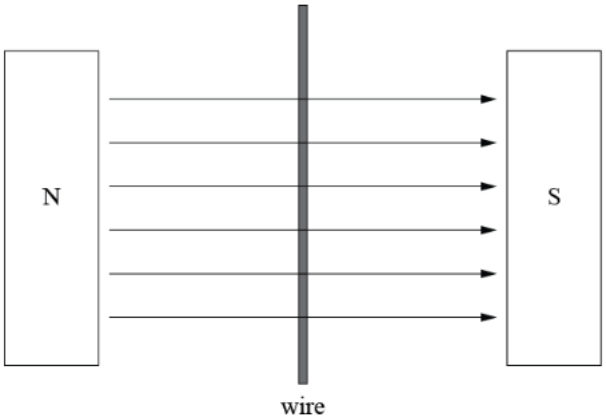
2024 Paper 2 Section 1 Question 8

Electromag.

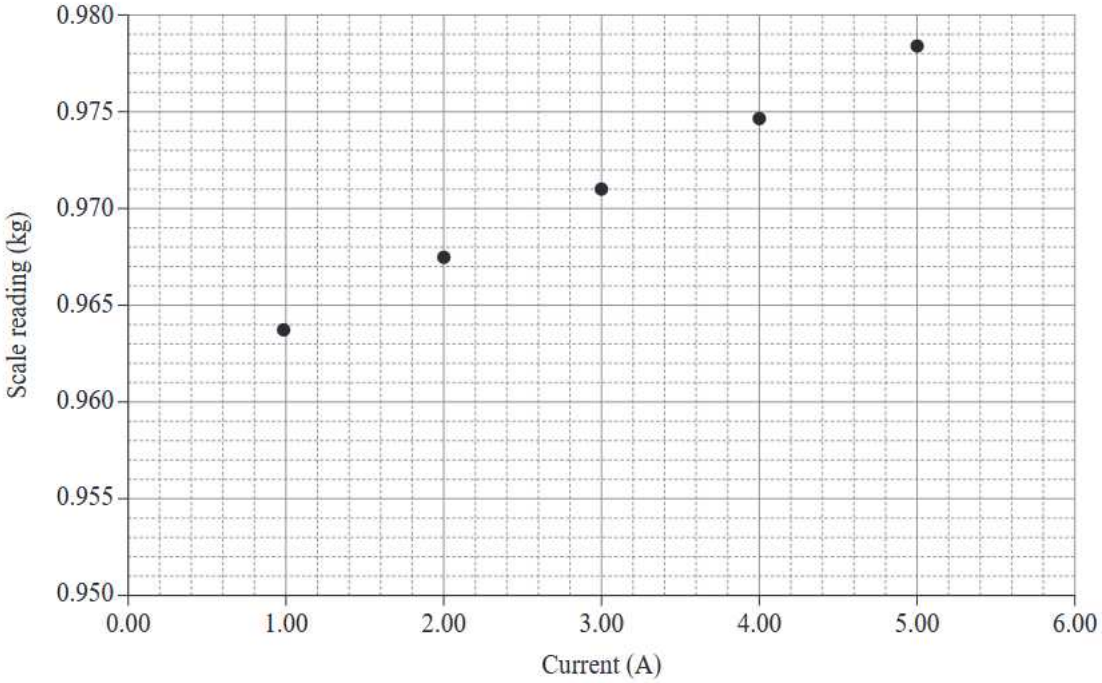
A U-shaped magnet was placed on a digital scale. A current-carrying wire was connected to a variable power supply and passed through the space between the poles of the magnet. The length of wire within the magnetic field was 0.08 m, and the wire did not touch the magnet.



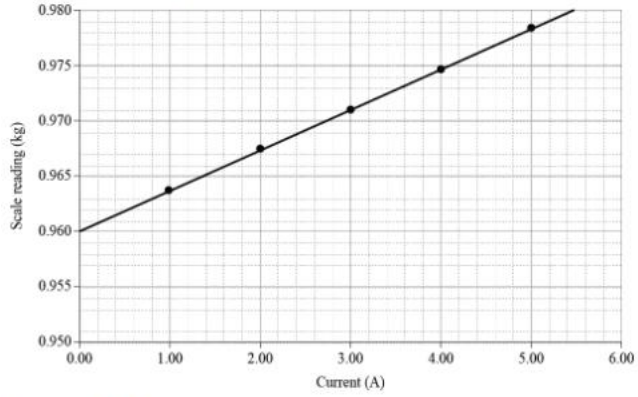
a) Sketch the magnetic field between the north and south poles of the magnet when there is no current in the wire. [1 mark]

Sample response	The response
	• sketches arrow/s from north to south **[1 mark]**

The power supply was switched on. Readings from the digital scale were recorded while the current in the wire was varied to produce the graph shown



b) Identify the mass of the magnet. [1 mark]

Sample response	The response
Mass of the magnet is equal to the y-intercept of the graph.  Mass = 0.96 kg	• identifies the mass of the magnet **[1 mark]**

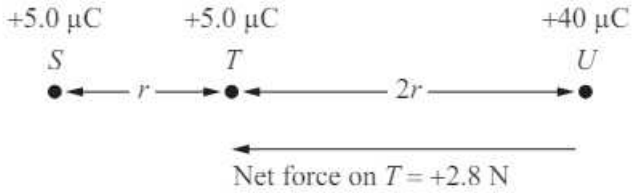
c) Determine the strength of the magnetic field produced by the magnet.
Show your working. [5 marks]

Sample response	The response
$F = BIL\sin\theta$ $\sin 90 = 1$ $F_{Magnetic} = F_{ScaleReading} - F_{WeightOfMag}$ $F_{ScaleReading} - F_{WeightOfMagnet} = BIL$ Referring to (3.00,0.971) $0.971\times9.8 - 0.960\times9.8 = B\times3.00\times0.08$ $B = \frac{9.52-9.41}{0.240}$ $= 0.449$ T	• recognises the scenario relates to magnetic field strength **[1 mark]** • recognises sin 90° = 1 **[1 mark]** • identifies appropriate data from the graph **[1 mark]** • shows appropriate mathematical reasoning **[1 mark]** • determines the magnetic field strength **[1 mark]**

2023
Paper 2
Section 1
Question 3

Electromag.

Three charges are in a straight line as shown.



a) Calculate the electric field strength at T. Show your working. [2 marks]

Sample response	The response
$E = \frac{F}{q}$ $= \frac{2.8}{5\times10^{-6}}$ $= 5.6\times10^{5}$ N C^{-1} Electric field strength = 5.6×10^{5} N C^{-1} (to two significant figures)	• recognises the scenario relates to force acting on a point within an electric field **[1 mark]** • calculates the electric field strength at T **[1 mark]**

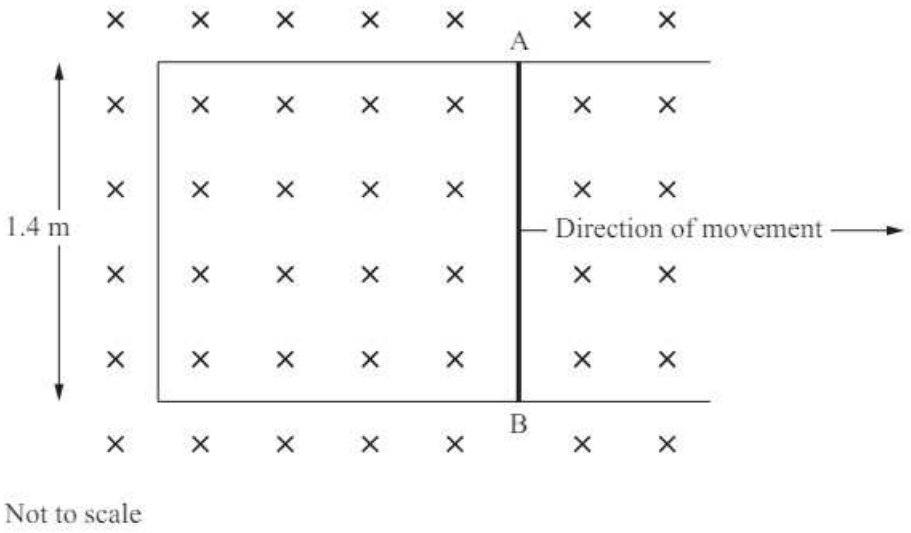
b) Determine the value of r. Show your working. [6 marks]

Sample response	The response
Using force Force between charges S and T: $F_{ST} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $= 9\times10^9 \times \frac{5\times10^{-6}\times5\times10^{-6}}{r^2}$ $= \frac{0.225}{r^2}$	• recognises the scenario relates to forces between charges **[1 mark]**
Force between charges T and U: $F_{TU} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $= 9\times10^9 \times \frac{5\times10^{-6}\times40\times10^{-6}}{(2r)^2}$ $= \frac{1.8}{4r^2}$ $= \frac{0.45}{r^2}$	• identifies the relationship between force and distance for – charges S and T **[1 mark]** – charges T and U **[1 mark]**
Equating the forces: $\lvert F_{net}\rvert = \lvert F_{ST} - F_{TU}\rvert$ $\lvert 2.8\rvert = \left\lvert \frac{0.225}{r^2} - \frac{0.45}{r^2}\right\rvert$ $r^2 = \left\lvert \frac{-0.225}{2.8}\right\rvert$ $r = 0.28$ m	• identifies the vector relationship between forces **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]**
r = 0.28 m (to two significant figures)	• calculates the value of r **[1 mark]**

2023 Paper 2 Section 1 Question 8

Electromag.

A length of wire, AB, is placed across an incomplete loop sitting within a magnetic field as shown. Wire AB then moves with a constant velocity of 40 m s^{-1} , creating an induced EMF of 23 µV.



Not to scale

a) Determine the magnitude of the magnetic field strength experienced by the loop. Show your working. [4 marks]

Sample response	The response
The induced current is a result of the changing area of the enclosed loop. $\Delta A = \Delta l w = wv\Delta t$ Therefore: $emf = -n\frac{\Delta(BA_{\perp})}{\Delta t}$ $emf = -1\times\frac{Bwv\Delta t}{\Delta t}$ $23\times10^{-6} = -B\times1.4\times40$ $B = \frac{23\times10^{-6}}{1.4\times40}$ $= 4.1\times10^{-7}$ T Magnetic field strength = 4.1×10^{-7} T (to two significant figures)	• recognises the scenario relates to Faraday's law and changing area **[1 mark]** • identifies relationship for the change in area over time **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the magnitude of the magnetic field strength **[1 mark]**

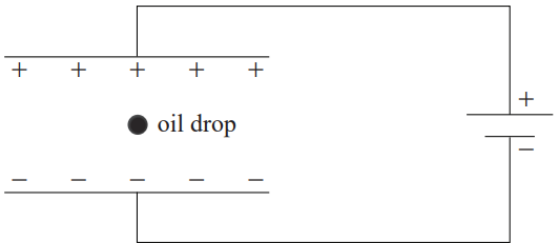
b) Draw a conclusion about the direction of the induced current within the loop. Justify your reasoning. [2 marks]

Sample response	The response
The induced current in the loop moves in an anticlockwise direction. This is because the induced current will oppose any change as described by Lenz's law.	• concludes the direction of the induced current in the loop is anticlockwise **[1 mark]** • justifies the conclusion using Lenz's law **[1 mark]**

2022
Paper 2
Section 1
Question 3

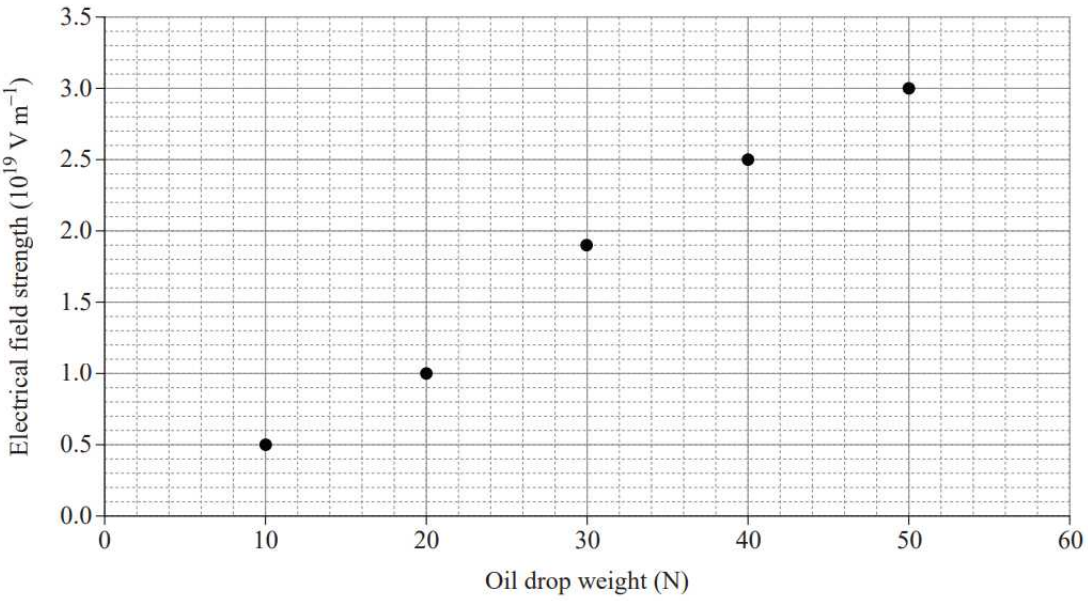
Electromag.

Negatively charged oil drops were placed in a uniform electric field generated by two parallel plates. By altering the applied voltage between the plates, the oil drops were suspended in the air between the plates.



Not to scale

The graph shows the electric field strength required (achieved by altering the applied voltage) to suspend negatively charged oil drops of varying weight.



a) Determine the average charge on the oil drops. Show your working. [4 marks]

Sample Response	The response
Since $E = \frac{F}{q}$, gradient of graph is equivalent to $\frac{1}{q}$ $gradient = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{2.8\times10^{19} - 1.0\times10^{19}}{46 - 18}$ $= 6.43\times10^{17}$ $q = \frac{1}{6.43\times10^{17}}$ $= 1.6\times10^{-18}$ Charge of electron = 1.6×10^{-18} C (to two significant figures)	• recognises the scenario relates to electric field strength and electron charge [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the gradient [1 mark] • determines the average charge on the oil drops [1 mark]

Another oil drop was suspended between the plates with an electric field strength of 2.0×10^{19} V m^{-1}.

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b) Determine the work done to move this oil drop a distance of 5 mm towards the negatively charged plate. Show your working. [4 marks]

Sample Response	The response
From the graph: $F_g = 33\ N$ $\Delta U = W = Fs$ $= 33 \times 0.005$ $= 1.7 \times 10^{-1}$ Work done = 0.17 J (to two significant figures)	• determines the weight of the oil drop [1 mark] • recognises the scenario relates to the work done in an electric field [1 mark] • demonstrates correct substitution [1 mark] • determines the work done [1 mark]

2021 Paper 2 Section 1 Question 1

Electromag.

A charge of 2.8×10^{-7} C experiences an electrostatic force of 5.2×10^{-1} N when placed near a charge of 3.2×10^{-7} C.

Calculate the distance between the two charges. [3 marks]

Sample Response	The response	Notes
$F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $r^2 = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{F}$ $r = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{Qq}{F}}$ $= \sqrt{9 \times 10^9 \times \frac{2.8 \times 10^{-7} \times 3.2 \times 10^{-7}}{0.52}}$ Distance = 0.039 m (to 2 significant figures)	• recognises the scenario relates to Coulomb's law [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the distance [1 mark]	Do not penalise for incorrect decimal places/significant figures.

2021 Paper 2 Section 1 Question 5

Electromag.

An alpha particle with a charge of $+3.2 \times 10^{-19}$ C moves through an electric field, accelerating from rest through a potential difference of 240 V.

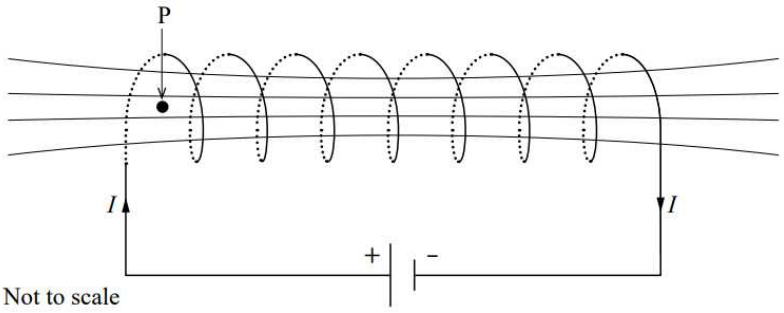
Determine the velocity of the particle at the end of its acceleration, expressing your answer in scientific notation. [4 marks]

Sample Response	The response	Notes
The change in potential energy of an electric charge moving through an electric field is equivalent to the work done on the charge. $V = \frac{\Delta U}{q}$ $\Delta U = Vq$ $= 240 \times 3.2 \times 10^{-19}$ $= 7.68 \times 10^{-17}\ J = W$ The work done on an object is equal to the change in kinetic energy. $E_k = \frac{1}{2}mv^2$ $7.68 \times 10^{-17} = \frac{1}{2} \times 6.64 \times 10^{-27} \times v^2$ $v^2 = \frac{7.68 \times 10^{-17}}{\frac{1}{2} \times 6.64 \times 10^{-27}}$ $v = \sqrt{\frac{7.68 \times 10^{-17}}{\frac{1}{2} \times 6.64 \times 10^{-27}}}$ Velocity = 1.5×10^5 m s^{-1} (to 2 significant figures)	• recognises the scenario relates to work done on a moving charge in an electric field [1 mark] • identifies that work done on the charge equates to its kinetic energy [1 mark] • provides appropriate mathematical reasoning [1 mark] • determines the velocity [1 mark]	Allow FT marks due to error/s in prior working. Do not penalise for incorrect decimal places/significant figures.

2021
Paper 2
Section 1
Question 6

Electromag.

The diagram shows the magnetic field lines inside a solenoid carrying a current of 2 A.



a) Calculate the number of turns per metre that would produce a magnetic field strength of 300 μT at Point P. [3 marks]

Sample Response	The response
$B = \mu_0 nI$ $n = \frac{B}{\mu_0 I}$ $n = \frac{300 \times 10^{-6}}{4\pi \times 10^{-7} \times 2} = 119 \text{ turns m}^{-1}$	• recognises the scenario relates to the magnetic field produced inside a solenoid [1 mark] • provides appropriate mathematical reasoning [1 mark] • calculates the number of turns [1 mark]

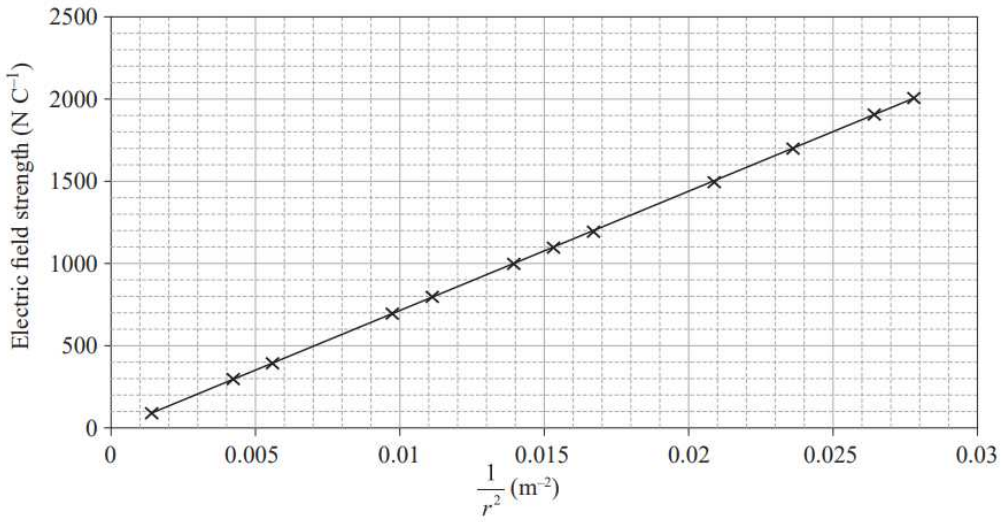
b) Determine the direction of the magnetic field produced by the solenoid. [1 mark]

Sample Response	The response	Notes
Left to right	• determines the field goes from left to right [1 mark]	Accept an arrow pointing to the right.

2020 Paper 2 Section 1 Question 2

Electromag.

A physicist measured the electric field strength at different distances away from a point charge. The data is plotted in the graph.



a) Identify the mathematical relationship between E and $\frac{1}{r^2}$ [3 marks]

Sample Response	The response	Notes
$c = 0$ $m = \frac{2000 - 0}{0.0278 - 0} = 72\ 000$ $E = 72\ 000(\frac{1}{r^2})$	• provides a correct value for the y-intercept [1 mark] • provides a correct value for the gradient of the graph [1 mark] • provides the equation [1 mark]	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done so in the sample response. In this case: Accept values for the y-intercept between 50 NC^{-1} and –50 NC^{-1} inclusive. Accept values for the gradient between 70 000 and 72 500 inclusive. Allow FT error for the equation.

b) Use the mathematical relationship identified in 2a) to deduce the magnitude of the charge creating the electric field. [3 marks]

Sample Response	The response	Notes
$(E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2})$ equate the gradient to kq. $q = 72\ 000 / 9 \times 10^9\ C = 8 \times 10^{-6}\ C$ Charge = 8.0×10^{-6} C	• indicates an understanding of the physical scenario in relation to the gradient being used to find the charge [1 mark] • provides pertinent mathematical operations correctly performed [1 mark] • determines the charge [1 mark]	Allow FT error from part a). Allow FT error for the charge. Do not penalise for incorrect decimal places/significant figures.

2020 Paper 2 Section 1 Question 5

Electromag.

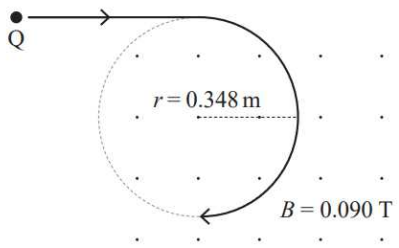
An electron is situated halfway between two nuclei that are separated from each other by a distance of 4.5×10^{-10} m. The first nucleus contains two protons. The second nucleus contains three protons. Calculate the magnitude of the overall electromagnetic force experienced by the electron. [4 marks]

Sample Response	The response	Notes
$F_2 = \frac{1}{4\pi\varepsilon_o}\frac{Q_1 \times q_e}{r_1^2}$ $= 9 \times 10^9 \times \frac{3(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 1.3 \times 10^{-8}\text{N}$ $F_1 = \frac{1}{4\pi\varepsilon_o}\frac{Q_2 \times q_e}{r_2^2}$ $= 9 \times 10^9 \times \frac{2(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 9.0 \times 10^{-9}\text{N}$ $\lvert F_{net}\rvert = \lvert F_1\rvert - \lvert F_2\rvert$ $= 1.4 \times 10^{-8} - 9.1 \times 10^{-9}$ Force = 4.0×10^{-9} N (to 1 decimal place)	• indicates an understanding of the physical scenario in relation to Coulomb's law [1 mark] • provides pertinent mathematical operation/s correctly performed [1 mark] • determines the forces (or electric field strength) imposed by each nuclei on the electron [1 mark] • determines the correct net force [1 mark]	An understanding of the physical scenario of Coulomb's law may include: - the electron experiences two forces due to the two charges … Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done so in the sample response. In this case: Accept values inclusive between: 1.3 x 10^{-8} N and 1.4 x 10^{-8} N for F2 9.0 x 10^{-9} N and 9.1 x 10^{-9} N for F1. Allow FT error for all force calculations.

2020 Paper 2 Section 1 Question 6

Electromag.

The diagram shows a particle, Q, entering a uniform magnetic field of 0.090 T. The particle has a speed of 1.5×10^6 m s^{-1} . Once in the magnetic field, the particle moves in a circular path as shown.



It is suspected that Q is one of the particles listed in the table.

Particle number	Charge, q (C)	Mass, m (kg)
1	-1.60×10^{-19}	9.11×10^{-31}
2	$+1.60 \times 10^{-19}$	9.11×10^{-31}
3	$+1.60 \times 10^{-19}$	1.67×10^{-27}
4	$+1.60 \times 10^{-19}$	3.34×10^{-27}
5	-1.60×10^{-19}	3.34×10^{-27}

Determine which particle Q is most likely to be. [4 marks]

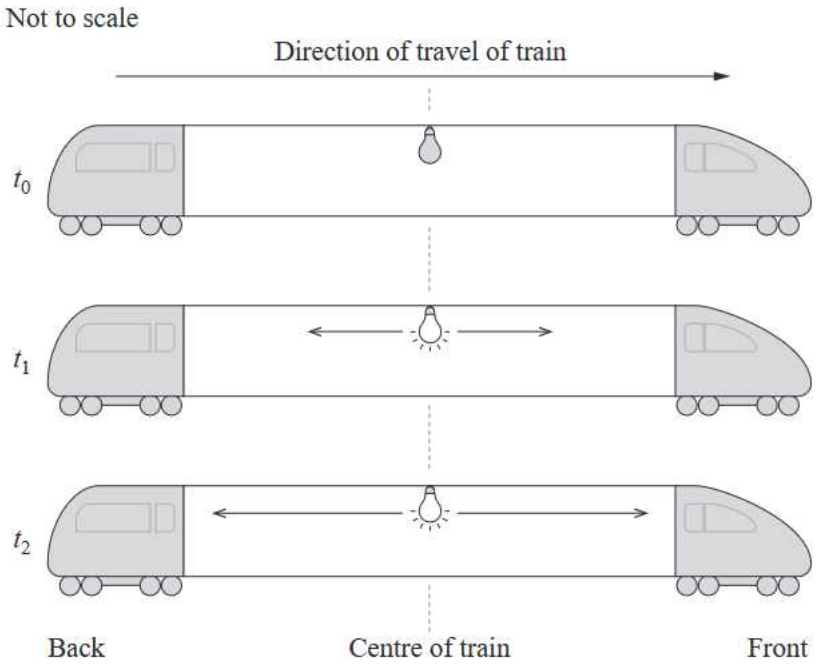
Sample Response	The response	Notes
Using the right-hand rule and the motion of the particle, it must be a positive particle. The particle moves in a circle due to the magnetic force. $F_{mag} = F_{circular}$ $qvB \sin\theta = \frac{mv^2}{r}$ Particle enters perpendicularly, therefore $\sin\theta = \sin 90^\circ = 1$ $qvB = \frac{mv^2}{r}$ $m = \frac{qBr}{v}$ $m = \frac{(1.60 \times 10^{-19})(0.090)(3.48 \times 10^{-1})}{1.50 \times 10^6}$ $m = 3.34 \times 10^{-27}$kg Therefore, Particle Q must be Particle 4.	• indicates an understanding of the physical scenario in relation to the force on a positive charge in a magnetic field, and centripetal force [1 mark] • provides pertinent mathematical operations correctly performed [1 mark] • determines the mass [1 mark] • identifies the correct particle using the mass and the charge of the particle [1 mark]	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept answers inclusive between 3.33 x 10^{-27} kg and 3.35 x 10^{-27} kg.

Unit 4 Revolutions in modern physics

Unit 4 – Topic 1: Special relativity

Paper 1 Section 1

2024 Paper 1 Section 1 Question 2 Special relativity	Which property of light is described by the postulates of special relativity? (A) The energy of light is greater when the frequency of the photons decreases. (B) The wavelength of light decreases as the velocity of the source increases. (C) The velocity of light remains constant in all inertial frames of reference. (D) The frequency of light changes depending on media

2024 Paper 1 Section 1 Question 9 Special relativity	A passenger at the centre of a train moving at a relativistic speed switches on a light. According to the passenger, light travels outwards as shown.  How would a stationary observer, watching the train pass by them, record this event? (A) Light will reach the back of the train first. (B) Light will reach the front of the train first. (C) Light will reach both ends of the train at t_0. (D) Light will reach both ends of the train simultaneously.

2024 Paper 1 Section 1 Question 17 Special relativity	A person on Earth experiences a time period of 15 years. Approximately how much time will have passed for a passenger on a spaceship travelling at 0.7 c relative to Earth during that time? (A) 8 years (B) 11 years (C) 21 years (D) 27 years

2023 **Paper 1** **Section 1** **Question 1** **Special relativity**	An object is unable to accelerate to the speed of light because (A) length contraction will change the height of the object. (B) time dilation will decrease the velocity of the object. (C) the object will gain infinite momentum. (D) the inertia of the object will decrease.

2023 **Paper 1** **Section 1** **Question 16** **Special relativity**	A train is travelling at relativistic speed and is about to move through a tunnel. An observer on the train measures the train and tunnel to each be 95 m long. A second observer is stationary relative to the tunnel. They would observe the train to (A) simultaneously enter and exit the tunnel. (B) decrease its mass while in the tunnel. (C) move faster while in the tunnel. (D) be shorter than the tunnel.

2023 **Paper 1** **Section 1** **Question 17** **Special relativity**	The half-life of an unstable subatomic particle is measured by a stationary detector to be longer when its velocity approaches the speed of light. This is because the particle (A) is moving relative to its frame of reference. (B) is in the same frame of reference as the detector. (C) experiences time differently relative to the detector. (D) cannot be accurately observed at relativistic speeds.

2022 **Paper 1** **Section 1** **Question 15** **Special relativity**	An object's velocity can only be measured relative to (A) a fixed reference frame. (B) the speed of light. (C) an object at rest. (D) an observer.

2021 **Paper 1** **Section 1** **Question 3** **Special relativity**	Identify the correct formula for the mass–energy equivalence relationship. (A) $E = mc^2$ (B) $E = mgh$ (C) $E = \frac{1}{2}mc^2$ (D) $E = \frac{1}{2}mv^2$

2021 **Paper 1** **Section 1** **Question 10** **Special relativity**	*Proper length* is the length measured in the frame of reference where the object is (A) at rest. (B) in motion. (C) accelerating. (D) in motion but not accelerating.

2021 **Paper 1** **Section 1** **Question 19** **Special relativity**	A spaceship with a velocity of 9.0×10^7 m s^{-1} is measured to be 125 m in length by an observer at rest. Calculate the length of the spaceship as measured by somebody on board the spaceship. (A) 119 m (B) 131 m (C) 137 m (D) 178 m

2020 **Paper 1** **Section 1** **Question 6** **Special relativity**	The definition of *relativistic momentum* is the (A) momentum of an object when measured in a Newtonian frame of reference. (B) momentum of an object when measured regardless of its frame of reference. (C) momentum of an object when measured in the frame of reference in which the object is in motion. (D) momentum of an object when measured in the frame of reference in which the object is stationary.

2020 **Paper 1** **Section 1** **Question 16** **Special relativity**	According to the theory of special relativity, the concept of *simultaneity* is best described as (A) when two events occur at the same time. (B) when an observer sees two events occurring at the same time. (C) two events observed to happen at the same time in a particular frame of reference. (D) the relation between two events assumed to happen at the same time when observed from any frame of reference.

Paper 1 Section 2

2024 Paper 1 Section 2 Question 22 **Special relativity**	Special relativity accounts for the observation that more muons from cosmic rays are detected near Earth's surface than expected. Explain this phenomenon by outlining why Newtonian physics cannot explain this scenario while special relativity can. Refer to the frames of reference of both the travelling muons and the observer near the Earth's surface. (5 marks)

2023 Paper 1 Section 2 Question 25 **Special relativity**	An observer who is stationary relative to a moving spaceship measures the velocity of the spaceship to be 2.0×108 m s-1 . Calculate the length of the spaceship if the observer records it as 18 m. Show your working. (3 marks) Length = _____ m (to two significant figures)

2020 Paper 1 Section 2 Question 23 Special relativity	Twin astronauts conduct an experiment where one travels with a velocity close to the speed of light to a distant planet, while the other stays on Earth. Each twin expects the other to be a different age by the time the first twin reaches and remains on the distant planet. Use the theory of special relativity to explain why the twins will no longer be the same age, and draw a conclusion about which twin will be younger. [2 marks]

2020 Paper 1 Section 2 Question 24 Special relativity	A spaceship travelled from Planet A to Planet B at a speed of 0.90c. An observer that was stationary relative to both planets measured the time taken for the trip to be 4.0 years. Calculate the time taken for the trip as measured by an observer on the spaceship. [4 marks] Time = _____ years (to 1 decimal place)

Paper 2 Section 1

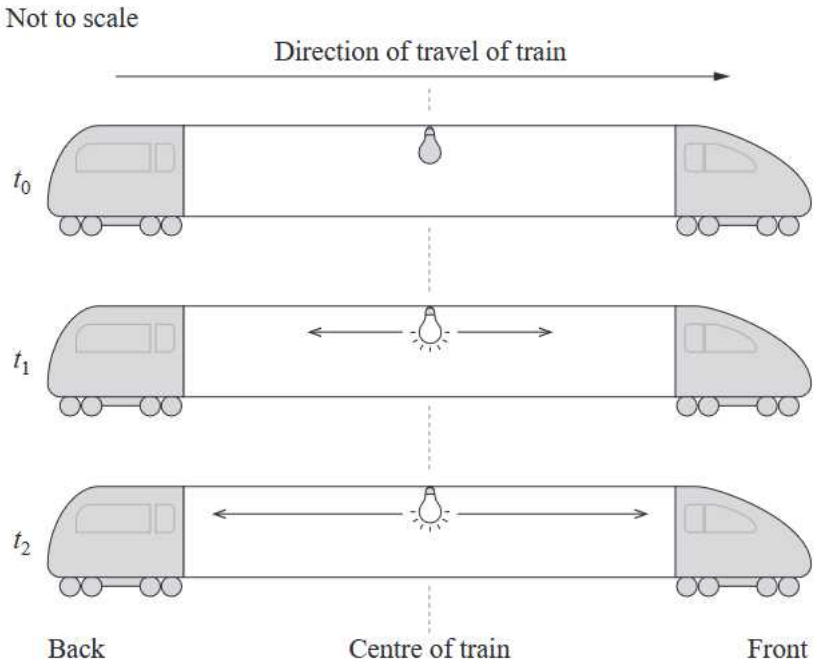
2023 Paper 2 Section 1 Question 1 **Special relativity**	Describe the effects of relativistic travel on an object. (3 marks)

2022 Paper 2 Section 1 Question 1 **Special relativity**	Two spaceports are stationary relative to each other. Astronaut A moves from one spaceport to the other at relativistic speed and observes the lights on both spaceports turn off at the same time. Astronaut B is at a stationary position equally distant relative to each spaceport and observes the lights turn off one after the other. Explain why the astronauts view these events differently. [2 marks]

2020 Paper 2 Section 1 Question 1 **Special relativity**	Explain why an object with mass cannot travel at the speed of light in a vacuum. [1 mark]

Marking Guide – Paper 1 Section 1

2024 Paper 1 Section 1 Question 2 Special relativity	Which property of light is described by the postulates of special relativity? (A) The energy of light is greater when the frequency of the photons decreases. (B) The wavelength of light decreases as the velocity of the source increases. **(C) The velocity of light remains constant in all inertial frames of reference. – Answer** (D) The frequency of light changes depending on media

2024 Paper 1 Section 1 Question 9 Special relativity	A passenger at the centre of a train moving at a relativistic speed switches on a light. According to the passenger, light travels outwards as shown.  How would a stationary observer, watching the train pass by them, record this event? **(A) Light will reach the back of the train first. – Answer** (B) Light will reach the front of the train first. (C) Light will reach both ends of the train at t_0. (D) Light will reach both ends of the train simultaneously.

2024 Paper 1 Section 1 Question 17 Special relativity	A person on Earth experiences a time period of 15 years. Approximately how much time will have passed for a passenger on a spaceship travelling at 0.7 c relative to Earth during that time? (A) 8 years **(B) 11 years – Answer** (C) 21 years (D) 27 years

2023 Paper 1 Section 1 Question 1 Special relativity	An object is unable to accelerate to the speed of light because (A) length contraction will change the height of the object. (B) time dilation will decrease the velocity of the object. **(C) the object will gain infinite momentum. – Answer** (D) the inertia of the object will decrease.

2023 **Paper 1** **Section 1** **Question 16** **Special relativity**	A train is travelling at relativistic speed and is about to move through a tunnel. An observer on the train measures the train and tunnel to each be 95 m long. A second observer is stationary relative to the tunnel. They would observe the train to (A) simultaneously enter and exit the tunnel. (B) decrease its mass while in the tunnel. (C) move faster while in the tunnel. **(D) be shorter than the tunnel. – Answer**

2023 **Paper 1** **Section 1** **Question 17** **Special relativity**	The half-life of an unstable subatomic particle is measured by a stationary detector to be longer when its velocity approaches the speed of light. This is because the particle (A) is moving relative to its frame of reference. (B) is in the same frame of reference as the detector. **(C) experiences time differently relative to the detector. – Answer** (D) cannot be accurately observed at relativistic speeds.

2022 **Paper 1** **Section 1** **Question 15** **Special relativity**	An object's velocity can only be measured relative to (A) a fixed reference frame. (B) the speed of light. (C) an object at rest. **(D) an observer. – Answer**

2021 **Paper 1** **Section 1** **Question 3** **Special relativity**	Identify the correct formula for the mass–energy equivalence relationship. (A) $E = mc^2$ (B) $E = mgh$ (C) $E = \frac{1}{2}mc^2$ (D) $E = \frac{1}{2}mv^2$ **Answer is A.**

2021 **Paper 1** **Section 1** **Question 10** **Special relativity**	*Proper length* is the length measured in the frame of reference where the object is **(A) at rest. – Answer** (B) in motion. (C) accelerating. (D) in motion but not accelerating.

2021 **Paper 1** **Section 1** **Question 19** **Special relativity**	A spaceship with a velocity of 9.0×10^7 m s^{-1} is measured to be 125 m in length by an observer at rest. Calculate the length of the spaceship as measured by somebody on board the spaceship. (A) 119 m **(B) 131 m – Answer** (C) 137 m (D) 178 m

2020 **Paper 1** **Section 1** **Question 6** **Special relativity**	The definition of *relativistic momentum* is the (A) momentum of an object when measured in a Newtonian frame of reference. (B) momentum of an object when measured regardless of its frame of reference. **(C) momentum of an object when measured in the frame of reference in which the object is in motion. – Answer** (D) momentum of an object when measured in the frame of reference in which the object is stationary.

2020 **Paper 1** **Section 1** **Question 16** **Special relativity**	According to the theory of special relativity, the concept of *simultaneity* is best described as (A) when two events occur at the same time. (B) when an observer sees two events occurring at the same time. **(C) two events observed to happen at the same time in a particular frame of reference. – Answer** (D) the relation between two events assumed to happen at the same time when observed from any frame of reference.

2024 Paper 1 Section 2 Question 22

Special relativity

Special relativity accounts for the observation that more muons from cosmic rays are detected near Earth's surface than expected.

Explain this phenomenon by outlining why Newtonian physics cannot explain this scenario while special relativity can. Refer to the frames of reference of both the travelling muons and the observer near the Earth's surface. (5 marks)

Sample response	The response
Since muons are short-lived particles, they shouldn't reach the Earth's surface according to Newtonian physics. But muons travel at close to the speed of light. As muons enter the atmosphere, an observer external to the particles' frame of reference will witness them existing longer than expected due to time dilation. Muons experience length contraction, so they can travel further than predicted by Newtonian physics.	• identifies that muons have a very short half-life **[1 mark]** • explains that muons are unlikely to reach Earth's surface using Newtonian physics **[1 mark]** • identifies that muons travel at relativistic speeds **[1 mark]** • explains that from the observer's frame of reference, the muon's half-life will be longer due to time dilation **[1 mark]** • explains that from the muon's frame of reference, it experiences length contraction **[1 mark]**

2023 Paper 1 Section 2 Question 25

Special relativity

An observer who is stationary relative to a moving spaceship measures the velocity of the spaceship to be 2.0×108 m s-1
.
Calculate the length of the spaceship if the observer records it as 18 m. Show your working. (3 marks)

Sample response	The response
$L = L_0\sqrt{1-\frac{v^2}{c^2}}$ $18 = L_0\sqrt{1-\frac{(2.0\times10^8)^2}{(3.0\times10^8)^2}}$ $L_0 = 24\ \text{m}$ Length = 24 m (to two significant figures)	• recognises the scenario relates to an object experiencing length contraction **[1 mark]** • correctly substitutes for relativistic length **[1 mark]** • calculates the length of the spaceship **[1 mark]**

2020
Paper 1
Section 2
Question 23

Special relativity

Twin astronauts conduct an experiment where one travels with a velocity close to the speed of light to a distant planet, while the other stays on Earth. Each twin expects the other to be a different age by the time the first twin reaches and remains on the distant planet.

Use the theory of special relativity to explain why the twins will no longer be the same age, and draw a conclusion about which twin will be younger. [2 marks]

Sample Response	The response	Notes
The theory of special relativity states that there is no absolute time. Instead, the measurement of time is relative to the frame of reference in which it is measured. The time measured by a stationary clock is greater than the time measured by a moving clock. From the perspective of either twin, the other twin will be younger.	[2 marks] • provides an explanation of why the twins will no longer be the same age • supports the explanation using the theory of special relativity • provides a conclusion about the respective ages of the twins that indicates an understanding of the twin paradox	Support using the theory of special relativity may include: - the concept of time dilation/length contraction - relevant calculations.
	[1 mark] • provides an explanation of why the twins will no longer be the same age • supports the explanation using the theory of special relativity OR • provides an explanation of why the twins will no longer be the same age • provides a conclusion about the respective ages of the twins that indicates an understanding of special relativity	

2020 Paper 1 Section 2 Question 24

Special relativity

A spaceship travelled from Planet A to Planet B at a speed of 0.90c. An observer that was stationary relative to both planets measured the time taken for the trip to be 4.0 years.

Calculate the time taken for the trip as measured by an observer on the spaceship. [4 marks]

Sample Response	The response	Notes
$t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$ $4.0 = \frac{t_o}{\sqrt{1-\frac{(0.90c)^2}{c^2}}}$ $t_o = 1.7$ years Time = 1.7 years (to 1 decimal place)	• indicates an understanding of the physical scenario in relation to time dilation, or other relevant physical concept/s [1 mark] • indicates an understanding that the time provided in the question represents relativistic time [1 mark] • provides pertinent mathematical operation/s correctly performed [1 mark] • determines the time [1 mark]	Only two marks can be awarded if the response confuses proper time and relativistic time. Accept answers between 1.7 years and 1.8 years inclusive. Do not penalise for incorrect decimal places/significant figures.

Marking Guide – Paper 2 Section 1

2023 Paper 2 Section 1 Question 1

Special relativity

Describe the effects of relativistic travel on an object. (3 marks)

Sample response	The response
An object travelling near the speed of light will experience an increase in mass, resulting in increased momentum. It will also experience time slower compared to an observer in another, non-relativistic frame of reference. Finally, an object moving at relativistic speeds would be observed to decrease in length in the direction of its travel.	• describes the effect of – time dilation **[1 mark]** – length contraction **[1 mark]** – relativistic momentum **[1 mark]**

2022 Paper 2 Section 1 Question 1

Special relativity

Two spaceports are stationary relative to each other.

Astronaut A moves from one spaceport to the other at relativistic speed and observes the lights on both spaceports turn off at the same time.

Astronaut B is at a stationary position equally distant relative to each spaceport and observes the lights turn off one after the other.

Explain why the astronauts view these events differently. [2 marks]

Sample Response	The response
For astronaut A to observe simultaneity, light from the first spaceport will need to travel further than light from the second spaceport. However, two events can only happen spontaneously in one inertial frame of reference, and therefore Astronaut B loses simultaneity in this instance.	• explains simultaneity from the perspective of astronaut A [1 mark] • explains the loss of simultaneity for astronaut B [1 mark]

2020 Paper 2 Section 1 Question 1

Special relativity

Explain why an object with mass cannot travel at the speed of light in a vacuum. [1 mark]

Sample Response	The response	Notes
An object with mass cannot travel at the speed of light because as its velocity approaches 1c, its momentum approaches infinity.	• states that as velocity approaches the speed of light (or equivalent), the object's momentum approaches infinity [1 mark] OR • states that as velocity approaches the speed of light (or equivalent), the energy required to accelerate the object approaches infinity [1 mark]	• Equivalent statements may include: - as velocity approaches *c* - … No mark is to be awarded if the response only indicates that the object's mass increases to infinity. Equivalent mathematical explanations are acceptable, e.g. $E_r = \sqrt{(m_o c^2)^2 + (pc)^2}$

Unit 4 – Topic 2: Quantum theory

Paper 1 Section 1

2024 Paper 1 Section 1 Question 4

Quantum theory

Two experiments were conducted, and the following observations were made.

Experiment 1	Light passing through a double slit produces a diffraction pattern.
Experiment 2	Above a specific frequency, light incident on a metallic surface produces photoelectrons with discrete amounts of energy.

Which statement can be supported by the observations?

(A) A wave theory of light can completely describe the nature of light.
(B) The bending of light is a result of light behaving as a particle.
(C) The particle model only describes some properties of light.
(D) Only light waves can travel in a vacuum.

2024 Paper 1 Section 1 Question 13

Quantum theory

Light with a frequency of 9.4×10^{15} Hz is incident upon an unknown metal, producing photoelectrons with a maximum kinetic energy of 5.6×10^{-18} J.

What is the work function of the metal?

(A) 1.0 eV

(B) 3.9 eV

(C) 5.9 eV

(D) 6.3 eV

2024 Paper 1 Section 1 Question 18

Quantum theory

Electromagnetic waves are produced by an oscillating electric charge resulting in an interaction between magnetic and electric fields.

How are these two fields aligned?

(A) parallel to each other
(B) varied in their wavelengths
(C) synchronised in their oscillations
(D) intersected at the peaks of their amplitudes

2024 Paper 1 Section 1 Question 20

Quantum theory

Identify the defining feature of a black body.

(A) All frequencies of electromagnetic radiation are absorbed and emitted.
(B) Light with two wavelength peaks is emitted at a specific temperature.
(C) Electrons are emitted in the presence of all frequencies of light.
(D) The peak of its spectral output does not vary with temperature.

2023 Paper 1 Section 1 Question 2

Quantum theory

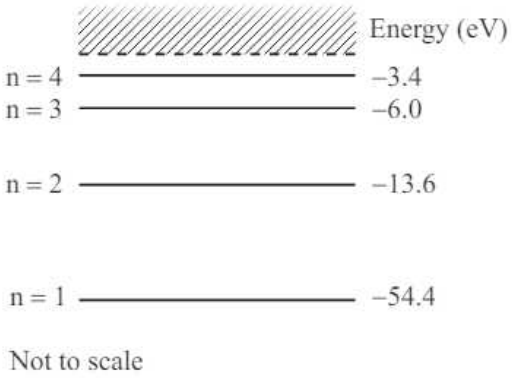
Photons are

(A) gauge bosons that exhibit wave characteristics.
(B) particles that can only travel in a medium.
(C) mediators of the weak nuclear force.
(D) leptons with no charge.

2023 **Paper 1** **Section 1** **Question 5** **Quantum theory**	Young's double slit experiment demonstrates that light (A) behaves differently in different frames of reference. (B) shares characteristics with mechanical waves. (C) is a longitudinal wave. (D) acts like a particle.

2023 **Paper 1** **Section 1** **Question 8** **Quantum theory**	Incident light with a frequency of 1.70×10^{15} Hz is shone onto a metal surface with a work function of 1.00×10^{-18} J. Determine the kinetic energy of a photoelectron ejected from the metal surface. (A) 7.9×10^{-1} eV (B) 1.7×10^{-15} eV (C) 1.3×10^{-19} eV (D) 2.0×10^{-38} eV

2023 **Paper 1** **Section 1** **Question 10** **Quantum theory**	A black body at a temperature of 6040 K produces photons across a range of frequencies. Calculate the frequency at which the maximum number of photons is produced. (A) 6.3×10^{14} Hz (B) 2.1×10^{6} Hz (C) 4.8×10^{-7} Hz (D) 1.6×10^{-15} Hz

2023 **Paper 1** **Section 1** **Question 20** **Quantum theory**	The energy level diagram for a simple atom is shown.  What transition is allowed for an electron that absorbs a photon with a frequency of 6.3×10^{14} Hz? (A) n = 1 to n = 3 (B) n = 1 to n = 4 (C) n = 2 to n = 3 (D) n = 3 to n = 4

2022 **Paper 1** **Section 1** **Question 2** **Quantum theory**	A photon is described as (A) a continuous wave of light energy. (B) a particle that can only propagate in a medium. (C) a quantum of all forms of electromagnetic energy. (D) a particle that mediates the forces between protons

2022 **Paper 1** **Section 1** **Question 6** **Quantum theory**	After coherent light has been passed through a double slit, the observation of an interference pattern on a screen is explained by the (A) wave nature of light. (B) equal width of the slits. (C) discrete packets of photons. (D) distance from the slits to the screen.

2022 **Paper 1** **Section 1** **Question 8** **Quantum theory**	Determine the wavelength of an electromagnetic wave with an energy of 2.4×10^{-23} J. (A) 7.2×10^{-15} m (B) 2.8×10^{-11} m (C) 8.3×10^{-3} m (D) 1.2×10^{2} m

2022 **Paper 1** **Section 1** **Question 11** **Quantum theory**	The maximum kinetic energy of an electron ejected from a metallic surface can be increased by (A) using a positively ionised metal. (B) using a metal with a larger work function. (C) increasing the intensity of the incident light. (D) decreasing the wavelength of the incident light.

2021 **Paper 1** **Section 1** **Question 9** **Quantum theory**	The Bohr atomic model describes an atom as (A) the smallest particle of any substance. (B) a small dense nucleus orbited by electrons. (C) electrons scattered throughout a sphere of positively charged fluid. (D) a small positive nucleus surrounded by negative electrons in set orbits of fixed energy

2021 **Paper 1** **Section 1** **Question 20** **Quantum theory**	A photoelectron with a kinetic energy of 2.5×10^{-19} J is ejected when a photon with a frequency of 1.3×10^{15} Hz is incident on the metal plate. Calculate the threshold frequency of light required to eject the photoelectron from the metal plate. (A) 6.1×10^{-19} Hz (B) 3.7×10^{14} Hz (C) 9.2×10^{14} Hz (D) 1.7×10^{15} Hz

2020 **Paper 1** **Section 1** **Question 7** **Quantum theory**	A quantum of any form of electromagnetic radiation is also known as (A) a photon. (B) an X-ray. (C) a positron. (D) an electron.

2020 **Paper 1** **Section 1** **Question 13** **Quantum theory**	The Rutherford atomic model describes an atom (A) as the smallest particle of any substance. (B) with a small, dense nucleus surrounded by orbiting electrons. (C) consisting of electrons scattered throughout a sphere of positively charged fluid. (D) consisting of a small positive nucleus surrounded by negative electrons in set orbits of fixed energy.

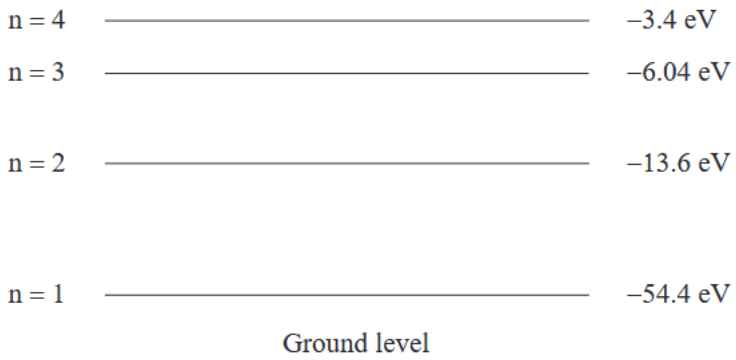
2020 **Paper 1** **Section 1** **Question 20** **Quantum theory**	Calculate the frequency of light that would be required to eject a photoelectron at a velocity of 1.90×10^6 m s^{-1} from a metal plate with a work function of 4.73 eV. (A) 1.14×10^{15} Hz (B) 1.34×10^{15} Hz (C) 2.48×10^{15} Hz (D) 3.62×10^{15} Hz

2024
Paper 1
Section 2
Question 24

Quantum theory

The atomic energy level diagram for an unknown multi-electron ion is shown.

Not to scale



a) Calculate the wavelength of light emitted as electrons move from n = 4 to n = 2.
Show your working. [4 marks]

Wavelength = _____ m

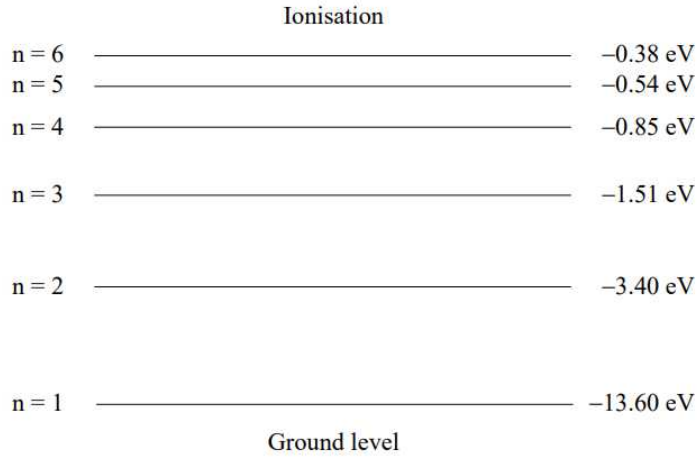
A photon with 40.8 eV of energy is incident on the unknown ion and collides with an electron in the first energy level.

b) Explain what would happen within the ion in terms of the photon and electron. [3 marks]

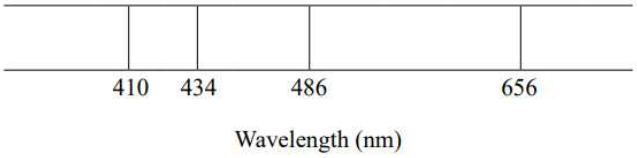
2023 Paper 1 Section 2 Question 21 Quantum theory	Describe how the atomic model proposed by Bohr addresses the limitation of Rutherford's model. (4 marks)

2023 Paper 1 Section 2 Question 26 Quantum theory	Calculate the energy (in electron volts) of a photon with a wavelength of 405 nm. Show your working. (4 marks) Energy = _____ eV (to three significant figures)

2022 Paper 1 Section 2 Question 21 Quantum theory	A hot iron bar was observed to have a deep red colour. As the iron bar was heated further, the colour changed to orange. Explain the observed colour change in terms of black-body radiation. [2 marks]

2022 Paper 1 Section 2 Question 23 Quantum theory	The diagram shows the electron energy levels for hydrogen.  a) Calculate the energy released, in joules, when an electron moves from the third to the first energy level. Show your working. [3 marks] Energy released = _____ J (to three significant figures)

The visible light emission spectrum for hydrogen is shown.



b) Explain why hydrogen only has four emission spectrum lines in the visible (i.e. 400–700 nm) spectrum. [3 marks]

2021
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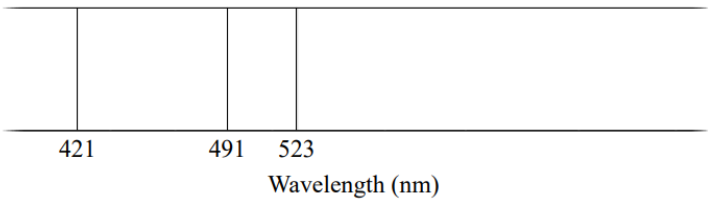
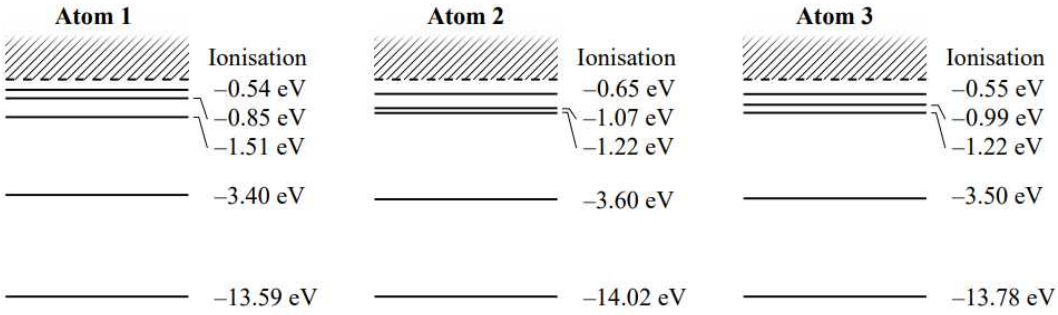
Section 2
Question 26

Quantum theory

A physicist has identified the absorption spectrum of an unknown atom.



The diagram shows the atomic energy levels for three atoms.



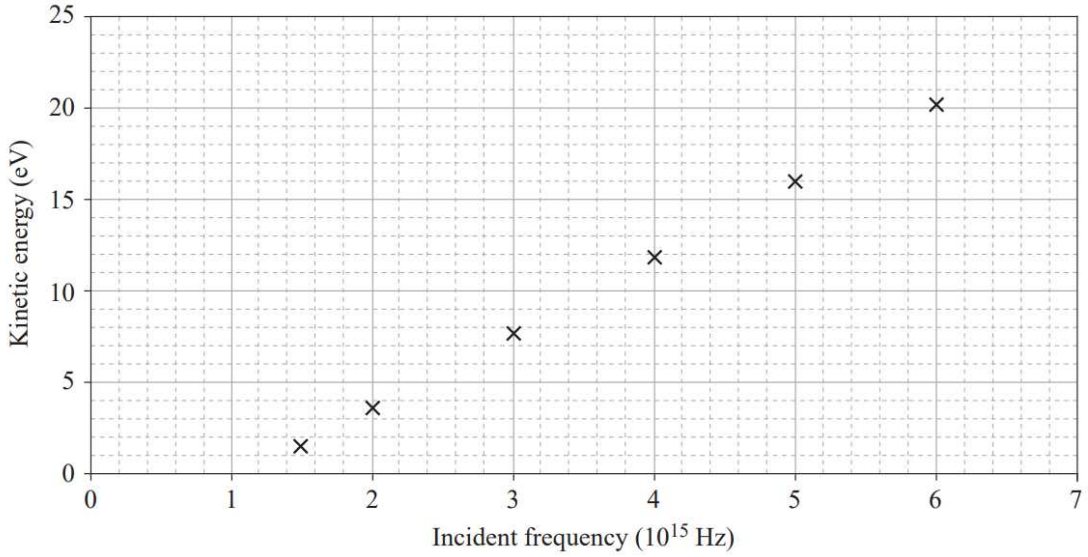
Not to scale

Determine which atom is most likely to be the unknown atom. [5 marks]

2020
Paper 1
Section 2
Question 26

Quantum theory

A photoelectric effect experiment was conducted by shining different frequencies of light on a plate made of an unknown metal. The graph shows the kinetic energies of ejected photoelectrons with respect to the frequency of incident light.



The table shows the work functions of various metals.

Metal	Work function (eV)
potassium	2.30
copper	4.70
osmium	5.93

Determine which metal is most likely to have ejected the photoelectrons in this experiment. [3 marks]

Metal = _____

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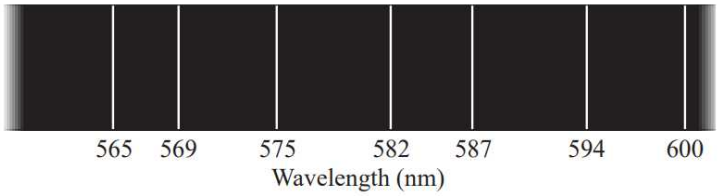
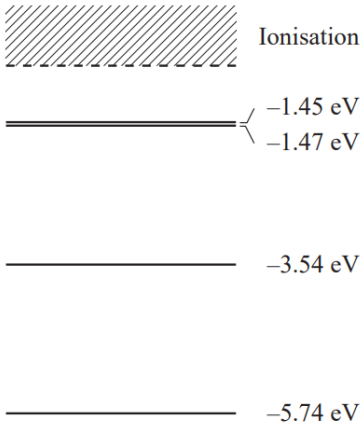
Paper 1
Section 2
Question 27

Quantum theory

The diagram shows a small section of the emission spectrum for a mixture of gases.



The diagram shows the atomic energy level diagram for a gas known as Element A.



Determine whether it is possible that Element A is one of the gases in the mixture. [4 marks]

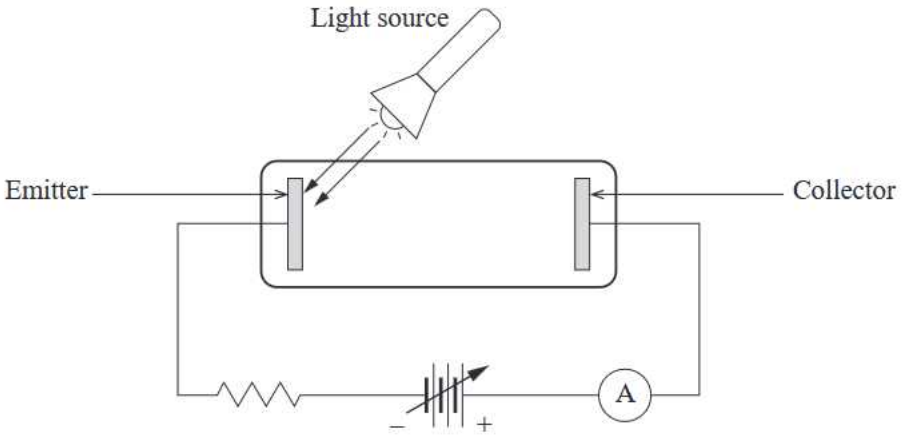
Paper 2 Section 1

2024 Paper 2 Section 1 Question 5 **Quantum theory**	Explain the significance of the threshold frequency when incident light with a range of frequencies shines on a metal.

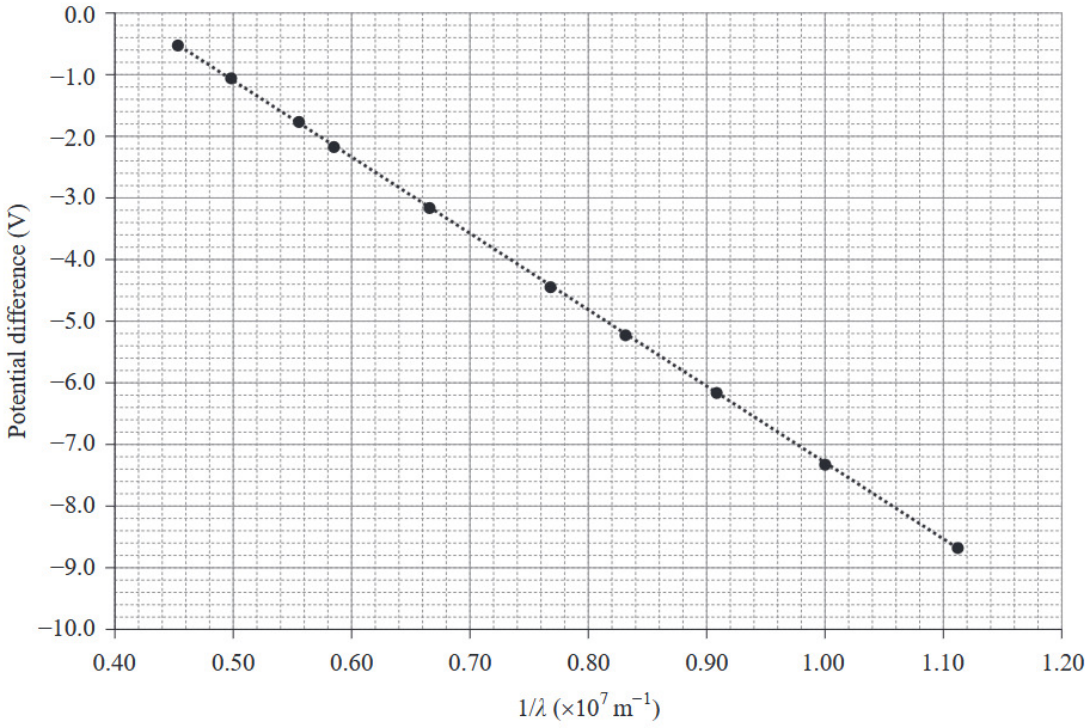
2024
Paper 2
Section 1
Question 6

Quantum theory

A photoelectric experiment was set up with a variable voltage between the collector and emitter, a resistor and an ammeter. There was no current detected when the light was off.



The potential difference required to reduce the current to 0 A was measured for different wavelengths of light.



a) Determine the potential difference required to reduce the current to 0 A when light with a wavelength of 125 nm is shone on the emitter. Show your working and refer to the graph. [2 marks]

Potential difference = _____ V

b) Use the graph to determine the work function of the emitter in eV. Show your working. [6 marks]

Work function = _____ eV

c) The experiment was changed so that the variable voltage was removed and the light, with a frequency above the threshold frequency, was shining on the emitter.

Predict the effect of increasing intensity from the light source on the current in the circuit. Explain your reasoning. [3 marks]

2023 Paper 2 Section 1 Question 5 Quantum theory	Describe what happens when light is shone onto a metallic surface in the context of the photoelectric effect. (4 marks)

2023 **Paper 2** **Section 1** **Question 7** **Quantum theory**	Discuss the nature of light by describing evidence from two key experiments. (7 marks)

2022
Paper 2
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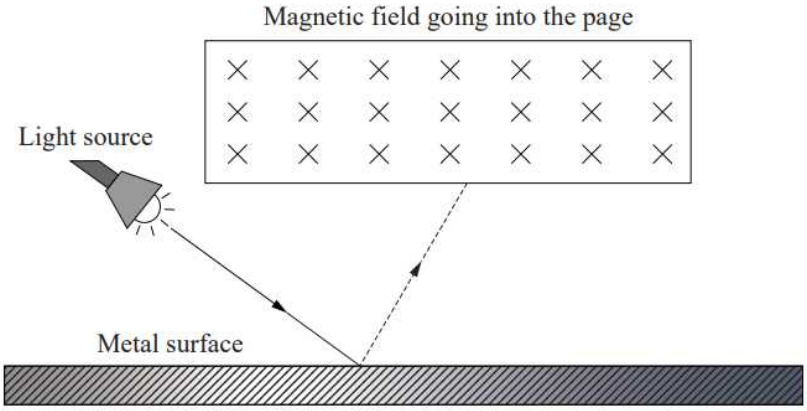
Question 6

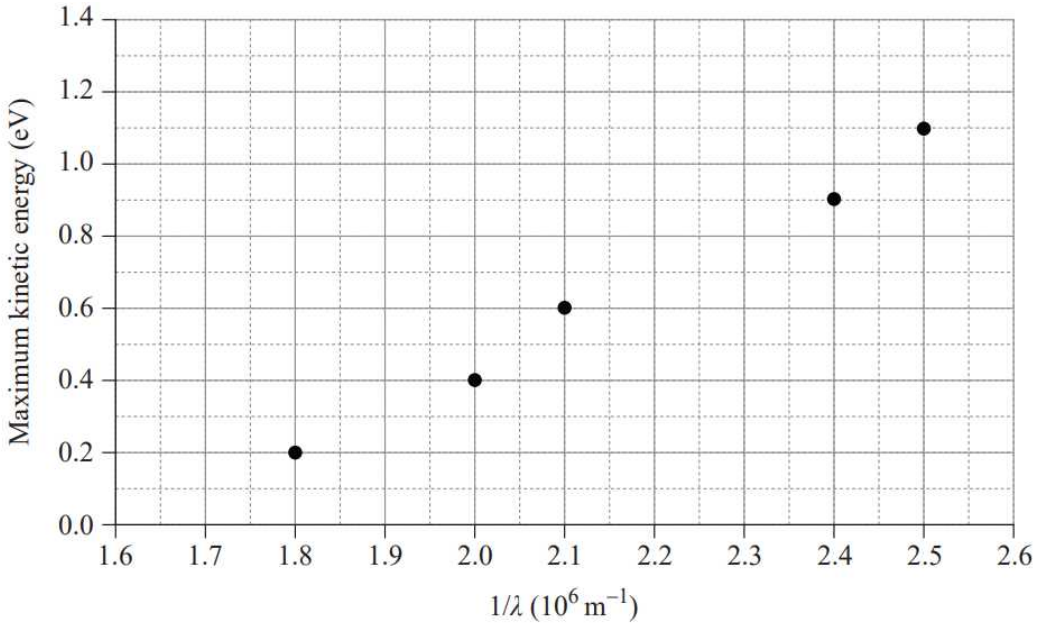
Quantum theory

A light was shone onto a metallic surface and the subsequently released photoelectron passed through a magnetic field.



a) Identify the direction the photoelectron would have curved as it passed through the magnetic field. [1 mark]

The graph shows the maximum kinetic energy of the photoelectron as the frequency of the light was changed.



b) Determine the work function for the metal. Show your working. [4 marks]

Work function = _____ J (to two significant figures)

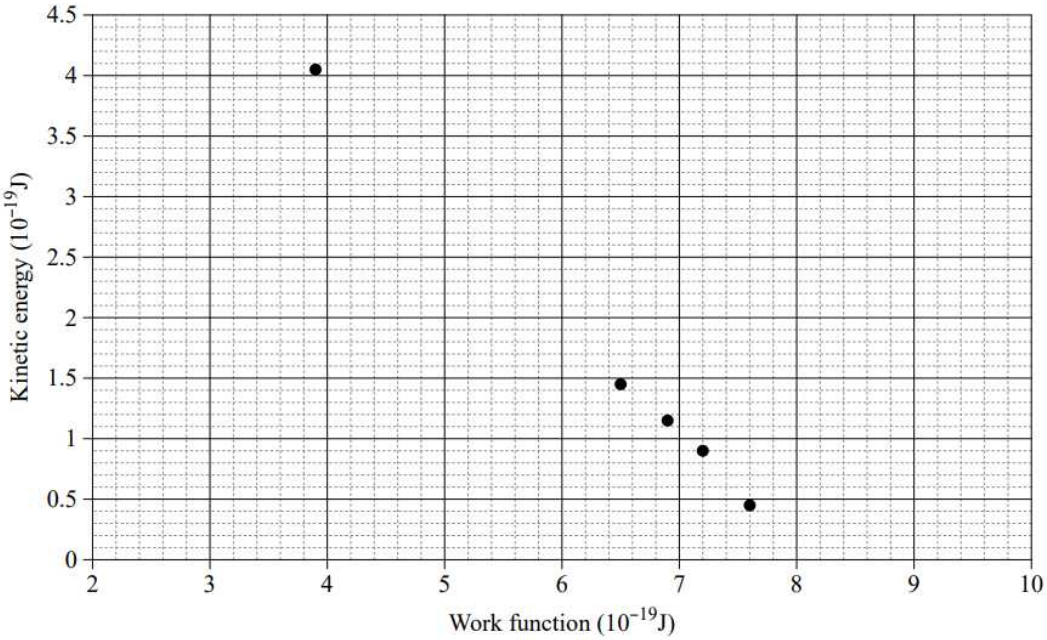
c) If the strength of the magnetic field is 5 μT, determine the maximum radius of the photoelectron's path through the magnetic field, when light of wavelength 450 nm was shone onto the metallic surface. Show your working. [9 marks]

Radius = _____ m (to two significant figures)

2021 Paper 2 Section 1 Question 8

Quantum theory

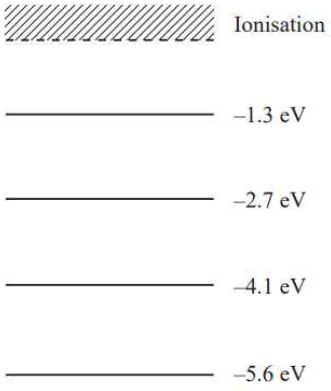
A photoelectric effect experiment was conducted by shining light from a laser at one frequency on five different metals with known work functions. The graph shows the maximum kinetic energy of the photoelectrons ejected from each metal with respect to their work functions.



Determine the wavelength of the light emitted by the laser. [4 marks]

Wavelength = _____ nm (to the nearest whole number)

2021 **Paper 2** **Section 1** **Question 9** **Quantum theory**	Explain how Young's double slit experiment provides evidence for the wave model of light. [3 marks]

2020 **Paper 2** **Section 1** **Question 3** **Quantum theory**	The diagram shows the atomic energy levels of the atoms in an unknown gas.  Predict the shortest wavelength of visible light that could be emitted from this unknown gas. (Note: The range of visible wavelengths of light is between 400 nm and 700 nm.)

Wavelength = _____ nm

2020 Paper 2 Section 1 Question 4 Quantum theory	Describe how experiments on the photoelectric effect provide evidence of the quantised nature of photons. [4 marks]

2020 **Paper 2** **Section 1** **Question 7** **Quantum theory**	A photoelectric effect experiment is conducted by shining different frequencies of light on a sample of aluminium. The kinetic energy of the ejected photoelectrons was measured. The data is plotted in the graph. Identify the mathematical relationship between kinetic energy, E_k, and incident frequency, f. [3 marks]

Marking Guide – Paper 1 Section 1

2024 Paper 1 Section 1 Question 4

Quantum theory

Two experiments were conducted, and the following observations were made.

Experiment 1	Light passing through a double slit produces a diffraction pattern.
Experiment 2	Above a specific frequency, light incident on a metallic surface produces photoelectrons with discrete amounts of energy.

Which statement can be supported by the observations?

(A) A wave theory of light can completely describe the nature of light.
(B) The bending of light is a result of light behaving as a particle.
(C) The particle model only describes some properties of light. – Answer
(D) Only light waves can travel in a vacuum.

2024 Paper 1 Section 1 Question 13

Quantum theory

Light with a frequency of 9.4×10^{15} Hz is incident upon an unknown metal, producing photoelectrons with a maximum kinetic energy of 5.6×10^{-18} J.

What is the work function of the metal?

(A) 1.0 eV

(B) 3.9 eV

(C) 5.9 eV

(D) 6.3 eV

Answer is B.

2024 Paper 1 Section 1 Question 18

Quantum theory

Electromagnetic waves are produced by an oscillating electric charge resulting in an interaction between magnetic and electric fields.

How are these two fields aligned?

(A) parallel to each other
(B) varied in their wavelengths
(C) synchronised in their oscillations – Answer
(D) intersected at the peaks of their amplitudes

2024 Paper 1 Section 1 Question 20

Quantum theory

Identify the defining feature of a black body.

(A) All frequencies of electromagnetic radiation are absorbed and emitted. – Answer
(B) Light with two wavelength peaks is emitted at a specific temperature.
(C) Electrons are emitted in the presence of all frequencies of light.
(D) The peak of its spectral output does not vary with temperature.

2023 Paper 1 Section 1 Question 2

Quantum theory

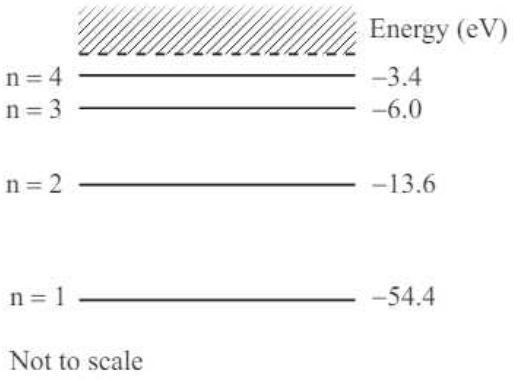
Photons are

(A) gauge bosons that exhibit wave characteristics. – Answer
(B) particles that can only travel in a medium.
(C) mediators of the weak nuclear force.
(D) leptons with no charge.

2023 **Paper 1** **Section 1** **Question 5** **Quantum theory**	Young's double slit experiment demonstrates that light (A) behaves differently in different frames of reference. **(B) shares characteristics with mechanical waves. – Answer** (C) is a longitudinal wave. (D) acts like a particle.

2023 **Paper 1** **Section 1** **Question 8** **Quantum theory**	Incident light with a frequency of 1.70×10^{15} Hz is shone onto a metal surface with a work function of 1.00×10^{-18} J. Determine the kinetic energy of a photoelectron ejected from the metal surface. **(A) 7.9×10^{-1} eV – Answer** (B) 1.7×10^{-15} eV (C) 1.3×10^{-19} eV (D) 2.0×10^{-38} eV

2023 **Paper 1** **Section 1** **Question 10** **Quantum theory**	A black body at a temperature of 6040 K produces photons across a range of frequencies. Calculate the frequency at which the maximum number of photons is produced. **(A) 6.3×10^{14} Hz – Answer** (B) 2.1×10^{6} Hz (C) 4.8×10^{-7} Hz (D) 1.6×10^{-15} Hz

2023 **Paper 1** **Section 1** **Question 20** **Quantum theory**	The energy level diagram for a simple atom is shown.  What transition is allowed for an electron that absorbs a photon with a frequency of 6.3×10^{14} Hz? (A) n = 1 to n = 3 (B) n = 1 to n = 4 (C) n = 2 to n = 3 **(D) n = 3 to n = 4 – Answer**

2022 **Paper 1** **Section 1** **Question 2** **Quantum theory**	A photon is described as (A) a continuous wave of light energy. (B) a particle that can only propagate in a medium. **(C) a quantum of all forms of electromagnetic energy. – Answer** (D) a particle that mediates the forces between protons

2022 **Paper 1** **Section 1** **Question 6** **Quantum theory**	After coherent light has been passed through a double slit, the observation of an interference pattern on a screen is explained by the **(A) wave nature of light. – Answer** (B) equal width of the slits. (C) discrete packets of photons. (D) distance from the slits to the screen.

2022 **Paper 1** **Section 1** **Question 8** **Quantum theory**	Determine the wavelength of an electromagnetic wave with an energy of 2.4×10^{-23} J. (A) 7.2×10^{-15} m (B) 2.8×10^{-11} m **(C) 8.3×10^{-3} m – Answer** (D) 1.2×10^{2} m

2022 **Paper 1** **Section 1** **Question 11** **Quantum theory**	The maximum kinetic energy of an electron ejected from a metallic surface can be increased by (A) using a positively ionised metal. (B) using a metal with a larger work function. (C) increasing the intensity of the incident light. **(D) decreasing the wavelength of the incident light. – Answer**

2021 **Paper 1** **Section 1** **Question 9** **Quantum theory**	The Bohr atomic model describes an atom as (A) the smallest particle of any substance. (B) a small dense nucleus orbited by electrons. (C) electrons scattered throughout a sphere of positively charged fluid. **(D) a small positive nucleus surrounded by negative electrons in set orbits of fixed energy – Answer**

2021 **Paper 1** **Section 1** **Question 20** **Quantum theory**	A photoelectron with a kinetic energy of 2.5×10^{-19} J is ejected when a photon with a frequency of 1.3×10^{15} Hz is incident on the metal plate. Calculate the threshold frequency of light required to eject the photoelectron from the metal plate. (A) 6.1×10^{-19} Hz (B) 3.7×10^{14} Hz (C) 9.2×10^{14} Hz **(D) 1.7×10^{15} Hz – Answer**

2020 **Paper 1** **Section 1** **Question 7** **Quantum theory**	A quantum of any form of electromagnetic radiation is also known as **(A) a photon. – Answer** (B) an X-ray. (C) a positron. (D) an electron.

2020 **Paper 1** **Section 1** **Question 13** **Quantum theory**	The Rutherford atomic model describes an atom (A) as the smallest particle of any substance. **(B) with a small, dense nucleus surrounded by orbiting electrons. – Answer** (C) consisting of electrons scattered throughout a sphere of positively charged fluid. (D) consisting of a small positive nucleus surrounded by negative electrons in set orbits of fixed energy.

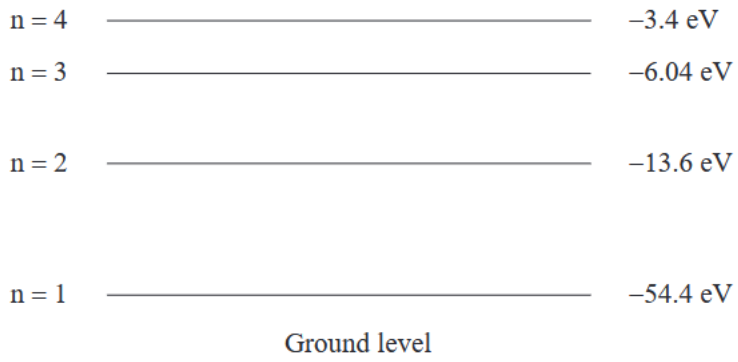
2020 **Paper 1** **Section 1** **Question 20** **Quantum theory**	Calculate the frequency of light that would be required to eject a photoelectron at a velocity of 1.90×10^6 m s^{-1} from a metal plate with a work function of 4.73 eV. (A) 1.14×10^{15} Hz (B) 1.34×10^{15} Hz (C) 2.48×10^{15} Hz **(D) 3.62×10^{15} Hz – Answer**

2024 Paper 1 Section 2 Question 24

Quantum theory

The atomic energy level diagram for an unknown multi-electron ion is shown.

Not to scale



a) Calculate the wavelength of light emitted as electrons move from n = 4 to n = 2.
Show your working. [4 marks]

Sample response	The response
Energy change for the n = 4 to n = 2 transition $13.6 - 3.4 = 10.2$ eV $E = hf = \frac{hc}{\lambda}$ $10.2 \times 1.6 \times 10^{-19} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$ $\lambda = 1.22 \times 10^{-7}$ Wavelength = 1.22×10^{-7} m	• calculates the change in energy between n = 2 and n = 4 energy levels to be 10.2 eV **[1 mark]** • converts between eV and J **[1 mark]** • shows mathematical reasoning that $E = \frac{hc}{\lambda}$ **[1 mark]** • calculates the wavelength **[1 mark]**

A photon with 40.8 eV of energy is incident on the unknown ion and collides with an electron in the first energy level.

b) Explain what would happen within the ion in terms of the photon and electron. [3 marks]

Sample response	The response
The photon will be absorbed. Since the photon energy of 40.8 eV corresponds to the difference in energies between the first and second energy levels, an electron in the first energy level will absorb the photon and jump to the second energy level in its excited state.	• identifies photon is absorbed by electron **[1 mark]** • explains photon energy as equivalent to the gap between n = 1 and n = 2 **[1 mark]** • explains photon will be absorbed because electron in n = 1 will jump to n = 2 **[1 mark]**

2023 Paper 1 Section 2 Question 21

Quantum theory

Describe how the atomic model proposed by Bohr addresses the limitation of Rutherford's model. (4 marks)

Sample response	The response
The Rutherford model provided evidence for the presence of electrons around the nucleus of an atom, while the Bohr atomic model described how electrons orbit the nucleus. However, Rutherford's model was limited, because it couldn't account for the stability of atoms, as electrons orbiting the nucleus would gradually lose energy and spiral into the nucleus. The Bohr model addressed this by explaining the quantised nature of these orbits and how electrons within the same orbit possess the same discrete quantity of energy.	• describes Rutherford's atomic model **[1 mark]** • describes Bohr's atomic model **[1 mark]** • describes a limitation of Rutherford's atomic model **[1 mark]** • describes significance of quantised energy levels **[1 mark]**

2023 Paper 1 Section 2 Question 26

Quantum theory

Calculate the energy (in electron volts) of a photon with a wavelength of 405 nm. Show your working. (4 marks)

Sample response	The response
$f = \frac{c}{\lambda}$ $= \frac{3\times10^{8}}{405\times10^{-9}}$ $= 7.41\times10^{14}$ Hz $E = hf$ $= 6.626\times10^{-34}\times7.41\times10^{14}$ $= 4.91\times10^{-19}$ J $= 3.07$ eV Energy = 3.07 eV (to three significant figures)	• recognises the scenario relates to conversion of wavelength to frequency **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the energy of photon **[1 mark]** • converts energy into eV **[1 mark]**

2022 Paper 1 Section 2 Question 21

Quantum theory

A hot iron bar was observed to have a deep red colour. As the iron bar was heated further, the colour changed to orange.

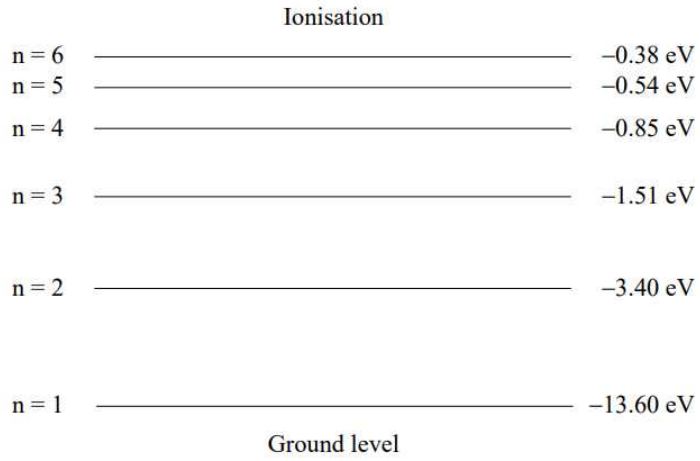
Explain the observed colour change in terms of black-body radiation. [2 marks]

Sample Response	The response
The iron bar represents a model of black-body radiation, where the spectrum of radiation emitted is due to the conversion of the object's thermal energy. This is outlined by Wien's Law, where $\lambda_{max} = \frac{b}{T}$. As the temperature increases, the peak wavelength will be shorter and this is observed by the colour change from red to orange.	• describes the scenario in terms of black-body radiation [1 mark] • uses Wien's Law to explain the colour change in the iron bar [1 mark]

2022 Paper 1 Section 2 Question 23

Quantum theory

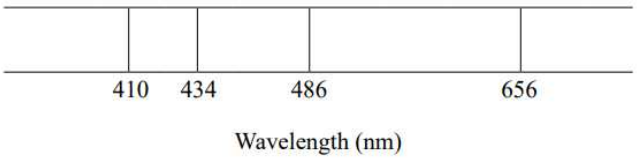
The diagram shows the electron energy levels for hydrogen.



a) Calculate the energy released, in joules, when an electron moves from the third to the first energy level. Show your working. [3 marks]

Sample Response	The response
$\Delta E = E_f - E_i$ $= -13.60 - (-1.51)$ $= -12.09eV$ $= -1.93\times10^{-18}\ J\ or\ 1.93\times10^{-18}\ J\ released$ Energy released = 1.93×10^{-18} J (to three significant figures)	• recognises the scenario relates to the change in electron energy as it moves between energy levels [1 mark] • determines the energy released [1 mark] • converts energy from electronvolts to joules [1 mark]

The visible light emission spectrum for hydrogen is shown.



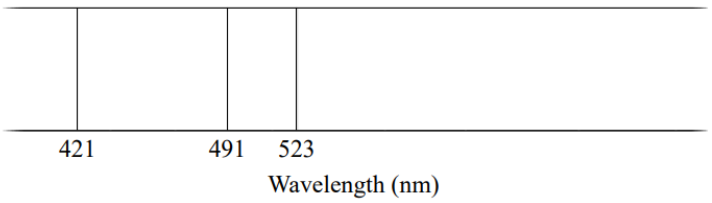
b) Explain why hydrogen only has four emission spectrum lines in the visible (i.e. 400–700 nm) spectrum. [3 marks]

Sample Response	The response
Emission spectrum lines relate to the wavelength of light produced by the release of energy as an electron moves from a higher energy level to a lower energy level within an atom. Since light in the visible spectrum corresponds to wavelengths between 400–700 nm, only energy emitted with wavelengths within this range will be observed. This corresponds to electrons moving between levels where n = 2, 3 or 4.	• explains the relationship between emission lines and orbital energies [1 mark] • identifies that only transitions occurring between orbitals where the energy difference corresponds to wavelengths between 400–700 nm would emit visible light [1 mark] • identifies specific aspects of the energy level diagram to support the explanation [1 mark]

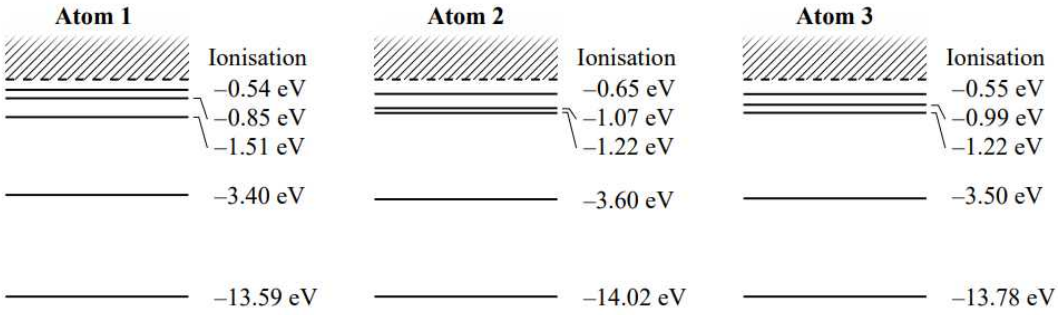
2021 Paper 1 Section 2 Question 26

Quantum theory

A physicist has identified the absorption spectrum of an unknown atom.



The diagram shows the atomic energy levels for three atoms.



Not to scale

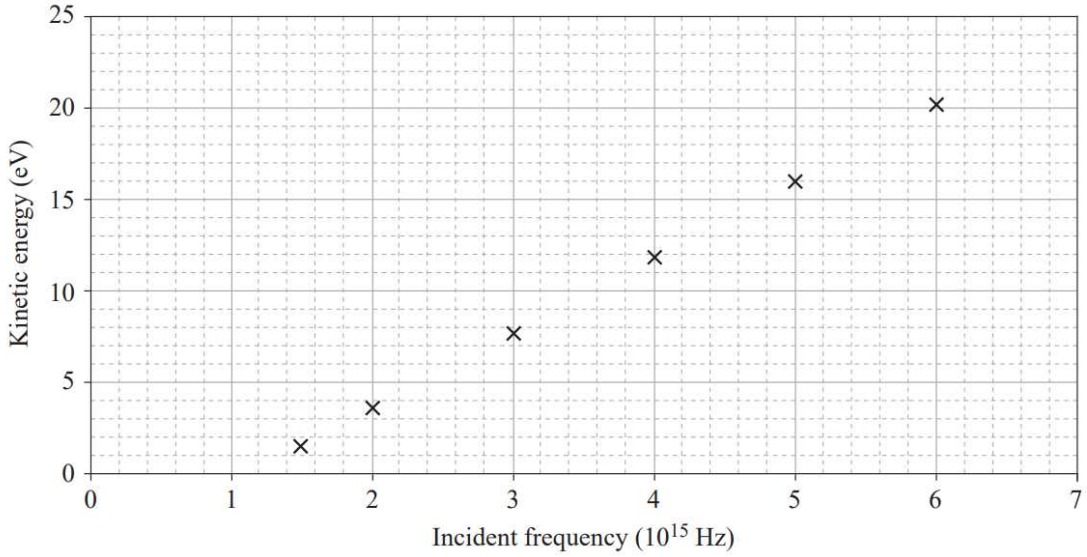
Determine which atom is most likely to be the unknown atom. [5 marks]

Sample Response	The response	Notes
Each wavelength of light corresponds to a quantum of energy, which can be worked out using the following equation: $E = hf = \frac{hc}{\lambda}$ The energies that have produced the three wavelengths of light are: Line 1: 421 nm $E = 4.72 \times 10^{-19}$ J = 2.95 eV Line 2: 491 nm $E = 4.05 \times 10^{-19}$ J = 2.53 eV Line 3: 523 nm $E = 3.8 \times 10^{-19}$ J = 2.38 eV Compared to the energy level diagrams, only Atom 2 has three electron transitions that match the wavelengths given: 5 to 2, 4 to 2 and 3 to 2.	• recognises how absorption spectra relate to energy level diagrams [1 mark] • determines the energy of photons absorbed by the atom [1 mark] • converts from joules to eV [1 mark] • identifies energy level transitions corresponding to absorbed photons [1 mark] • determines the atom [1 mark]	Allow FT marks for error/s in prior working.

2020
Paper 1
Section 2
Question 26

Quantum theory

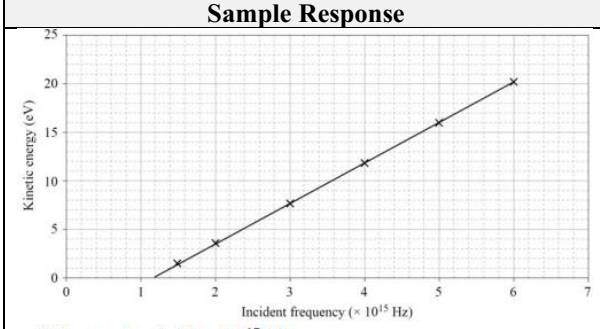
A photoelectric effect experiment was conducted by shining different frequencies of light on a plate made of an unknown metal. The graph shows the kinetic energies of ejected photoelectrons with respect to the frequency of incident light.



The table shows the work functions of various metals.

Metal	Work function (eV)
potassium	2.30
copper	4.70
osmium	5.93

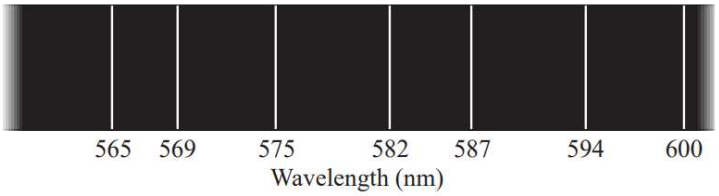
Determine which metal is most likely to have ejected the photoelectrons in this experiment. [3 marks]

Sample Response	The response	Notes
 x-intercept = 1.13 x 10^{15} Hz $W_o = hf_o = 6.626 \times 10^{-34} \times 1.13 \times 10^{15} / 1.6 \times 10^{-19}$ $= 4.7$ eV Unknown metal = copper	• identifies a relevant value or feature of the graph [1 mark] • provides pertinent mathematical operation/s correctly performed or sound mathematical reasoning [1 mark] • identifies the unknown metal [1 mark]	Relevant values/features of the graph may include: - x-intercept - y-intercept - … Students may deduce the unknown metal by approximating the y-intercept and using it to estimate the work function. Full marks should be awarded if this occurs. Students may annotate graph, but this is not essential to marking.

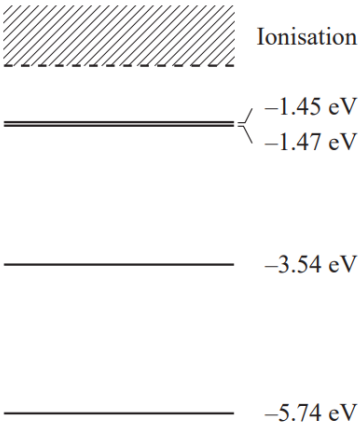
2020
Paper 1
Section 2
Question 27

Quantum theory

The diagram shows a small section of the emission spectrum for a mixture of gases.



The diagram shows the atomic energy level diagram for a gas known as Element A.



Determine whether it is possible that Element A is one of the gases in the mixture. [4 marks]

Sample Response	The response	Notes
The possible wavelengths of light emitted by Element A are as follows: Energy transition | Difference in energy (eV) | Difference in energy (J) | Associated wavelength (nm) $E_n \rightarrow E_i$ | $E_n - E_i = E_d$ | $E_d \times 1.60 \times 10^{-19}$ | $\lambda = \frac{hc}{E_d}$ 1.45–1.47 | –0.02 | -3.2×10^{-21} | 62 100 1.45–3.54 | –2.09 | -3.344×10^{-19} | 594 1.45–5.74 | –4.29 | -6.864×10^{-19} | 290 1.47–3.54 | –2.07 | -3.312×10^{-19} | 600 1.47–5.74 | –4.28 | -6.848×10^{-19} | 290 3.54–5.74 | –2.2 | -3.52×10^{-19} | 565 It is possible that Element A is one of the gases comprising the gas mixture.	• provides pertinent mathematical operation/s correctly performed to determine the differences between the energy levels in the energy level diagram [1 mark] • provides pertinent mathematical operation/s to convert eV to joules [1 mark] • indicates wavelengths produced by Element A that are also included in the emission spectra [1 mark] • provides an answer that indicates the possibility that Element A is one of the gases comprising the gas mixture [1 mark]	Allow FT error for the final answer.

2024 Paper 2 Section 1 Question 5

Quantum theory

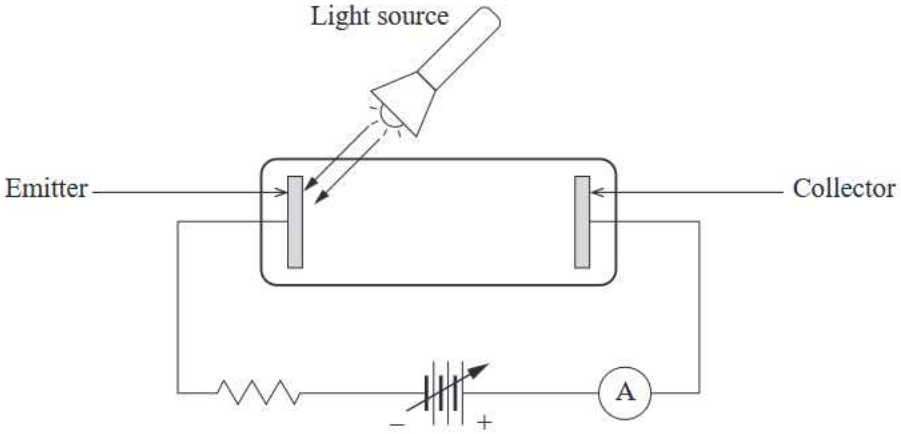
Explain the significance of the threshold frequency when incident light with a range of frequencies shines on a metal.

Sample response	The response
Threshold frequency is the minimum frequency of a photon required to eject a photoelectron from the surface of a metal. In this case, photons with frequencies equal to or greater than the threshold frequency will eject photoelectrons from the surface of the metal, while photons with a lower frequency will scatter off the metal's surface.	• describes threshold frequency as the minimum frequency of an incident photon required to eject a photoelectron **[1 mark]** • explains that photons with frequencies greater than the threshold frequency will have enough energy to eject a photoelectron **[1 mark]** • explains that photons with frequencies less than the threshold frequency will be scattered **[1 mark]**

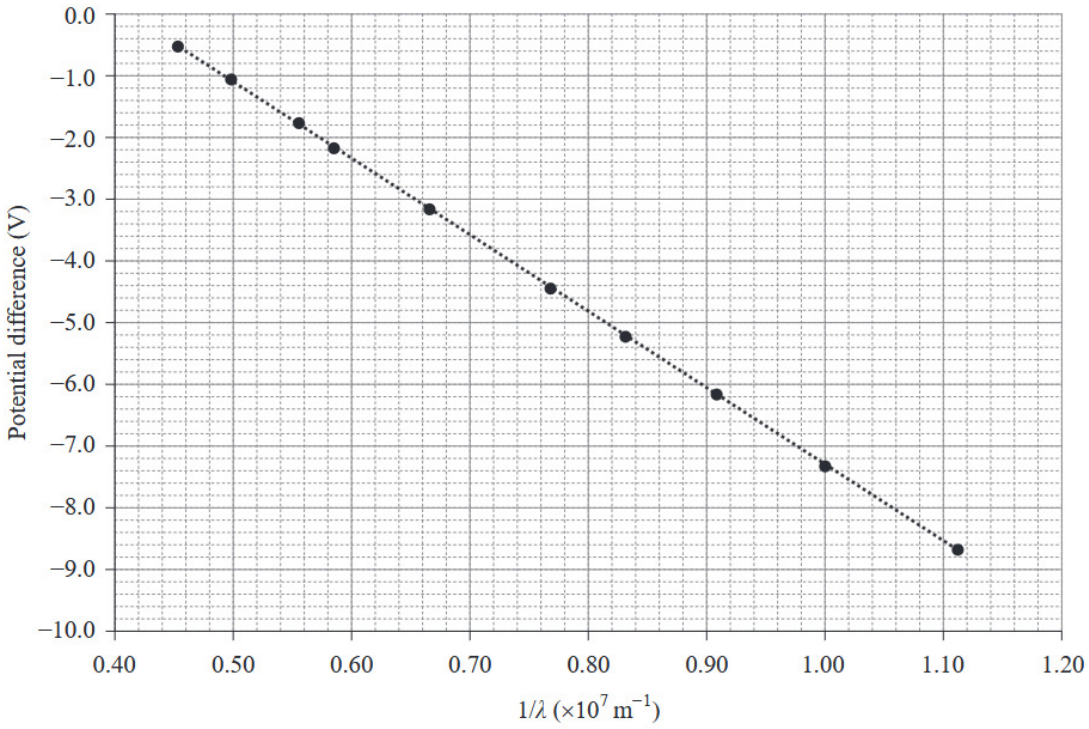
2024 Paper 2 Section 1 Question 6

Quantum theory

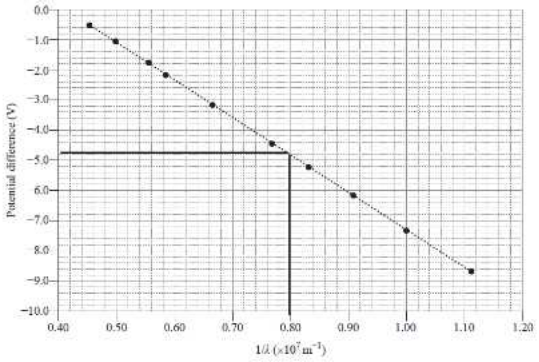
A photoelectric experiment was set up with a variable voltage between the collector and emitter, a resistor and an ammeter. There was no current detected when the light was off.



The potential difference required to reduce the current to 0 A was measured for different wavelengths of light.



a) Determine the potential difference required to reduce the current to 0 A when light with a wavelength of 125 nm is shone on the emitter. Show your working and refer to the graph. [2 marks]

Sample response	The response
$\frac{1}{\lambda} = \frac{1}{125\times10^{-9}} = 0.8\times10^{7}$ Refer to graph:  Potential difference = –4.8 V	• determines inverse wavelength to be $0.8\times10^{7}\ \text{m}^{-1}$ **[1 mark]** • determines the potential difference from graph **[1 mark]**

b) Use the graph to determine the work function of the emitter in eV. Show your working. [6 marks]

Sample response	The response
$E_k = hf - W$ For the stopping voltage, $Vq = E_k$ For (0.8 × 10^7, –4.8): $hf = \frac{hc}{\lambda}$ $= (6.626\times10^{-34})\times(3\times10^{8})\times(0.8\times10^{7})$ $= 1.59024\times10^{-18}$ J convert to eV $hf = (1.59024\times10^{-18})\times(1.6\times10^{-19})$ $= 9.939$ eV $E_k = hf - W$ $4.8 = 9.939 - W$ $W \approx 5.1$ eV	• recognises the relationship between – maximum kinetic energy of photoelectrons and work function **[1 mark]** – maximum kinetic energy of photoelectrons and stopping voltage **[1 mark]** – frequency and wavelength of ligh **[1 mark]** • identifies appropriate data from the graph **[1 mark]** • shows appropriate mathematical reasoning **[1 mark]** • determines the work function in eV **[1 mark]**

c) The experiment was changed so that the variable voltage was removed and the light, with a frequency above the threshold frequency, was shining on the emitter.

Predict the effect of increasing intensity from the light source on the current in the circuit. Explain your reasoning. [3 marks]

Sample response	The response
Since the frequency is above the threshold frequency, increasing the intensity of light will produce more photons which, in turn, will increase the likelihood of more photoelectrons being 'knocked off' from the metal surface. More photoelectrons in the circuit will increase the current.	• explains that increasing light intensity will increase the number of photons **[1 mark]** • explains there will be an increase in the number of photoelectrons ejected from the emitter **[1 mark]** • explains there will be an increase in current in the circuit **[1 mark]**

2023 Paper 2 Section 1 Question 5

Quantum theory

Describe what happens when light is shone onto a metallic surface in the context of the photoelectric effect. (4 marks)

Sample response	The response
Light with energy equivalent to *hf* has the ability to produce photoelectrons from a metallic surface. When the frequency of light is below the threshold frequency for the metallic surface, the light will be reflected with no transfer of energy. When the frequency of light is above the threshold frequency for the metallic surface, the energy of the photons will be absorbed and photoelectrons with kinetic energy proportional to the excess energy will be released. The intensity of incident light is proportional to the number of photoelectrons for frequencies greater than the threshold frequency.	• identifies incident light has energy equivalent to *hf* **[1 mark]** • describes transfer of energy when frequency of light is – below the threshold frequency **[1 mark]** – above the threshold frequency **[1 mark]** • identifies relationship between intensity of incident light and resultant photoelectrons **[1 mark]**

2023 Paper 2 Section 1 Question 7

Quantum theory

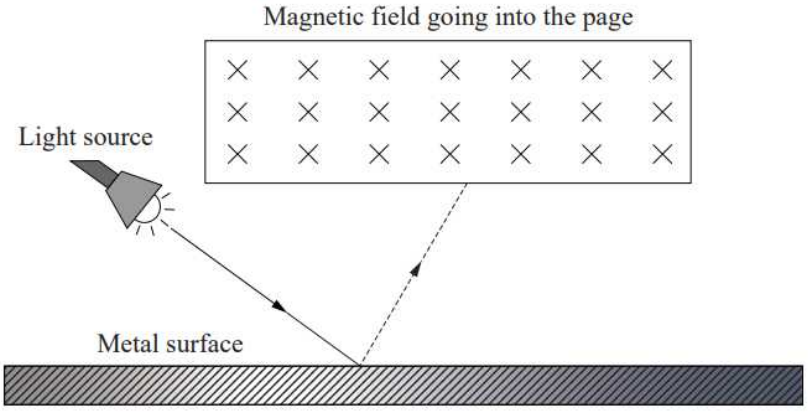
Discuss the nature of light by describing evidence from two key experiments. (7 marks)

Sample response	The response
Young's double slit experiment and black-body radiation both provide evidence for the behaviour of light. In Young's double slit experiment, the interference patterns formed as light passed between the two slits demonstrates the wave nature of light. In contrast, black-body radiation demonstrates the quantised nature of light as electrons can only absorb or emit energy in discrete amounts. Therefore, light has some wave properties and some particle properties.	• identifies evidence for the nature of light comes from – Young's double slit experiment **[1 mark]** – black-body radiation **[1 mark]** • describes evidence for wave nature of light **[1 mark]** • describes evidence for photons **[1 mark]** • concludes light has the properties of both waves and particles **[1 mark]**

2022 Paper 2 Section 1 Question 6

Quantum theory

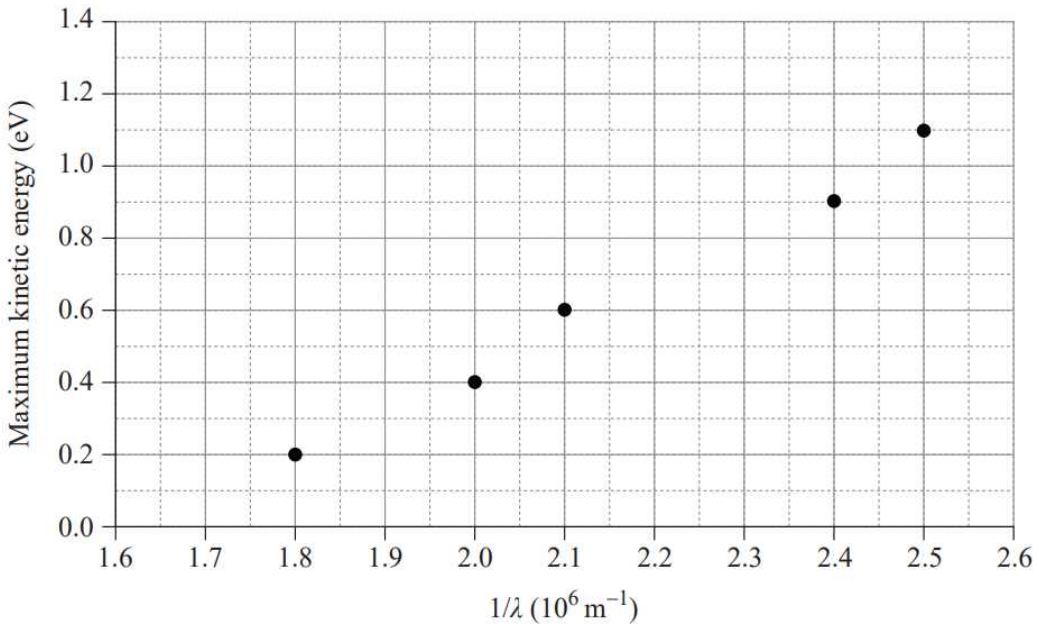
A light was shone onto a metallic surface and the subsequently released photoelectron passed through a magnetic field.



a) Identify the direction the photoelectron would have curved as it passed through the magnetic field. [1 mark]

Sample Response	The response
The electron would have curved to the right.	• identifies the direction of curvature [1 mark]

The graph shows the maximum kinetic energy of the photoelectron as the frequency of the light was changed.



b) Determine the work function for the metal. Show your working. [4 marks]

Sample Response	The response
The *x*-intercept corresponds to the threshold frequency for the metal. Therefore, based on the line of best fit, the corresponding wavelength is $\frac{1}{1.65\times10^{6}\ m} = 606\ \text{nm}$. $f_0 = \frac{c}{\lambda}$ $= \frac{3.00\times10^{8}}{606\times10^{-9}}$ $= 4.95\times10^{14}\ Hz$ $W = hf_0$ $= 6.626\times10^{-34}\times4.95\times10^{14}$ $= 3.3\times10^{-19}\ J$ Work function = 3.3×10^{-19} J (to two significant figures)	• determines the threshold frequency [1 mark] • recognises the scenario relates to work function [1 mark] • provides appropriate reasoning [1 mark] • determines the work function [1 mark]

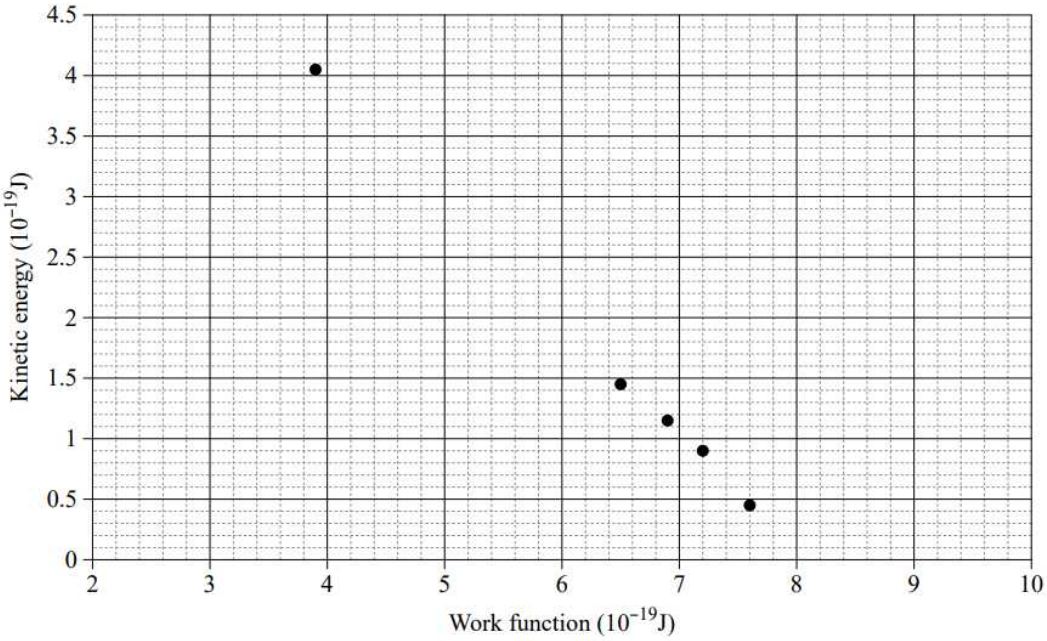
c) If the strength of the magnetic field is 5 μT, determine the maximum radius of the photoelectron's path through the magnetic field, when light of wavelength 450 nm was shone onto the metallic surface. Show your working. [9 marks]

Sample Response	The response
Inverse of wavelength = $\frac{1}{450\times10^{-9}} = 2.2\times10^{6}\ \text{m}^{-1}$ Maximum kinetic energy of photoelectron: $E_k = 0.7\times1.6\times10^{-19} = 1.12\times10^{-19}\ J$ Maximum velocity of photoelectron: $E_k = \frac{1}{2}mv^2$ $1.12\times10^{-19} = \frac{1}{2}\times9.109\times10^{-31}v^2$ $v = \sqrt{\frac{1.12\times10^{-19}}{4.55\times10^{-31}}}$ $= 5.0\times10^{5}\ \text{m s}^{-1}$ Force acting on photoelectron in the magnetic field: $F = qvB\sin\theta$ $= 1.6\times10^{-19}\times5.0\times10^{5}\times5.0\times10^{-6}\times\sin 90$ $= 4.0\times10^{-19}\ N$ Radius of photoelectron's path: $F = \frac{mv^2}{r}$ $4.0\times10^{-19} = \frac{9.109\times10^{-31}\times\left(5.0\times10^{5}\right)^2}{r}$ $r = 0.57\ m$ Radius of photoelectron's path = **0.57** m (to two significant figures)	• determines the corresponding inverse of wavelength [1 mark] • determines the maximum kinetic energy of the photoelectron [1 mark] • recognises the scenario relates to velocity of photoelectrons [1 mark] • determines the maximum velocity of the photoelectron [1 mark] • recognises the scenario relates to force on photoelectrons [1 mark] • determines the force on the photoelectron [1 mark] • recognises the scenario relates to the radius of the circular path [1 mark] • provides appropriate mathematical reasoning to determine radius [1 mark] • determines the maximum radius of the photoelectron's path [1 mark]

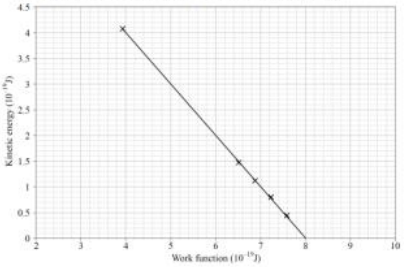
2021 Paper 2 Section 1 Question 8

Quantum theory

A photoelectric effect experiment was conducted by shining light from a laser at one frequency on five different metals with known work functions. The graph shows the maximum kinetic energy of the photoelectrons ejected from each metal with respect to their work functions.



Determine the wavelength of the light emitted by the laser. [4 marks]

Sample Response	The response	Notes
$E_k = hf - W$ $E_k = -W + hf$ The y-intercept of the line will be hf  $y = mx + c$ To determine the gradient, the data (6, 2) and (8, 0) were used $m = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{0 - 2}{8 - 6}$ $= -1$ Therefore $y = -1x + c$ Substitute (8, 0) $0 = -1 \times 8 + c$ $c = 8$ Therefore $hf = c$ $f = \frac{c}{h}$ $= \frac{8 \times 10^{-19}}{6.626 \times 10^{-34}}$ $\approx 1.2 \times 10^{15}$ Hz Wavelength = 248 nm (to the nearest whole number)	• recognises the scenario relates to $E_k = hf - W$ [1 mark] • uses appropriate features of the graph to determine a value for hf [1 mark] • provides correct reasoning [1 mark] • determines wavelength [1 mark]	Appropriate features of the graph include: - the x-intercept a point on the line of best fit - or any other relevant feature. Do not penalise for incorrect decimal places/significant figures.

2021 Paper 2 Section 1 Question 9

Quantum theory

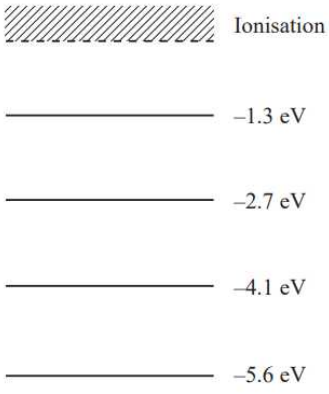
Explain how Young's double slit experiment provides evidence for the wave model of light. [3 marks]

Sample Response	The response	Notes
Young's double slit experiment consisted of light shining through two thin slits. This produced light and dark spots on a screen behind the slits, caused by constructive and destructive interference of the light. This interference is a behaviour seen in mechanical waves and provides evidence for the wave nature of light.	• describes the results of Young's double slit experiment [1 mark] • recognises that Young's experiment involves constructive and destructive interference [1 mark] • states that the result is similar to that of a mechanical wave [1 mark]	For *mechanical wave* accept other suitable responses consistent with a reasonable understanding of a transverse wave.

2020 Paper 2 Section 1 Question 3

Quantum theory

The diagram shows the atomic energy levels of the atoms in an unknown gas.



Predict the shortest wavelength of visible light that could be emitted from this unknown gas.
(Note: The range of visible wavelengths of light is between 400 nm and 700 nm.)

Sample Response	The response	Notes
The shortest wavelength in the visible spectrum will have the largest energy difference. $E = hf$ $= \frac{hc}{\lambda}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{400 \times 10^{-9}}$ $= 4.9695 \times 10^{-19}$ J $E = \frac{4.9695 \times 10^{-19}}{1.60 \times 10^{-19}}$ ≈ 3.106 eV The largest transition below 3.106 eV is between −2.7 eV and −5.6 eV. $E = -2.7 - -5.6$ $= 2.9$ eV In joules, $E = 2.9 \times 1.60 \times 10^{-19}$ $= 4.64 \times 10^{-19}$ J $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4.64 \times 10^{-19}}$ Wavelength = 428 nm	Solution 1 • indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram [1 mark] • provides pertinent mathematical operation/s correctly performed to move between values for wavelength and energy [1 mark] • identifies the largest allowable energy transition for visible light to be emitted (consequentially correct) [1 mark] • identifies the consequentially correct transition to produce the shortest wavelength of visible light [1 mark] • determines the wavelength of light [1 mark] OR	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept answers inclusive between 428 nm and 432 nm. Allow FT error for the wavelength.

		Solution 2 • indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram [1 mark] • provides pertinent mathematical operation/s correctly performed to calculate all energy differences [1 mark] • provides pertinent mathematical operation/s correctly performed to identify all possible wavelengths emitted by the atom [1 mark] • identifies the consequentially correct wavelengths within the visible spectrum [1 mark] • determines the wavelength of light [1 mark]	Do not penalise for incorrect decimal places/significant figures.

2020 Paper 2 Section 1 Question 4

Quantum theory

Describe how experiments on the photoelectric effect provide evidence of the quantised nature of photons. [4 marks]

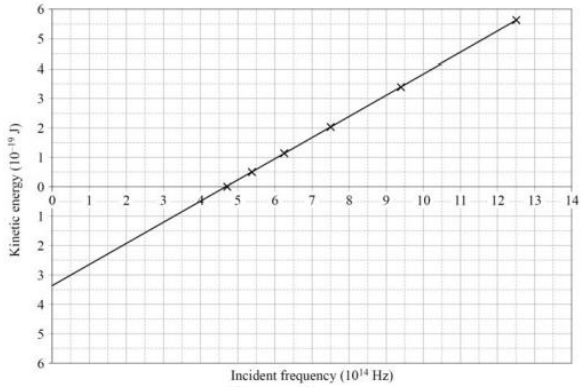
Sample Response	The response	Notes
The photoelectric effect experiment demonstrates that the number of electrons ejected from a metal plate is proportional to the intensity of incident light, whereas the kinetic energy of the ejected electrons is proportional to the frequency of incident light. The fact that frequencies lower than a threshold value will not eject an electron suggests that light energy is quantised. As the frequency increases, the kinetic energy of the ejected electrons increases, suggesting that light can be conceived as packets of energy (photons). The fact that a greater intensity of light causes more electrons to be ejected suggests that the greater the intensity, the more photons (or packets of energy) are incident on the metal plate, also confirming the idea of light as a photon.	• identifies that the intensity of light is proportional to the number of photoelectrons [1 mark] • identifies that the proportionality between intensity and the number of photoelectrons provides evidence that light is made of photons/packets [1 mark] • identifies that the frequency of light relates to a set/quantised/packet of energy [1 mark] • identifies that the kinetic energy of the emitted electron is related to the energy per photon (or equivalent) [1 mark] • identifies that the increase of kinetic energy as the frequency of incident light increases suggests the quantised nature of photons [1 mark]	Only three marks can be awarded for an accurate explanation of the photoelectric effect.

2020 Paper 2 Section 1 Question 7

Quantum theory

A photoelectric effect experiment is conducted by shining different frequencies of light on a sample of aluminium. The kinetic energy of the ejected photoelectrons was measured. The data is plotted in the graph.

Identify the mathematical relationship between kinetic energy, E_k, and incident frequency, f. [3 marks]

Sample Response	The response	Notes
 Gradient = $\frac{\Delta E_K}{\Delta f} = \frac{5.6\times10^{-19}-1.5\times10^{-21}}{1.25\times10^{15}-4.68\times10^{14}} = 7.2\times10^{-34}$ Work function = y-intercept = 3.3×10^{-19}J $E_K = 7.2\times10^{-34}\times f - 3.3\times10^{-19}$	• provides a correct value for the y-intercept [1 mark] • provides a correct value for the gradient of the graph [1 mark] • provides the equation [1 mark]	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept values inclusive between: 7.1 x 10^{-34} and 7.3 x 10^{-34} for the gradient. 3.3 x 10^{-19} and 3.5 x 10^{-19} for the y-intercept. Students may annotate graph, but this is not essential to marking. Allow FT error for the equation.

Unit 4 – Topic 3: The Standard Model

Paper 1 Section 1

2024 Paper 1 Section 1 Question 1

The Standard Model

Which option describes a feature of baryons?

(A) eliminated by positrons

(B) comprised of three quarks

(C) a type of elementary particle

(D) electrical charge equates to $+\frac{2}{3}e^{-}$

2024 Paper 1 Section 1 Question 16

The Standard Model

The table shows a combination of mediating particles and possible forces they experience.
Which row is correct?

	Particle	Strong nuclear force	Weak nuclear force	Electromagnetic force
(A)	Photon	✓	✓	✓
(B)	Lepton	✓	✓	
(C)	Quark	✓		✓
(D)	Meson	✓	✓	✓

2023 Paper 1 Section 1 Question 12

The Standard Model

What is a consequence of symmetry in particle interactions?

(A) The law of conservation of momentum is obeyed.
(B) Charges on particles will always be different.
(C) Antiparticles travel backwards through time.
(D) Total mass of the particles will decrease.

2023 Paper 1 Section 1 Question 14

The Standard Model

An electron is best described as a

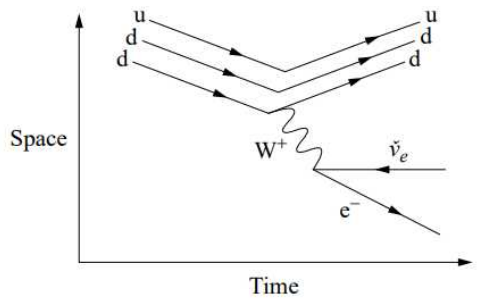
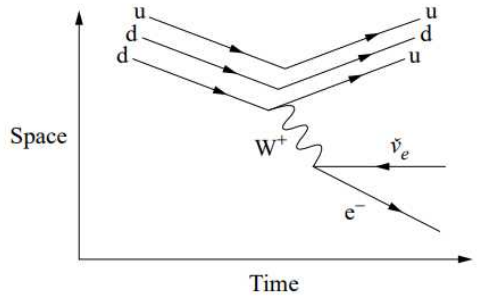
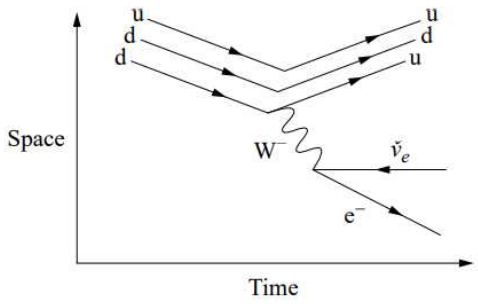
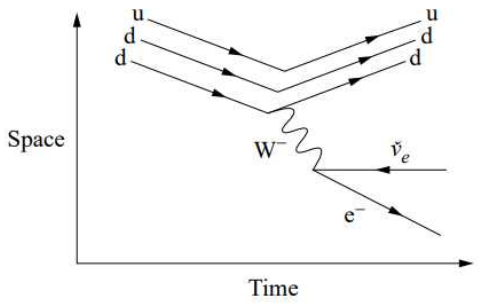
(A) lepton with a larger mass than a positron.
(B) baryon with a smaller mass than a proton.
(C) meson that experiences the strong nuclear force.
(D) particle whose interactions can be mediated by photons.

2022 Paper 1 Section 1 Question 5

The Standard Model

Tau particles are classified as

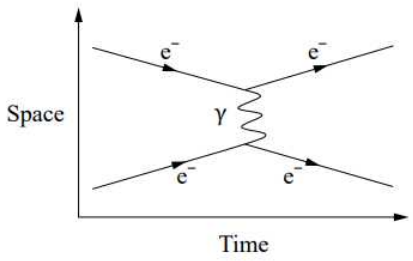
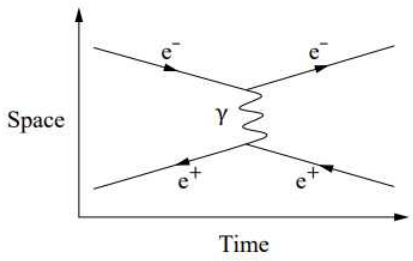
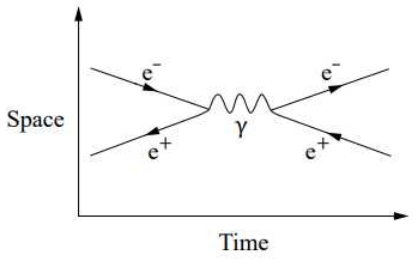
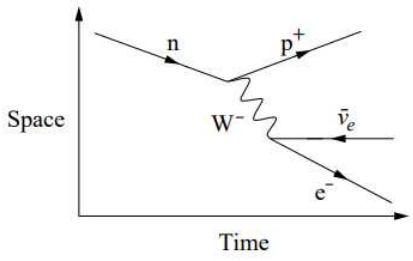
(A) bosons.
(B) leptons.
(C) mesons.
(D) baryons

2022 **Paper 1** **Section 1** **Question 14** **The Standard Model**	Which Feynman diagram correctly depicts neutron decay? (A)  (B)  (C)  (D) 

2022 **Paper 1** **Section 1** **Question 20** **The Standard Model**	Which option lists the gauge bosons in ascending order of the strength of force they mediate? (A) W boson < Z boson < Photon (B) Gluon < Z boson < W boson (C) Photon < W boson < Gluon (D) Z boson < Photon < Gluon

2021 Paper 1 Section 1 Question 1 The Standard Model	Leptons do not experience the (A) weak force. (B) strong force. (C) gravitational force. (D) electromagnetic force.

2021 Paper 1 Section 1 Question 5 The Standard Model	Mesons are (A) subatomic particles composed of one quark and one antiquark. (B) elementary particles that are classified as leptons. (C) elementary particles exchanged between quarks. (D) subatomic particles composed of three quarks.

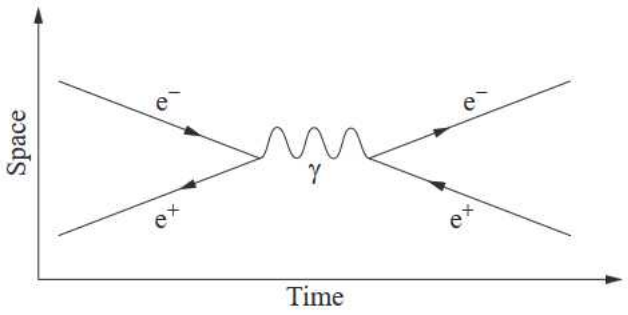
2021 Paper 1 Section 1 Question 15 The Standard Model	Which Feynman diagram shows an electron interacting with another electron? (A)  (B)  (C)  (D) 

2020 Paper 1 Section 1 Question 9 The Standard Model	Select the list containing the six types of quarks. (A) in, out, up, down, top and bottom (B) right, left, charm, strange, in and out (C) up, down, charm, strange, top and bottom (D) charm, strange, right, left, top and bottom

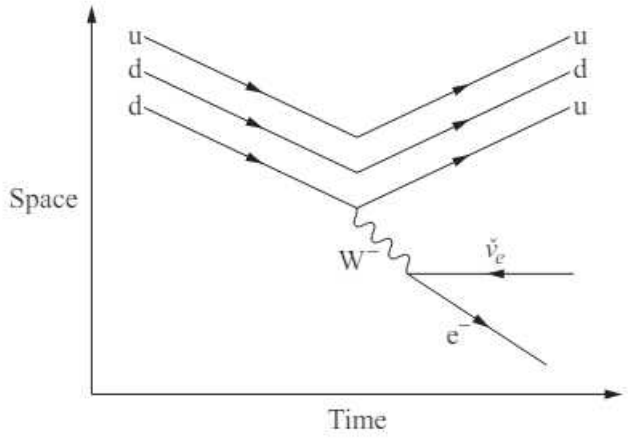
2020 Paper 1 Section 1 Question 10 The Standard Model	The force that quarks experience that leptons do not is the (A) weak force. (B) strong force. (C) normal force. (D) electromagnetic force.

2020 **Paper 1** **Section 1** **Question 14** **The Standard Model**	Select the list that contains only gauge bosons. (A) gluon, photon, meson and hadron (B) lepton, baryon, meson and hadron (C) gluon, photon, Z boson and W boson (D) Z boson, W boson, photon and lepton

Paper 1 Section 2

2024 Paper 1 Section 2 Question 21 **The Standard Model**	Describe the particle interaction shown. (3 marks) 
2023 Paper 1 Section 2 Question 22 **The Standard Model**	Particles move at a rate of 1.3×10^6 times per second around a circular particle accelerator with a radius of 35 m. Calculate the average speed of the particles. Show your working. (3 marks) Average speed = _____ m s^{-1} (to two significant figures)

2023 Paper 1 Section 2 Question 23 **The Standard Model**	List the forces that can be experienced by leptons (1 mark)

2023 Paper 1 Section 2 Question 28 **The Standard Model**	The Feynman diagram for a neutron decaying into a proton and electron is shown.  Describe the significance of the electron antineutrino in this particle interaction. (2 marks)

2022 Paper 1 Section 2 Question 22 The Standard Model	A collection of mesons was observed by a detector to move an average distance of 11.0 m when travelling at 95% of the speed of light. However, based on their properties, the mesons were expected to travel an average distance of 3.4 m. Explain the difference between the observed and expected average distances. [2 marks]

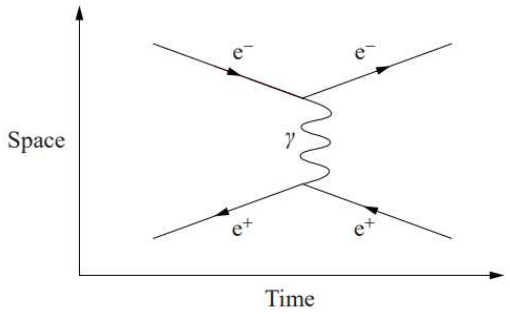
2022 Paper 1 Section 2 Question 26 The Standard Model	Carbon-14 undergoes nuclear decay to nitrogen-14. $${}^{14}_{6}C \rightarrow {}^{14}_{7}N + e^{-} + \check{\nu}_e$$ List the two types of particles whose total number must be conserved in this reaction. [1 mark]

2020 Paper 1 Section 2 Question 22 The Standard Model	List the six types of leptons. [1 mark] 1. 2. 3. 4. 5. 6.

Paper 2 Section 1

2024 Paper 2 Section 1 Question 7 **The Standard Model**	a) Contrast baryons and mesons in terms of composition. [2 marks] b) Contrast quarks and leptons in terms of the possible fundamental forces they experience. [2 marks]

2022 Paper 2 Section 1 Question 2 **The Standard Model**	Contrast the properties of up quarks and tau particles. [2 marks]

2022 Paper 2 Section 1 Question 5 The Standard Model	The Feynman diagram for a particle interaction is shown.  Describe the particle interaction taking place. [3 marks]

2021 Paper 2 Section 1 Question 2 The Standard Model	List the four gauge bosons in the Standard Model. [1 mark] 1. 2. 3. 4.

Marking Guide – Paper 1 Section 1

2024 Paper 1 Section 1 Question 1

The Standard Model

Which option describes a feature of baryons?

(A) eliminated by positrons

(B) comprised of three quarks

(C) a type of elementary particle

(D) electrical charge equates to $+\frac{2}{3}e^{-}$

Answer is B.

2024 Paper 1 Section 1 Question 16

The Standard Model

The table shows a combination of mediating particles and possible forces they experience.
Which row is correct?

	Particle	Strong nuclear force	Weak nuclear force	Electromagnetic force
(A)	Photon	✓	✓	✓
(B)	Lepton	✓	✓	
(C)	Quark	✓		✓
(D)	Meson	✓	✓	✓

Answer is D.

2023 Paper 1 Section 1 Question 7

The Standard Model

An electron and positron can annihilate into a photon, producing another electron and positron pair in the process. An outcome of this interaction is that

(A) total mass decreases.
(B) fewer baryons will be produced.
(C) the lepton number does not change. – Answer
(D) the number of particles will decrease.

2023 Paper 1 Section 1 Question 12

The Standard Model

What is a consequence of symmetry in particle interactions?

(A) The law of conservation of momentum is obeyed. – Answer
(B) Charges on particles will always be different.
(C) Antiparticles travel backwards through time.
(D) Total mass of the particles will decrease.

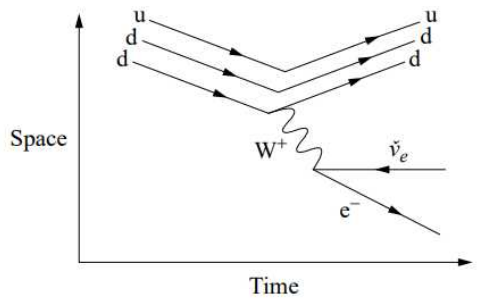
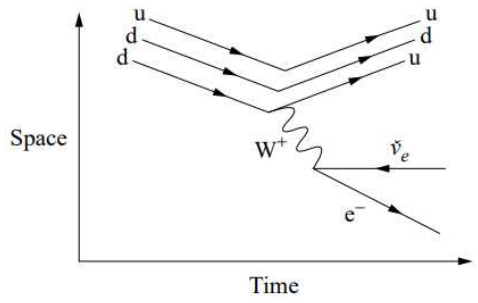
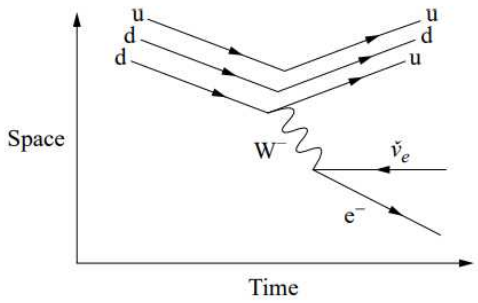
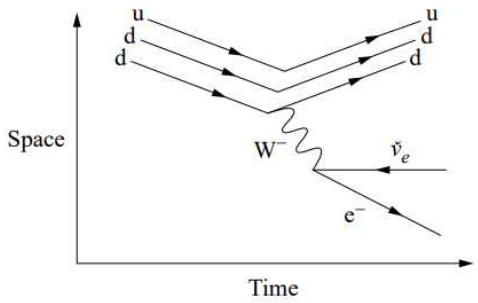
2023 Paper 1 Section 1 Question 14

The Standard Model

An electron is best described as a

(A) lepton with a larger mass than a positron.
(B) baryon with a smaller mass than a proton.
(C) meson that experiences the strong nuclear force.
(D) particle whose interactions can be mediated by photons. – Answer

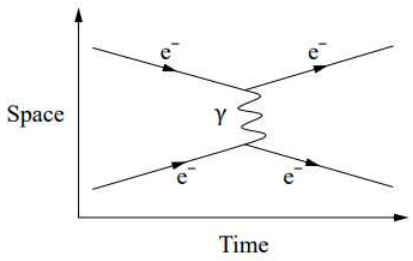
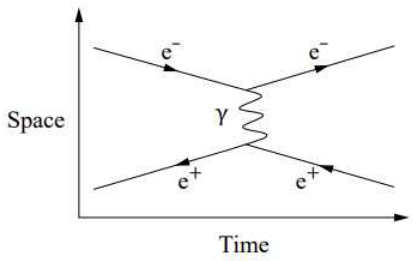
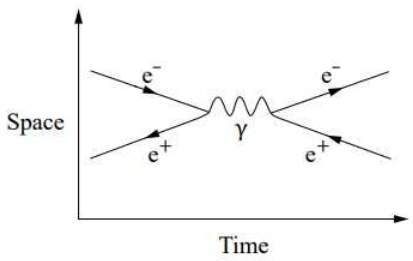
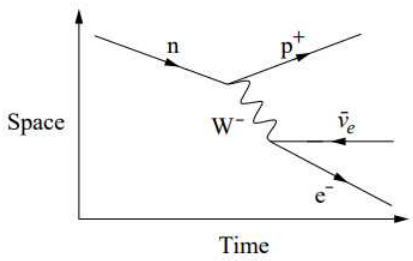
2022 Paper 1 Section 1 Question 5 The Standard Model	*Tau* particles are classified as (A) bosons. **(B) leptons. – Answer** (C) mesons. (D) baryons

2022 Paper 1 Section 1 Question 14 The Standard Model	Which Feynman diagram correctly depicts neutron decay? (A)  (B)  (C)  (D)  **Answer is C.**

2022 **Paper 1** **Section 1** **Question 20** **The Standard Model**	Which option lists the gauge bosons in ascending order of the strength of force they mediate? (A) W boson < Z boson < Photon (B) Gluon < Z boson < W boson (C) Photon < W boson < Gluon **(D) Z boson < Photon < Gluon – Answer**

2021 **Paper 1** **Section 1** **Question 1** **The Standard Model**	Leptons do not experience the (A) weak force. **(B) strong force. – Answer** (C) gravitational force. (D) electromagnetic force.

2021 **Paper 1** **Section 1** **Question 5** **The Standard Model**	Mesons are **(A) subatomic particles composed of one quark and one antiquark. – Answer** (B) elementary particles that are classified as leptons. (C) elementary particles exchanged between quarks. (D) subatomic particles composed of three quarks.

2021 **Paper 1** **Section 1** **Question 15** **The Standard Model**	Which Feynman diagram shows an electron interacting with another electron? (A)  (B)  (C)  (D)  **Answer is A.**

2020 **Paper 1** **Section 1** **Question 9** **The Standard Model**	Select the list containing the six types of quarks. (A) in, out, up, down, top and bottom (B) right, left, charm, strange, in and out **(C) up, down, charm, strange, top and bottom – Answer** (D) charm, strange, right, left, top and bottom

2020 **Paper 1** **Section 1** **Question 10** **The Standard Model**	The force that quarks experience that leptons do not is the (A) weak force. **(B) strong force. – Answer** (C) normal force. (D) electromagnetic force.

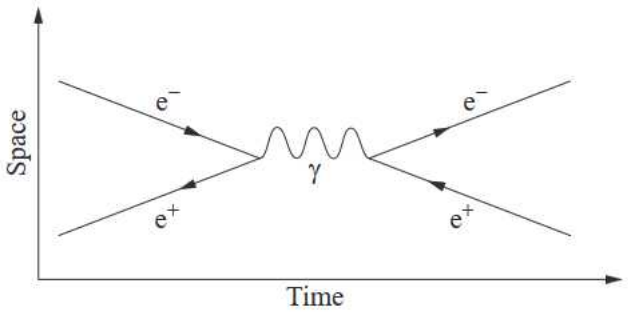
2020 **Paper 1** **Section 1** **Question 14** **The Standard Model**	Select the list that contains only gauge bosons. (A) gluon, photon, meson and hadron (B) lepton, baryon, meson and hadron **(C) gluon, photon, Z boson and W boson – Answer** (D) Z boson, W boson, photon and lepton

Marking Guide – Paper 1 Section 2

2024 Paper 1 Section 2 Question 21

The Standard Model

Describe the particle interaction shown. (3 marks)



Sample response	The response
The Feynman diagram represents the interaction between an electron and a positron. During this interaction the two particles are annihilated into a photon. The photon will then 'pair produce' another electron and positron.	• identifies that the interaction involves an electron and a positron **[1 mark]** • identifies that a photon is created through annihilation **[1 mark]** • describes 'pair produced' creation of another electron and positron **[1 mark]**

2023 Paper 1 Section 2 Question 22

The Standard Model

Particles move at a rate of 1.3×10^6 times per second around a circular particle accelerator with a radius of 35 m.

Calculate the average speed of the particles. Show your working. (3 marks)

Sample response	The response
$C = 2\pi r = 2 \times \pi \times 35 \approx 219.91\ m$ $f = \frac{1}{T}$ $\therefore v = \frac{2\pi r}{T} = 219.91 \times 1.3 \times 10^6 = 2.86 \times 10^8\ m\ s^{-1}$ Average speed = 2.9×10^8 m s^{-1} (to two significant figures)	• recognises the scenario relates to average speed of objects in uniform circular motion **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the average speed of the particles **[1 mark]**

2023 Paper 1 Section 2 Question 23

The Standard Model

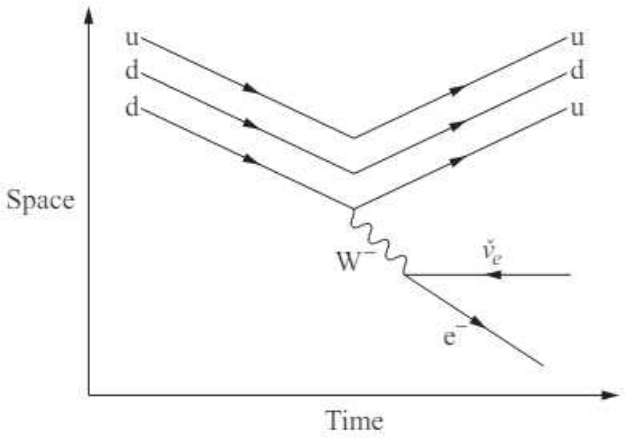
List the forces that can be experienced by leptons (1 mark)

Sample response	The response
Weak nuclear force Electromagnetic force Gravitational force	• identifies the forces **[1 mark]**

2023 Paper 1 Section 2 Question 28

The Standard Model

The Feynman diagram for a neutron decaying into a proton and electron is shown.



Describe the significance of the electron antineutrino in this particle interaction. (2 marks)

Sample response	The response
The law of conservation requires the baryon and lepton numbers to be conserved during a particle interaction. The electron antineutrino is required to maintain symmetry for this interaction. The law of conservation also requires mass to be conserved so an antineutrino is required to ensure this.	• identifies conservation of lepton number / symmetry of the interaction **[1 mark]** • describes conservation of mass **[1 mark]**

2022 Paper 1 Section 2 Question 22

The Standard Model

A collection of mesons was observed by a detector to move an average distance of 11.0 m when travelling at 95% of the speed of light. However, based on their properties, the mesons were expected to travel an average distance of 3.4 m.

Explain the difference between the observed and expected average distances. [2 marks]

Sample Response	The response
The relativistic speed of the mesons indicates they experience time dilation relative to the observed time over the distance travelled. This means the mesons appear to travel for a longer period of time and hence cover a larger distance.	• identifies that an object at relativistic speed experiences time dilation [1 mark] • explains the relationship between time travelled and observed distance [1 mark]

2022 Paper 1 Section 2 Question 26

The Standard Model

Carbon-14 undergoes nuclear decay to nitrogen-14.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + e^{-} + \bar{\nu}_e$$

List the two types of particles whose total number must be conserved in this reaction. [1 mark]

Sample Response	The response
Baryons Leptons	• identifies baryons and leptons [1 mark]

2020 Paper 1 Section 2 Question 22

The Standard Model

List the six types of leptons. [1 mark]

Sample Response	The response	Notes
1. Electron 2. Electron neutrino 3. Tau 4. Tau neutrino 5. Muon 6. Muon neutrino	• identifies the six leptons [1 mark]	Listing the respective antiparticles is permitted but only in addition to, not in place of, the leptons listed in the sample response. Listing the symbols (e, ν_e, ν_μ, μ, ν_T, τ) in addition to, or in place of, lepton names is permitted. If both are provided then the symbol must match the name. Misspelling of lepton names is permitted as long as the error does not impede meaning.

Marking Guide – Paper 2 Section 1

2024 Paper 2 Section 1 Question 7

The Standard Model

a) Contrast baryons and mesons in terms of composition. [2 marks]

Sample response	The response
Baryons are composed of three quarks. Whereas mesons are composed of one quark and one antiquark.	• identifies baryons are composed of 3 quarks **[1 mark]** • identifies mesons are composed of 1 quark and 1 antiquark **[1 mark]**

b) Contrast quarks and leptons in terms of the possible fundamental forces they experience. [2 marks]

Sample response	The response
Quarks experience all four fundamental forces (strong nuclear force, weak nuclear force, electromagnetic force and gravitational force). Whereas leptons experience only the weak nuclear force, gravitational force and electromagnetic force (if they have a charge).	• recognises quarks experience all forces whereas leptons do not experience the strong nuclear force **[1 mark]** • identifies that only charged leptons would experience electromagnetic force **[1 mark]**

2022 Paper 2 Section 1 Question 2

The Standard Model

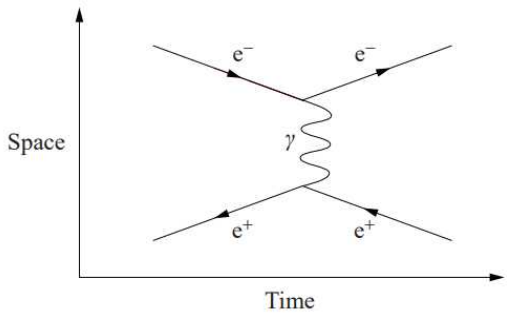
Contrast the properties of up quarks and tau particles. [2 marks]

Sample Response	The response
Up quarks are fundamental particles that experience the strong nuclear force and may be combined with other quarks to form mesons and baryons. Tau particles are also fundamental particles belonging to the lepton group of subatomic particles. These particles experience the weak nuclear force, and unlike quarks they do not combine with other leptons to form other subatomic particles.	• identifies a difference between the nature of particles [1 mark] interaction forces [1 mark]

2022 Paper 2 Section 1 Question 5

The Standard Model

The Feynman diagram for a particle interaction is shown.



Describe the particle interaction taking place. [3 marks]

Sample Response	The response
The Feynman diagram represents the interaction between an electron and a positron through Bhaba scattering. During this interaction, a photon is exchanged between the electron and positron, before both particles change velocity as they move away from each other.	• identifies that the interaction involves an electron and a positron [1 mark] • identifies that a photon is exchanged [1 mark] • describes that both particles change velocity due to the interaction [1 mark]

2021 Paper 2 Section 1 Question 2

The Standard Model

List the four gauge bosons in the Standard Model. [1 mark]

Sample Response	The response	Notes
1. Gluon 2. Photon 3. W boson 4. Z boson	• lists the four gauge bosons [1 mark]	Accept symbols: g, y, W, Z. If symbols and names are provided, they must match. Accept misspelling of boson names if it does not impede meaning.