

# Apex Exam Guide

## Physics

Year 12 QCE

Queensland Curriculum

2025 Edition

Frederick Wong

# Apex Exam Guide

## Physics

### Year 12 QCE

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#### Acknowledgements

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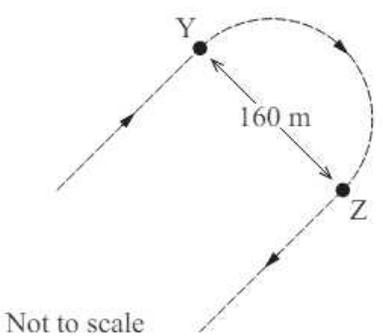
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## Unit 3 Gravity and electromagnetism

### Unit 3 – Topic 1: Gravity and motion

#### Paper 1 Section 1

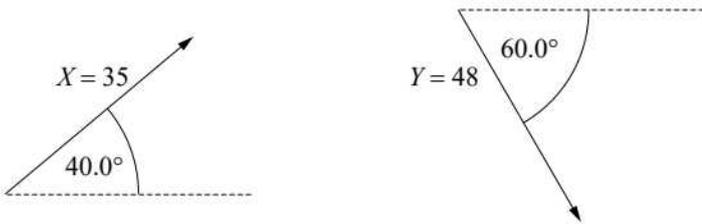
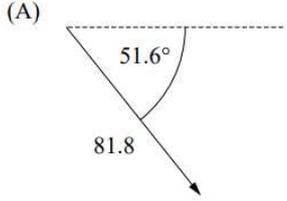
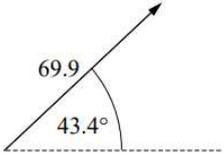
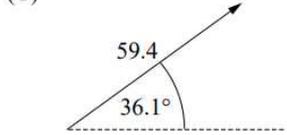
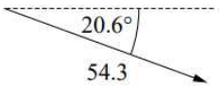
<b>2023 Paper 1 Section 1 Question 4 Gravity and motion</b>	<p>Kepler's third law</p> <p>(A) describes the elliptical orbit of planets. (B) combines Newton's first law of motion with uniform circular motion. (C) equates the area of the arc sweep of a planet to the time taken to complete it. (D) describes the relationship between uniform circular motion and the Law of Universal Gravitation.</p>
<b>2023 Paper 1 Section 1 Question 6 Gravity and motion</b>	<p>An object of mass <math>6.0 \times 10^2</math> kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.</p>  <p>Calculate the centripetal force experienced by the object as it moves from Y to Z.</p> <p>(A) <math>3.0 \times 10^3</math> N (B) <math>7.6 \times 10^2</math> N (C) <math>3.8 \times 10^2</math> N (D) <math>7.6 \times 10^1</math> N</p>
<b>2023 Paper 1 Section 1 Question 15 Gravity and motion</b>	<p>Two objects experience a gravitational force, <math>F</math>, between them.</p> <p>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.</p> <p>(A) <math>\frac{1}{4} F</math> (B) <math>\frac{1}{2} F</math> (C) <math>1 F</math> (D) <math>2 F</math></p>
<b>2023 Paper 1 Section 1 Question 18 Gravity and motion</b>	<p>A 20 kg object is placed on an inclined plane with a slope of <math>35^\circ</math>. If the object experiences a frictional force of 40 N and no additional applied force, calculate its acceleration down the inclined plane.</p> <p>(A) <math>3.6 \text{ m s}^{-2}</math> (B) <math>5.6 \text{ m s}^{-2}</math> (C) <math>6.0 \text{ m s}^{-2}</math> (D) <math>7.6 \text{ m s}^{-2}</math></p>

<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Gravity and motion</b></p>	<p>Which free body diagram best represents an object being pulled at a constant speed up an inclined plane?</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>(A)</p> </div> <div style="text-align: center;"> <p>(B)</p> </div> <div style="text-align: center;"> <p>(C)</p> </div> <div style="text-align: center;"> <p>(D)</p> </div> </div>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Gravity and motion</b></p>	<p>An object orbiting Earth has an orbital period of <math>5.6 \times 10^3</math> s.</p> <p>What is the object's orbital radius?</p> <p>(A) <math>3.8 \times 10^5</math> m          (B) <math>6.8 \times 10^6</math> m          (C) <math>1.8 \times 10^{10}</math> m          (D) <math>1.3 \times 10^{12}</math> m</p>
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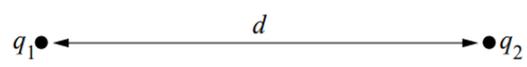
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Gravity and motion</b></p>	<p>Which diagram would result in the furthest horizontal distance travelled?</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>(A)</p> </div> <div style="text-align: center;"> <p>(B)</p> </div> <div style="text-align: center;"> <p>(C)</p> </div> <div style="text-align: center;"> <p>(D)</p> </div> </div> <p>Not to scale</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>An object experiencing uniform circular motion in a horizontal plane travels at an average speed of <math>8.0 \text{ m s}^{-1}</math>.</p> <p>Calculate the radius of the object's path if it takes 0.3 s to complete a full rotation.</p> <p>(A) <math>3.8 \times 10^{-1}</math> m          (B) <math>2.6 \times 10^0</math> m          (C) <math>1.5 \times 10^1</math> m          (D) <math>1.7 \times 10^2</math> m</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b></p> <p><b>Gravity and motion</b></p>	<p>Two vectors are shown.</p>  <p>Which option represents the resultant vector of <math>X + Y</math>?</p> <p>(A)  (B) </p> <p>(C)  (D) </p> <p>Not to scale</p>
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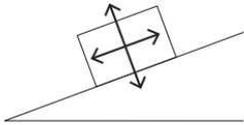
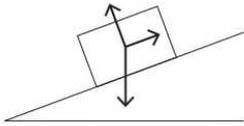
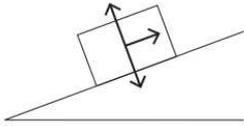
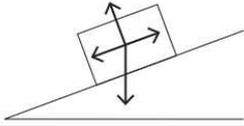
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b></p> <p><b>Gravity and motion</b></p>	<p>An object is in orbit 400 km above the surface of the Earth. The Earth has a radius of <math>6.4 \times 10^6</math> m.</p> <p>What is the magnitude of the gravitational field strength experienced by the object?</p> <p>(A) <math>8.6 \times 10^0 \text{ m s}^{-2}</math>          (B) <math>9.7 \times 10^0 \text{ m s}^{-2}</math>          (C) <math>2.5 \times 10^3 \text{ m s}^{-2}</math>          (D) <math>5.9 \times 10^7 \text{ m s}^{-2}</math></p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the initial horizontal velocity of a projectile with an initial velocity of <math>38 \text{ m s}^{-1}</math> at an angle of <math>42^\circ</math> up from the horizontal.</p> <p>(A) <math>25 \text{ m s}^{-1}</math>          (B) <math>28 \text{ m s}^{-1}</math>          (C) <math>34 \text{ m s}^{-1}</math>          (D) <math>40 \text{ m s}^{-1}</math></p>
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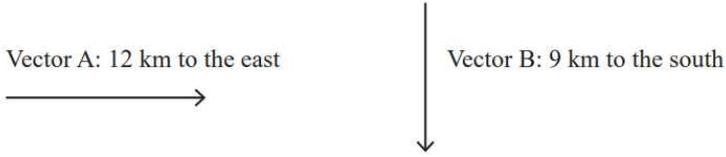
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two charges (<math>q_1</math> and <math>q_2</math>) separated by a distance (<math>d</math>).</p>  <p>There is a force, <math>F</math>, acting between the two charges.</p> <p>Calculate the magnitude of the force acting between the two charges if <math>d</math> is halved and the charge of <math>q_2</math> is doubled.</p> <p>(A) <math>1F</math>          (B) <math>2F</math>          (C) <math>4F</math>          (D) <math>8F</math></p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Gravity and motion</b></p>	<p><i>Normal force</i> is the force acting along an imaginary line</p> <p>(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.</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two displacement vectors.</p> <div style="text-align: center;"> </div> <p>Calculate the resultant vector above the horizontal axis when Vector A is added to Vector B.</p> <p>(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°</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b></p> <p><b>Gravity and motion</b></p>	<p>Uniform circular motion occurs when an object is travelling in a circle at a constant</p> <p>(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.</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the maximum height reached by a projectile with an initial velocity of <math>15 \text{ m s}^{-1}</math> at an angle of <math>30^\circ</math> up from the horizontal.</p> <p>(A) 2.87 m (B) 3.83 m (C) 8.61 m (D) 11.5 m</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the orbital period of a satellite travelling around the Earth with a radius of <math>4.00 \times 10^8 \text{ m}</math>.</p> <p>(A) <math>3.49 \times 10^{-2}</math> hours (B) <math>3.94 \times 10^2</math> hours (C) <math>6.99 \times 10^2</math> hours (D) <math>1.76 \times 10^9</math> hours</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b></p> <p><b>Gravity and motion</b></p>	<p>The weight of a 5 kg object on Earth is</p> <p>(A) 0.49 N (B) 0.51 N (C) 49 N (D) 51 N</p>

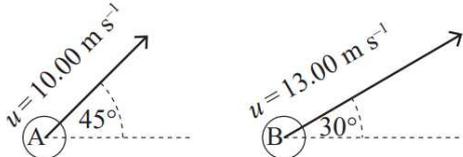
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b></p> <p><b>Gravity and motion</b></p>	<p>A gravitational field is the</p> <p>(A) net gravitational force per unit mass at a particular point in space.          (B) energy stored in an object as a result of its position relative to another 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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Gravity and motion</b></p>	<p>Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane?</p> <p>(A) </p> <p>(B) </p> <p>(C) </p> <p>(D) </p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Gravity and motion</b></p>	<p>The definition of <i>average speed</i> is the rate of change of</p> <p>(A) velocity.          (B) distance.          (C) acceleration.          (D) displacement.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two vectors.</p> <p style="text-align: center;">  </p> <p>Calculate the magnitude of the resultant vector when Vector A is added to Vector B.</p> <p>(A) 15 km          (B) 16.5 km          (C) 21 km          (D) 108 km</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Gravity and motion</b></p>	<p>An object 46 m above the ground is projected horizontally, with an initial velocity of 25 m s<sup>-1</sup>.</p> <p>Calculate the horizontal displacement of the object at the time it reaches the ground.</p> <p>(A) 77 m          (B) 120 m          (C) 190 m          (D) 240 m</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows object A and object B being projected at different velocities.</p>  <p>Which of the following statements is true?</p> <p>(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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>Which of the following is one of Kepler's laws of planetary motion?</p> <p>(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, <math>c</math>, 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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the orbital period of a satellite travelling on a <math>3.00 \times 10^8</math> m radius orbit around the Earth.</p> <p>(A) <math>1.44 \times 10^{-2}</math> hours          (B) <math>4.54 \times 10^2</math> hours          (C) <math>1.64 \times 10^6</math> hours          (D) <math>7.44 \times 10^8</math> hours</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the initial vertical velocity of a projectile with an initial velocity of <math>68 \text{ m s}^{-1}</math> at an angle of <math>51^\circ</math> up from the horizontal.</p> <p>(A) <math>43 \text{ m s}^{-1}</math>          (B) <math>51 \text{ m s}^{-1}</math>          (C) <math>53 \text{ m s}^{-1}</math>          (D) <math>68 \text{ m s}^{-1}</math></p>
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**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]

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Distance = \_\_\_\_\_ m (to two significant figures)

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

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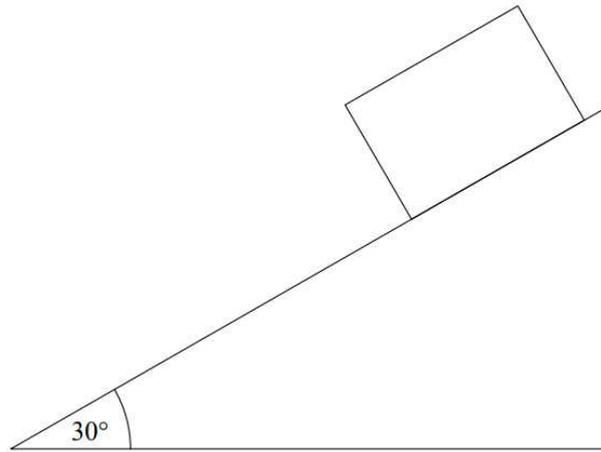
Centripetal force = \_\_\_\_\_ N (to two significant figures)



**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  $30^\circ$  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]

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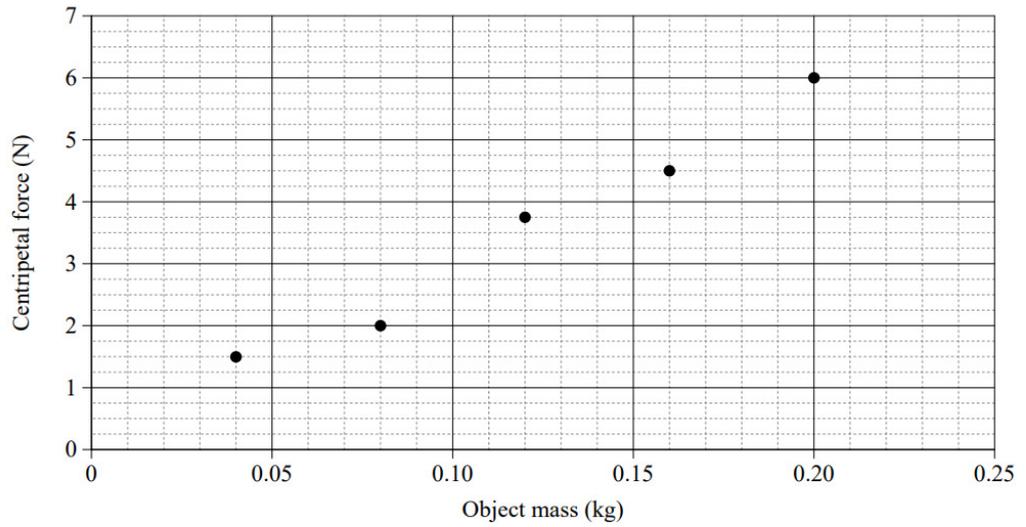
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Magnitude of net force = \_\_\_\_\_ N (to 1 decimal place)

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]

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Speed = \_\_\_\_\_  $\text{m s}^{-1}$  (to 1 decimal place)

<b>2020 Paper 1 Section 2 Question 21</b>  <b>Gravity and motion</b>	An object that is $7.12 \times 10^6$ 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)

<b>2020 Paper 1 Section 2 Question 25</b>  <b>Gravity and motion</b>	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)



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 ( $\text{m s}^{-2}$ )
A	79	1.6
B	32	3.7

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

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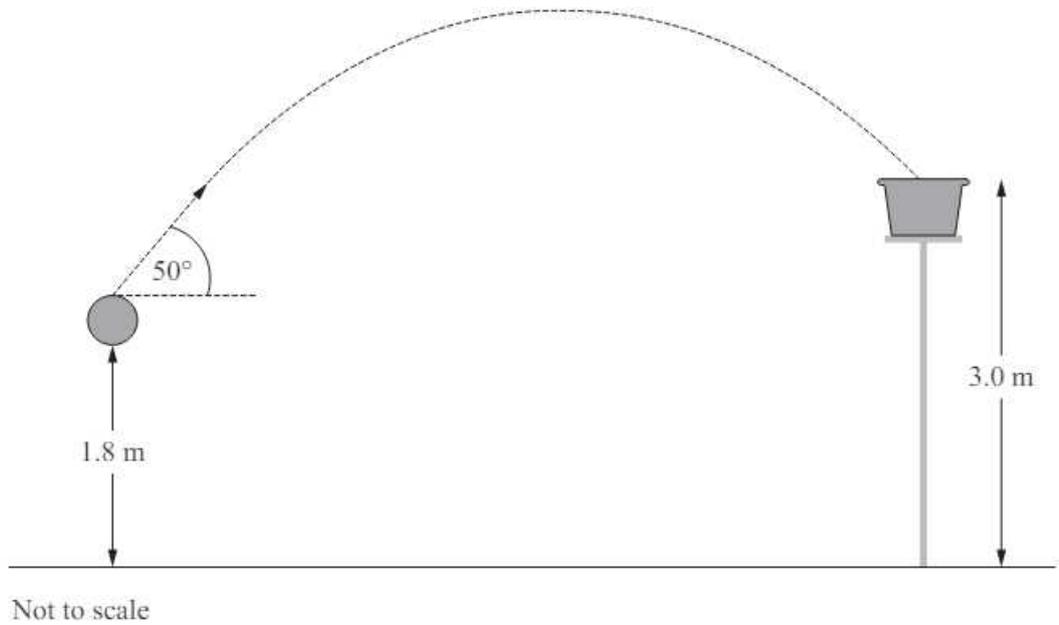
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2023  
Paper 2  
Section 1  
Question 6  
  
Gravity and  
motion

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



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

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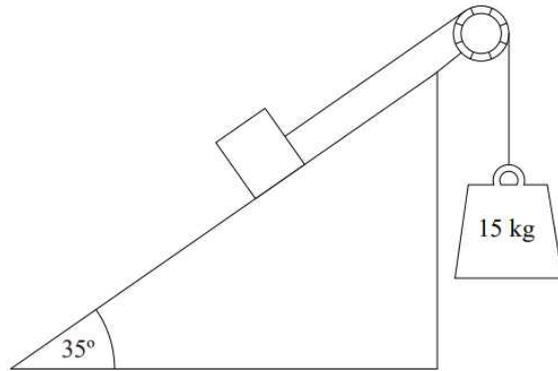
Time = \_\_\_\_\_ s (to two significant figures)



**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]

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Mass = \_\_\_\_\_ kg (to two significant figures)

**2022  
Paper 2  
Section 1  
Question 7**  
**Gravity and  
motion**

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

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

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Distance = \_\_\_\_\_ m (to two significant figures)







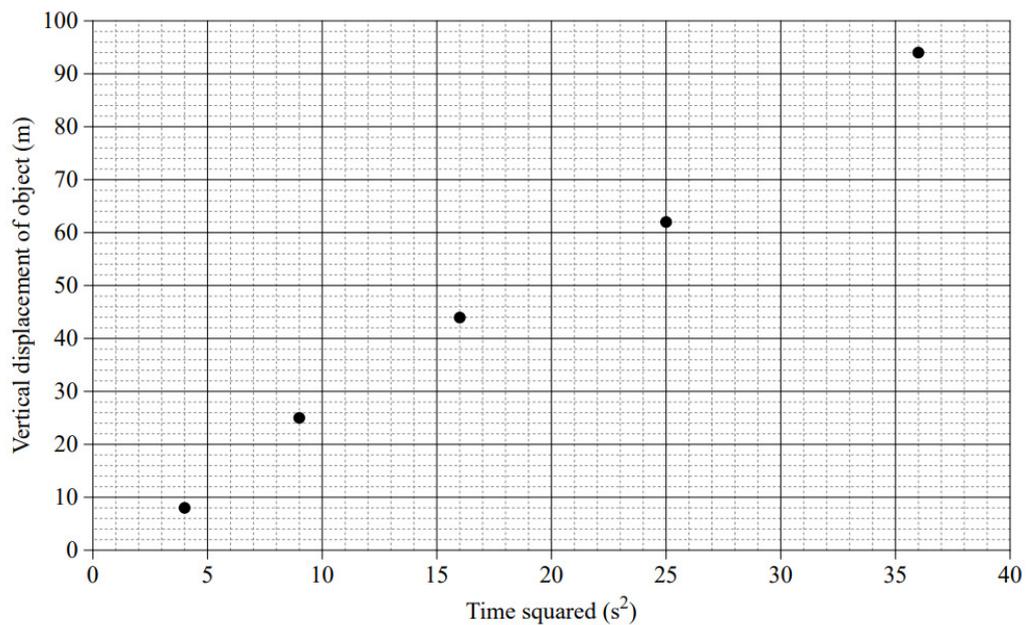
Distance from Asteroid B = \_\_\_\_\_ km (to the nearest whole number)

**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]

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

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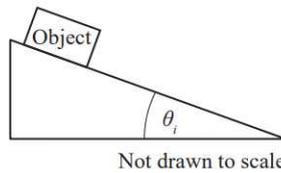
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Acceleration = \_\_\_\_\_  $\text{m s}^{-2}$  (to 2 significant figures)

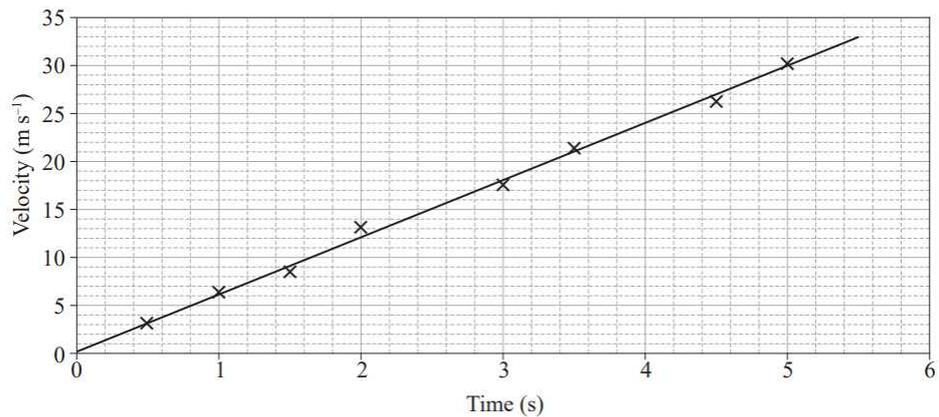
2020  
Paper 2  
Section 1  
Question 8

Gravity and  
motion

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



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



Determine the angle of incline,  $\theta_i$ , of the inclined plane. Show your working

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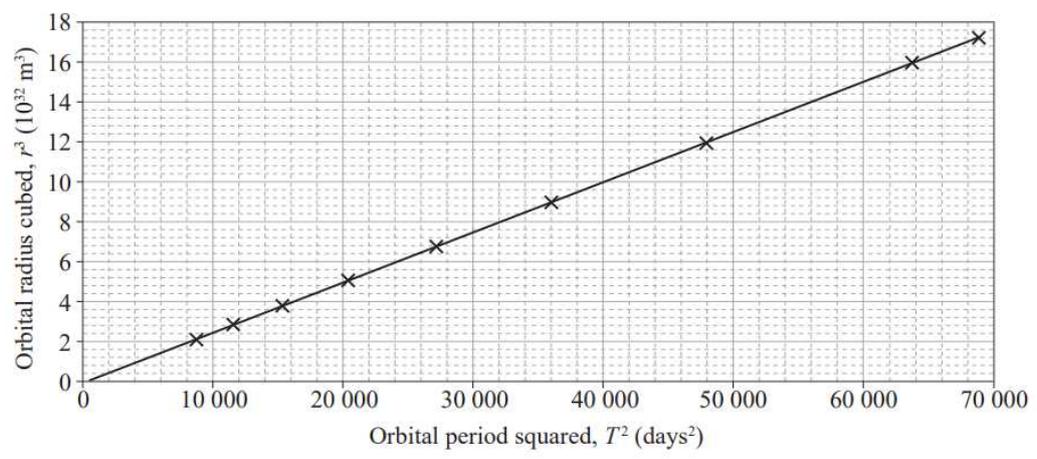
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$$\theta_i = \underline{\hspace{10em}}^\circ$$

**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]

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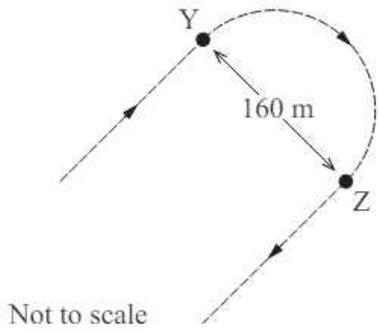


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	Mass = _____ kg (to 1 decimal place)

**Marking Guide – Paper 1 Section 1**

<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Gravity and motion</b></p>	<p>Kepler’s third law</p> <p>(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. <b>(D) describes the relationship between uniform circular motion and the Law of Universal Gravitation. – Answer</b></p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Gravity and motion</b></p>	<p>An object of mass <math>6.0 \times 10^2</math> kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.</p>  <p>Calculate the centripetal force experienced by the object as it moves from Y to Z.</p> <p>(A) <math>3.0 \times 10^3</math> N <b>(B) <math>7.6 \times 10^2</math> N – Answer</b> (C) <math>3.8 \times 10^2</math> N (D) <math>7.6 \times 10^1</math> N</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b></p> <p><b>Gravity and motion</b></p>	<p>Two objects experience a gravitational force, <math>F</math>, between them.</p> <p>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.</p> <p>(A) <math>\frac{1}{4} F</math> (B) <math>\frac{1}{2} F</math> (C) <math>1 F</math> (D) <math>2 F</math></p> <p><b>Answer is B.</b></p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b></p> <p><b>Gravity and motion</b></p>	<p>A 20 kg object is placed on an inclined plane with a slope of <math>35^\circ</math>. If the object experiences a frictional force of 40 N and no additional applied force, calculate its acceleration down the inclined plane.</p> <p><b>(A) <math>3.6 \text{ m s}^{-2}</math> – Answer</b> (B) <math>5.6 \text{ m s}^{-2}</math> (C) <math>6.0 \text{ m s}^{-2}</math> (D) <math>7.6 \text{ m s}^{-2}</math></p>
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**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  $5.6 \times 10^3$  s.  
What is the object's orbital radius?

(A)  $3.8 \times 10^5$  m  
**(B)  $6.8 \times 10^6$  m – Answer**  
 (C)  $1.8 \times 10^{10}$  m  
 (D)  $1.3 \times 10^{12}$  m

**2022 Paper 1 Section 1 Question 9**  
Gravity and motion

Which diagram would result in the furthest horizontal distance travelled?

(A)

(B)

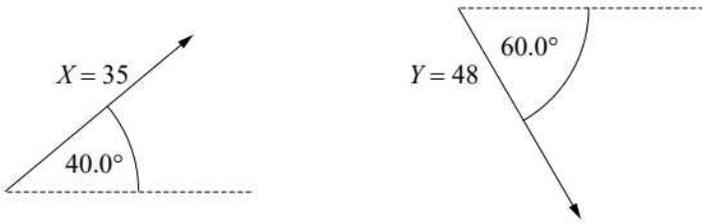
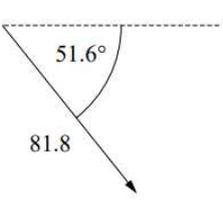
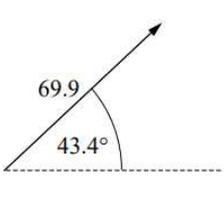
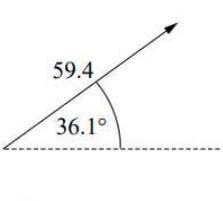
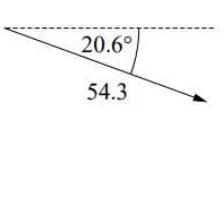
(C)

(D)

Not to scale

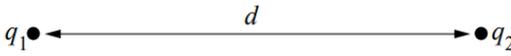
**Answer is B.**

<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>An object experiencing uniform circular motion in a horizontal plane travels at an average speed of <math>8.0 \text{ m s}^{-1}</math>.</p> <p>Calculate the radius of the object's path if it takes <math>0.3 \text{ s}</math> to complete a full rotation.</p> <p>(A) <math>3.8 \times 10^{-1} \text{ m}</math> – Answer (B) <math>2.6 \times 10^0 \text{ m}</math> (C) <math>1.5 \times 10^1 \text{ m}</math> (D) <math>1.7 \times 10^2 \text{ m}</math></p>
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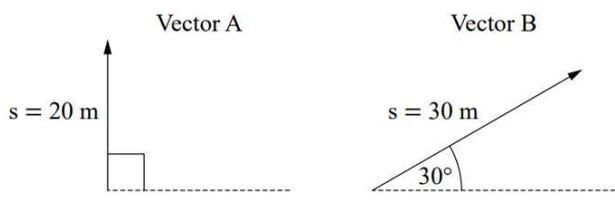
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b></p> <p><b>Gravity and motion</b></p>	<p>Two vectors are shown.</p>  <p>Which option represents the resultant vector of <math>X + Y</math>?</p> <p>(A)  (B) </p> <p>(C)  (D) </p> <p>Not to scale</p> <p><b>Answer is D.</b></p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b></p> <p><b>Gravity and motion</b></p>	<p>An object is in orbit <math>400 \text{ km}</math> above the surface of the Earth. The Earth has a radius of <math>6.4 \times 10^6 \text{ m}</math>.</p> <p>What is the magnitude of the gravitational field strength experienced by the object?</p> <p>(A) <math>8.6 \times 10^0 \text{ m s}^{-2}</math> – Answer (B) <math>9.7 \times 10^0 \text{ m s}^{-2}</math> (C) <math>2.5 \times 10^3 \text{ m s}^{-2}</math> (D) <math>5.9 \times 10^7 \text{ m s}^{-2}</math></p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the initial horizontal velocity of a projectile with an initial velocity of <math>38 \text{ m s}^{-1}</math> at an angle of <math>42^\circ</math> up from the horizontal.</p> <p>(A) <math>25 \text{ m s}^{-1}</math> (B) <math>28 \text{ m s}^{-1}</math> – Answer (C) <math>34 \text{ m s}^{-1}</math> (D) <math>40 \text{ m s}^{-1}</math></p>
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<p><b>2021 Paper 1 Section 1 Question 4</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two charges (<math>q_1</math> and <math>q_2</math>) separated by a distance (<math>d</math>).</p>  <p>There is a force, <math>F</math>, acting between the two charges.</p> <p>Calculate the magnitude of the force acting between the two charges if <math>d</math> is halved and the charge of <math>q_2</math> is doubled.</p> <p>(A) <math>1F</math>          (B) <math>2F</math>          (C) <math>4F</math>  <b>(D) <math>8F</math> – Answer</b></p>
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<p><b>2021 Paper 1 Section 1 Question 7</b></p> <p><b>Gravity and motion</b></p>	<p><i>Normal force</i> is the force acting along an imaginary line</p> <p>(A) parallel to the surface.  <b>(B) perpendicular to the surface. – Answer</b>          (C) opposite to the gravitational force.          (D) in the same direction as the gravitational force.</p>
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<p><b>2021 Paper 1 Section 1 Question 8</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two displacement vectors.</p>  <p>Calculate the resultant vector above the horizontal axis when Vector A is added to Vector B.</p> <p>(A) 43.6 m at <math>36.6^\circ</math>  <b>(B) 43.6 m at <math>53.4^\circ</math> – Answer</b>          (C) 48.4 m at <math>18.1^\circ</math>          (D) 48.4 m at <math>71.9^\circ</math></p>
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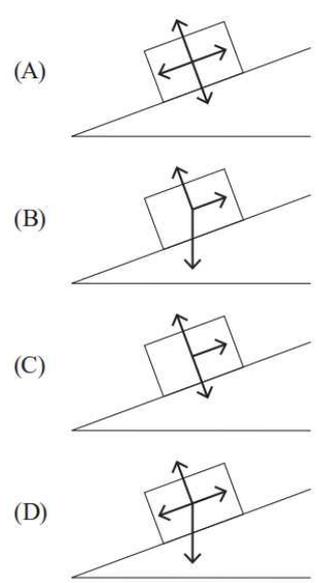
<p><b>2021 Paper 1 Section 1 Question 11</b></p> <p><b>Gravity and motion</b></p>	<p>Uniform circular motion occurs when an object is travelling in a circle at a constant</p> <p>(A) speed, due to a force of constant magnitude acting in a parallel direction to its velocity.          (B) velocity, due to a force of constant magnitude acting in a parallel direction to its speed.  <b>(C) speed, due to a force of constant magnitude acting in a perpendicular direction to its velocity. – Answer</b>          (D) velocity, due to a force of constant magnitude acting in a perpendicular direction to its speed.</p>
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<p><b>2021 Paper 1 Section 1 Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the maximum height reached by a projectile with an initial velocity of <math>15 \text{ m s}^{-1}</math> at an angle of <math>30^\circ</math> up from the horizontal.</p> <p>(A) <b>2.87 m – Answer</b>          (B) 3.83 m          (C) 8.61 m          (D) 11.5 m</p>
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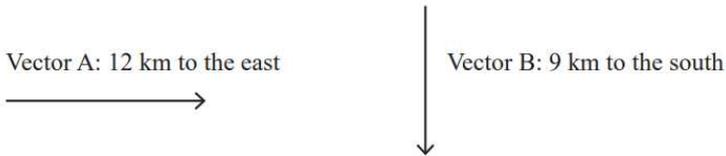
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b>  <b>Gravity and motion</b>	Calculate the orbital period of a satellite travelling around the Earth with a radius of $4.00 \times 10^8$ m. (A) $3.49 \times 10^{-2}$ hours (B) $3.94 \times 10^2$ hours <b>(C) <math>6.99 \times 10^2</math> hours – Answer</b> (D) $1.76 \times 10^9$ hours
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<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b>  <b>Gravity and motion</b>	The weight of a 5 kg object on Earth is (A) 0.49 N (B) 0.51 N <b>(C) 49 N – Answer</b> (D) 51 N
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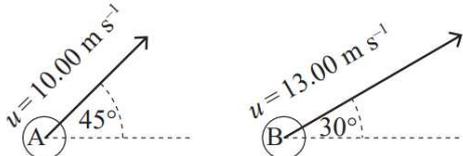
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b>  <b>Gravity and motion</b>	A gravitational field is the (A) net gravitational force per unit mass at a particular point in space. (B) energy stored in an object as a result of its position relative to another object. <b>(C) region of space surrounding a body in which another body experiences a force of gravitational attraction. – Answer</b> (D) position in space where objects experience a force or acquire potential energy as they are ‘worked’ into that position.
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b>  <b>Gravity and motion</b>	Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane?  <b>Answer is B.</b>
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b>  <b>Gravity and motion</b>	The definition of <i>average speed</i> is the rate of change of (A) velocity. <b>(B) distance. – Answer</b> (C) acceleration. (D) displacement.
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows two vectors.</p> <div style="text-align: center;">  <p>Vector A: 12 km to the east</p> <p>Vector B: 9 km to the south</p> </div> <p>Calculate the magnitude of the resultant vector when Vector A is added to Vector B.</p> <p>(A) 15 km – Answer (B) 16.5 km (C) 21 km (D) 108 km</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Gravity and motion</b></p>	<p>An object 46 m above the ground is projected horizontally, with an initial velocity of 25 m s<sup>-1</sup>.</p> <p>Calculate the horizontal displacement of the object at the time it reaches the ground.</p> <p>(A) 77 m – Answer (B) 120 m (C) 190 m (D) 240 m</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b></p> <p><b>Gravity and motion</b></p>	<p>The diagram shows object A and object B being projected at different velocities.</p> <div style="text-align: center;">  </div> <p>Which of the following statements is true?</p> <p>(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</p>
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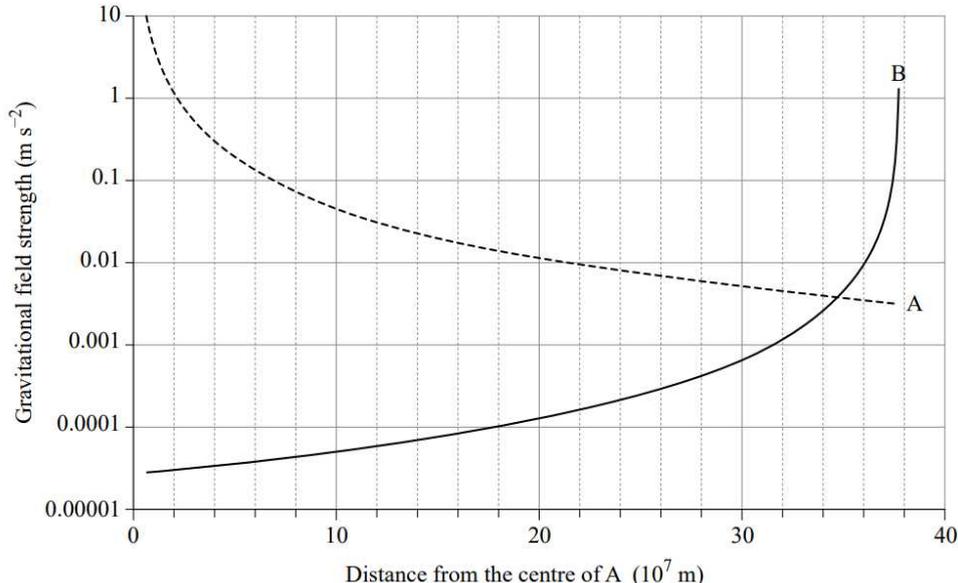
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b></p> <p><b>Gravity and motion</b></p>	<p>Which of the following is one of Kepler's laws of planetary motion?</p> <p>(A) The laws of physics are the same in all inertial frames of reference. (B) All planets move about the Sun in elliptical 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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b></p> <p><b>Gravity and motion</b></p>	<p>Calculate the orbital period of a satellite travelling on a <math>3.00 \times 10^8</math> m radius orbit around the Earth.</p> <p>(A) <math>1.44 \times 10^{-2}</math> hours (B) <math>4.54 \times 10^2</math> hours – Answer (C) <math>1.64 \times 10^6</math> hours (D) <math>7.44 \times 10^8</math> hours</p>
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b> <b>Gravity and motion</b>	Calculate the initial vertical velocity of a projectile with an initial velocity of $68 \text{ m s}^{-1}$ at an angle of $51^\circ$ up from the horizontal.  (A) $43 \text{ m s}^{-1}$ (B) $51 \text{ m s}^{-1}$ (C) <b><math>53 \text{ m s}^{-1}</math> – Answer</b> (D) $68 \text{ m s}^{-1}$
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Marking Guide – Paper 1 Section 2

<p>2023 Paper 1 Section 2 Question 27</p> <p>Gravity and motion</p>	<p>A satellite orbits a planet of mass <math>6.42 \times 10^{23}</math> kg at a height of 5000 km from the surface. The planet has a diameter of 6780 km.</p> <p>Determine the speed required for the satellite to maintain its orbit. Show your working. (5 marks)</p> <table border="1" data-bbox="292 309 1482 902"> <thead> <tr> <th data-bbox="292 309 970 342">Sample response</th> <th data-bbox="970 309 1482 342">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 342 970 902"> <math display="block">\frac{T^2}{r^3} = \frac{4\pi^2}{GM}</math> <math display="block">\frac{T^2}{(3390 \times 10^3 + 5000 \times 10^3)^3} = \frac{4\pi^2}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}</math> <math display="block">T = \sqrt{\frac{4\pi^2 \times 5.91 \times 10^{20}}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}}</math> <math display="block">= 2.33 \times 10^4 \text{ s}</math> <math display="block">v = \frac{2\pi r}{T}</math> <math display="block">= \frac{2\pi \times 8.39 \times 10^6}{2.33 \times 10^4}</math> <math display="block">= 2.3 \times 10^3 \text{ m s}^{-1}</math> <p>Speed = <math>2.3 \times 10^3 \text{ m s}^{-1}</math> (to two significant figures)</p> </td> <td data-bbox="970 342 1482 902"> <ul style="list-style-type: none"> <li>recognises the scenario relates to                             <ul style="list-style-type: none"> <li>orbital mechanics [1 mark]</li> <li>circular motion [1 mark]</li> </ul> </li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates the speed [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$ $\frac{T^2}{(3390 \times 10^3 + 5000 \times 10^3)^3} = \frac{4\pi^2}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}$ $T = \sqrt{\frac{4\pi^2 \times 5.91 \times 10^{20}}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}}$ $= 2.33 \times 10^4 \text{ s}$ $v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 8.39 \times 10^6}{2.33 \times 10^4}$ $= 2.3 \times 10^3 \text{ m s}^{-1}$ <p>Speed = <math>2.3 \times 10^3 \text{ m s}^{-1}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to                             <ul style="list-style-type: none"> <li>orbital mechanics [1 mark]</li> <li>circular motion [1 mark]</li> </ul> </li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates the speed [1 mark]</li> </ul>
Sample response	The response				
$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$ $\frac{T^2}{(3390 \times 10^3 + 5000 \times 10^3)^3} = \frac{4\pi^2}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}$ $T = \sqrt{\frac{4\pi^2 \times 5.91 \times 10^{20}}{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}}$ $= 2.33 \times 10^4 \text{ s}$ $v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 8.39 \times 10^6}{2.33 \times 10^4}$ $= 2.3 \times 10^3 \text{ m s}^{-1}$ <p>Speed = <math>2.3 \times 10^3 \text{ m s}^{-1}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to                             <ul style="list-style-type: none"> <li>orbital mechanics [1 mark]</li> <li>circular motion [1 mark]</li> </ul> </li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates the speed [1 mark]</li> </ul>				

<p>2022 Paper 1 Section 2 Question 27</p> <p>Gravity and motion</p>	<p>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.</p>  <p>Determine the total distance between the centre of the two objects. Show your working. [5 marks]</p> <table border="1" data-bbox="292 1780 1482 1798"> <thead> <tr> <th data-bbox="292 1780 887 1798">Sample Response</th> <th data-bbox="887 1780 1482 1798">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 1798 887 1798"></td> <td data-bbox="887 1798 1482 1798"></td> </tr> </tbody> </table>	Sample Response	The response		
Sample Response	The response				

	<p>Point where lines intersect indicates distance from centre of A where net gravitational field strength is equal to zero.</p> $r_A = 35; r_B = x - 35$ $g_A - g_B = 0$ $g_A = g_B$ $\frac{GM_A}{r_A^2} = \frac{GM_B}{r_B^2}$ $\frac{5M_B}{35^2} = \frac{M_B}{(x-35)^2}$ $\frac{35^2}{5} = (x-35)^2$ $\sqrt{\frac{35^2}{5}} = x - 35$ $x = \frac{35}{\sqrt{5}} + 35$ $= 50.7$ <p>Total distance = <math>51 \times 10^7</math> m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to gravitational field strength [1 mark]</li> <li>identifies distance from A where net gravitational field strength is zero [1 mark]</li> <li>constructs an equation that can be solved for the distance between the objects [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the distance between the centre of the two objects [1 mark]</li> </ul>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 28</b></p> <p><b>Gravity and motion</b></p>	<p>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.</p> <p>a) Calculate the distance travelled by the object after 3.9 s. Show your working. [2 marks]</p> <table border="1" style="width: 100%;"> <thead> <tr> <th style="background-color: #e0e0e0;">Sample Response</th> <th style="background-color: #e0e0e0;">The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">\text{distance} = 2\pi r \times \text{number of revolutions}</math> <math display="block">= 2\pi \times 0.25 \times \frac{3.9}{0.3}</math> <math display="block">= 20.4 \text{ m}</math> <p>Distance travelled = 20 m (to two significant figures)</p> </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to the circumference of circular motion [1 mark]</li> <li>calculates total distance travelled [1 mark]</li> </ul> </td> </tr> </tbody> </table> <p>b) Calculate the centripetal force acting on the object. Show your working. [5 marks]</p> <table border="1" style="width: 100%;"> <thead> <tr> <th style="background-color: #e0e0e0;">Sample Response</th> <th style="background-color: #e0e0e0;">The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">v = \frac{2\pi r}{T}</math> <math display="block">= \frac{2\pi \times 0.25}{0.3}</math> <math display="block">= 5.236... \text{ m s}^{-1}</math> <math display="block">F_{net} = \frac{mv^2}{r}</math> <math display="block">= \frac{0.2 \times 5.236^2}{0.25}</math> <math display="block">= 21.93 \text{ N}</math> <p>Centripetal force = 22 N (to two significant figures)</p> </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to velocity in circular motion [1 mark] centripetal motion [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates centripetal force of object [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	$\text{distance} = 2\pi r \times \text{number of revolutions}$ $= 2\pi \times 0.25 \times \frac{3.9}{0.3}$ $= 20.4 \text{ m}$ <p>Distance travelled = 20 m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to the circumference of circular motion [1 mark]</li> <li>calculates total distance travelled [1 mark]</li> </ul>	Sample Response	The response	$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.25}{0.3}$ $= 5.236... \text{ m s}^{-1}$ $F_{net} = \frac{mv^2}{r}$ $= \frac{0.2 \times 5.236^2}{0.25}$ $= 21.93 \text{ N}$ <p>Centripetal force = 22 N (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to velocity in circular motion [1 mark] centripetal motion [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates centripetal force of object [1 mark]</li> </ul>
Sample Response	The response								
$\text{distance} = 2\pi r \times \text{number of revolutions}$ $= 2\pi \times 0.25 \times \frac{3.9}{0.3}$ $= 20.4 \text{ m}$ <p>Distance travelled = 20 m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to the circumference of circular motion [1 mark]</li> <li>calculates total distance travelled [1 mark]</li> </ul>								
Sample Response	The response								
$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.25}{0.3}$ $= 5.236... \text{ m s}^{-1}$ $F_{net} = \frac{mv^2}{r}$ $= \frac{0.2 \times 5.236^2}{0.25}$ $= 21.93 \text{ N}$ <p>Centripetal force = 22 N (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to velocity in circular motion [1 mark] centripetal motion [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>calculates centripetal force of object [1 mark]</li> </ul>								

**2021  
Paper 1  
Section 2  
Question 22**

**Gravity and motion**

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

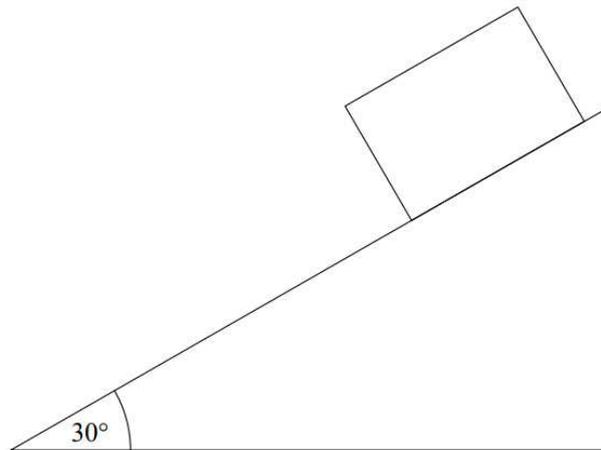
Calculate the average speed of the planet. [3 marks]

Sample Response	The response	Notes
<p>Assume the planet is undergoing uniform circular motion.</p> $F = \frac{mv^2}{r}$ <p>This is equal to the force of gravity.</p> $F = \frac{GMm}{r^2}$ <p>Equating these two equations and rearranging for velocity gives:</p> $v = \sqrt{\frac{GM}{r}}$ $v = \sqrt{\frac{6.67 \times 10^{-11} \times 3.38 \times 10^{31}}{4.23 \times 10^{11}}}$ <p><math>v = 73 \text{ km s}^{-1}</math> or <math>73\,005 \text{ m s}^{-1}</math> Average speed = <math>73\,005 \text{ m s}^{-1}</math> (to the nearest whole number)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to uniform circular motion and universal gravitation [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the average speed [1 mark]</li> </ul>	<p>Allow FT error from incorrect substitution.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

**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  $30^\circ$  up from the horizontal.



Not to scale

The object experiences a frictional force of 4.5 N.

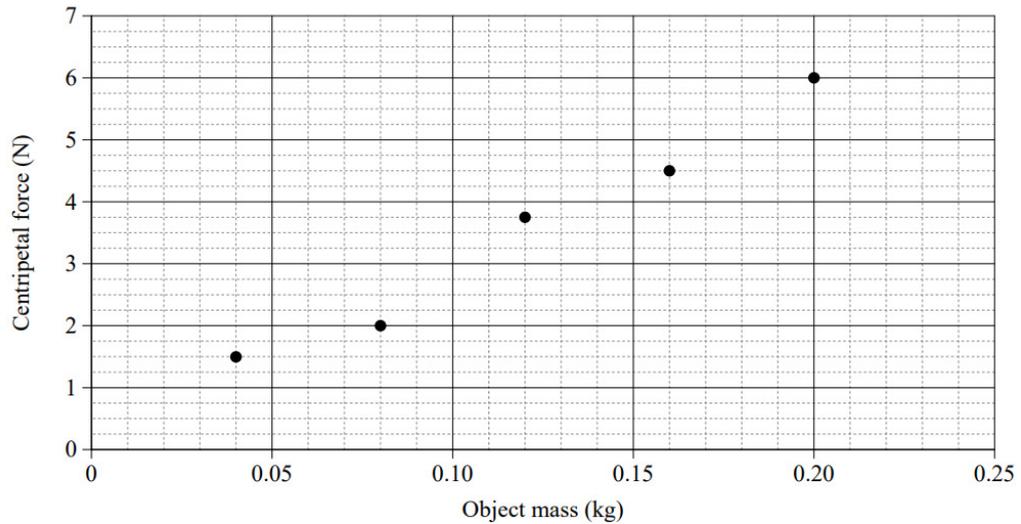
Calculate the magnitude of the net force acting on the object. [3 marks]

Sample Response	The response	Notes
<p><math>F_{g,x} = mg \sin \theta = 1.5 \times 9.8 \times \sin 30 = 7.4 \text{ N}</math> <math>F_{net} = F_{g,x} - F_f = 7.4 - 4.5 = 2.9 \text{ N}</math> Magnitude of net force = <math>2.9 \text{ N}</math> (to 1 decimal place)</p>	<ul style="list-style-type: none"> <li>identifies the forces acting on the object [1 mark]</li> <li>calculates the component of the gravitational force acting down the slope [1 mark]</li> <li>calculates the magnitude of the net force [1 mark]</li> </ul>	<p>Allow FT error for the magnitude of the net force.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

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
$F = \frac{mv^2}{r}$ $\text{gradient} = \frac{v^2}{r}$ $\text{gradient} = \frac{6.0 - 0.0}{0.2 - 0.0} = 30$ $v = \sqrt{0.2 \times \text{gradient}}$ $v = \sqrt{0.2 \times 30}$ $v = 2.4 \text{ m s}^{-1}$ Speed = 2.4 m s <sup>-1</sup> (to 1 decimal place)	<ul style="list-style-type: none"> <li>recognises how the scenario relates to <math>F = \frac{mv^2}{r}</math> [1 mark]</li> <li>identifies line of best fit [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the speed [1 mark]</li> </ul>	Appropriate mathematical reasoning may include: <ul style="list-style-type: none"> <li>determining the gradient</li> <li>substituting the gradient into a formula for <math>v</math></li> <li>or other suitable response consistent with a reasonable understanding.</li> </ul> Allow FT error from the line of best fit (LOBF). LOBF may be identified by: <ul style="list-style-type: none"> <li>line drawn on graph</li> <li>appropriate values derived from graph used in calculations.</li> </ul> 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  $7.12 \times 10^6$  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	<ul style="list-style-type: none"> <li>indicates an understanding of the physical scenario in relation to Newton's law of universal gravitation or other relevant physical concept/s [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed [1 mark]</li> <li>determines the mass [1 mark]</li> </ul>	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.

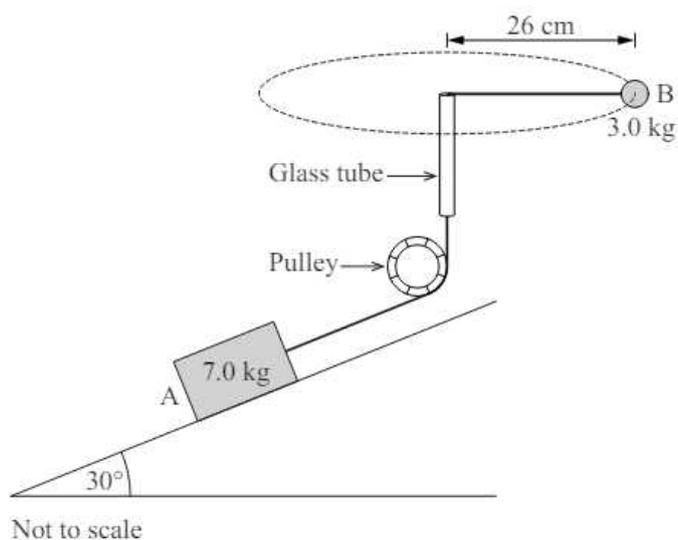
Calculate the time it takes Mars to orbit the Sun. [3 marks]

Sample Response	The response	Notes
$\frac{T_{\text{Mars}}^2}{r_{\text{Mars}}^3} = \frac{4\pi^2}{Gm}$ $T = \sqrt{\frac{4\pi^2}{Gm} r^3}$ $T_{\text{Mars}} = \sqrt{\frac{4\pi^2}{Gm} (1.5 \times r_{\text{Earth}})^3}$ <p>Therefore <math>T_{\text{Mars}} = \sqrt{1.5^3} T_{\text{Earth}}</math>  <math>T_{\text{Mars}} = 1.8371 \times 365 \text{ days}</math>  <math>T_{\text{Mars}} = 670.5 \text{ days}</math>  Time = 671 days</p>	<ul style="list-style-type: none"> <li>• indicates an understanding of the physical scenario in relation to Kepler's Law or other relevant physical concept/s [1 mark]</li> <li>• provides pertinent mathematical operation/s correctly performed [1 mark]</li> <li>• determines the time [1 mark]</li> </ul>	<p>Accept answers between:</p> <ul style="list-style-type: none"> <li>• 1.83 and 1.84 years inclusive</li> <li>• 670 days and 671 days inclusive</li> <li>• 16 080 and 16 107 hours inclusive</li> <li>• 57 888 000 seconds and 57 974 400 seconds inclusive.</li> </ul> <p>Allow FT error for the time.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

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.



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

Sample response	The response
<p>For object A to remain stationary, <math>F_{g,parallel} = F_T</math> and <math>F_T = F_c</math></p> $F_{g,parallel} = 7 \times 9.8 \times \sin 30 = 34.3 = F_c$ $F = \frac{mv^2}{r}$ $34.3 = \frac{7.0 \times v^2}{0.26}$ $v = \sqrt{\frac{34.3 \times 0.26}{3.0}}$ $= 1.7 \text{ m s}^{-1}$ <p>Speed = 1.7 m s<sup>-1</sup> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>identifies the equivalence of the parallel component of force due to gravity and centripetal force [1 mark]</li> <li>calculates the parallel component of force due to gravity [1 mark]</li> <li>recognises the scenario relates to centripetal force acting on an object [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the speed of object B [1 mark]</li> </ul>

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 ( $\text{m s}^{-2}$ )
A	79	1.6
B	32	3.7

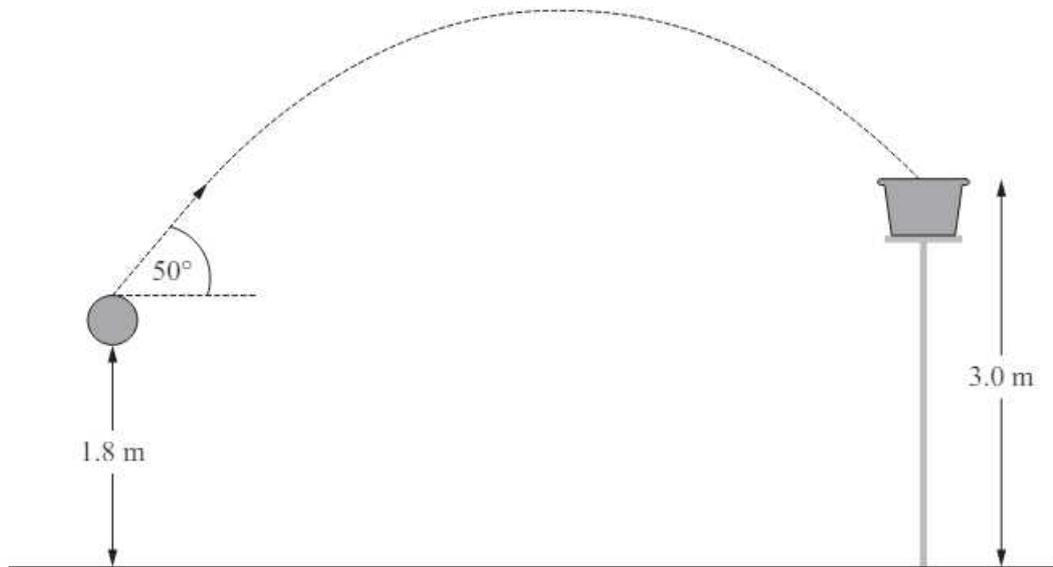
Determine which object has the greatest force acting on it. Show your working. (3 marks)

Sample response	The response
Force on object A = $mg = 79 \times 1.6 = 126.4 \text{ N} \approx 130 \text{ N}$ down Force on object B = $mg = 32 \times 3.7 = 118 \text{ N} \approx 120 \text{ N}$ down  Object A experiences the greatest force.	<ul style="list-style-type: none"> <li>recognises the scenario relates to relationship between the force due to gravity and mass [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>identifies the object experiencing the greatest force acting on it [1 mark]</li> </ul>

2023  
Paper 2  
Section 1  
Question 6

Gravity and  
motion

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

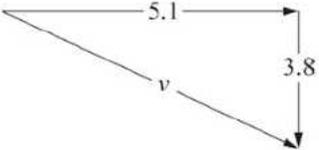


Not to scale

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

Sample response	The response
$u_y = 8.0 \sin 50 = 6.13 \text{ m s}^{-1}$ $v_y = gt + u_y$ $0 = -9.8t + 6.13$ $t = 0.63 \text{ s}$ Time = 0.63 s (to two significant figures)	<ul style="list-style-type: none"> <li>recognises the scenario relates to an object undergoing projectile motion [1 mark]</li> <li>calculates the initial vertical velocity [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates time taken to reach maximum height [1 mark]</li> </ul>

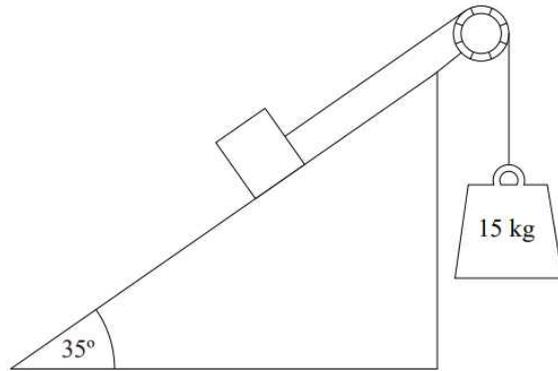
b) Calculate the magnitude of the ball's final velocity when it enters the bucket. Show your working. [6 marks]

Sample response	The response
<p>Method 1: Vector solution</p> <p>Impact velocity equal to the vector sum of <math>v_x</math> and <math>v_y</math></p> $v_y^2 = 2gs_y + u_y^2$ $= 2 \times -9.8 \times 1.2 + 6.13^2$ $= 14.1$ $v_y = 3.7 \text{ m s}^{-1}$ $v_x = u_x = 8.0 \cos 50 = 5.1 \text{ m s}^{-1}$  $v = \sqrt{5.1^2 + 3.7^2} = 6.3 \text{ m s}^{-1}$ <p>Final velocity = <math>6.3 \text{ m s}^{-1}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to the relationship between initial and final velocities <ul style="list-style-type: none"> <li>- vertically [1 mark]</li> <li>- horizontally [1 mark]</li> </ul> </li> <li>• calculates final <ul style="list-style-type: none"> <li>- vertical velocity [1 mark]</li> <li>- horizontal velocity [1 mark]</li> </ul> </li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the final velocity [1 mark]</li> </ul>
<p>Method 2: Energy solution</p> $\sum E_i = \sum E_f$ $KE_i = KE_f + GPE$ $\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$ $\frac{1}{2} \times 8^2 = \frac{1}{2}v^2 + 9.8 \times 1.2$ $v^2 = 40.48$ $v = 6.36 \text{ m s}^{-1}$ <p>Final velocity = <math>6.4 \text{ m s}^{-1}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to <ul style="list-style-type: none"> <li>- conservation of energy [1 mark]</li> <li>- kinetic energy [1 mark]</li> <li>- gravitational potential energy [1 mark]</li> </ul> </li> <li>• demonstrates correct substitution [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the final velocity [1 mark]</li> </ul>

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]

Sample Response	The response
$F_A = F_B$ $m_A g \sin \theta = m_B g$ $m_A \times 9.8 \times \sin 35^\circ = 15 \times 9.8$ $5.62m_A = 147$ $m_A = 26$ Mass of object = 26 kg (to two significant figures)	<ul style="list-style-type: none"> <li>• identifies equivalent forces acting parallel to the plane [1 mark]</li> <li>• recognises the scenario relates to tensile force acting on the object on an inclined plane [1 mark]</li> <li>the component of force on the object acting down the plane [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• calculates the mass of the object [1 mark]</li> </ul>

2022  
Paper 2  
Section 1  
Question 7  
  
Gravity and  
motion

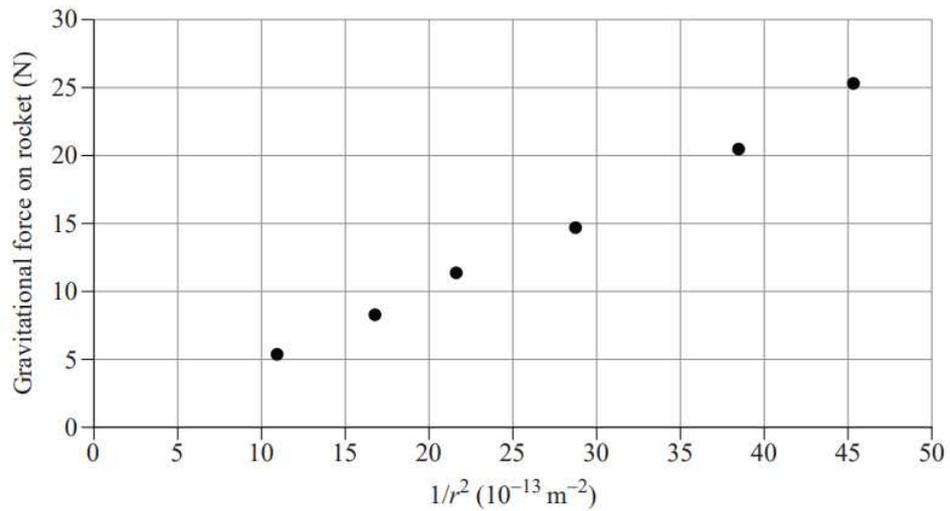
Two asteroids experience a gravitational force of  $3.3 \times 10^3$  N between them. Their masses are  $2.7 \times 10^{17}$  kg and  $6.1 \times 10^{15}$  kg.

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

Sample Response	The response
$F = \frac{GMm}{r^2}$ $3.3 \times 10^3 = \frac{6.67 \times 10^{-11} \times 2.7 \times 10^{17} \times 6.1 \times 10^{15}}{r^2}$ $r = \sqrt{\frac{6.67 \times 10^{-11} \times 2.7 \times 10^{17} \times 6.1 \times 10^{15}}{3.3 \times 10^3}}$ $= 5.8 \times 10^9 \text{ m}$ Distance between asteroids = $5.8 \times 10^9$ m (to two significant figures)	<ul style="list-style-type: none"> <li>• recognises the scenario relates to Newton's Law of Universal Gravitation [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• calculates the distance between the asteroids [1 mark]</li> </ul>

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
<p>Given <math>F = \frac{GMm}{r^2}</math>, gradient = <math>GMm</math></p> $\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{24 - 8}{44 \times 10^{-13} - 16 \times 10^{-13}}$ $= 5.71 \times 10^{12}$ <p>gradient = <math>GMm</math></p> $5.71 \times 10^{12} = 6.67 \times 10^{-11} \times 750M$ $M = \frac{5.71 \times 10^{12}}{6.67 \times 10^{-11} \times 750}$ $= 1.1 \times 10^{20} \text{ kg}$ <p>Mass of asteroid = <math>1.1 \times 10^{20}</math> kg (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to Newton's Law of Universal Gravitation [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the gradient [1 mark]</li> <li>• determines the mass of the asteroid [1 mark]</li> </ul>

<p><b>2022</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Gravity and motion</b></p>	<p>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.</p> <p>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]</p>				
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">v = \frac{2\pi r}{T}</math> <math display="block">= \frac{2\pi \times 0.8}{5 \div 12}</math> <math display="block">= 12.1 \text{ m s}^{-1}</math> <math display="block">a_c = \frac{v^2}{r}</math> <math display="block">= \frac{12.1^2}{0.8}</math> <math display="block">= 180 \text{ m s}^{-2}</math> <p>Centripetal acceleration = 180 m s<sup>-2</sup> (to two significant figures)</p> </td> <td> <ul style="list-style-type: none"> <li>• recognises the scenario relates to velocity in circular motion [1 mark]</li> <li>• centripetal acceleration [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• calculates the centripetal acceleration of the object [1 mark]</li> </ul> </td> </tr> </tbody> </table> <p>b) Calculate the total horizontal displacement for the object after it is released. Show your working. [5 marks]</p>	Sample Response	The response	$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.8}{5 \div 12}$ $= 12.1 \text{ m s}^{-1}$ $a_c = \frac{v^2}{r}$ $= \frac{12.1^2}{0.8}$ $= 180 \text{ m s}^{-2}$ <p>Centripetal acceleration = 180 m s<sup>-2</sup> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to velocity in circular motion [1 mark]</li> <li>• centripetal acceleration [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• calculates the centripetal acceleration of the object [1 mark]</li> </ul>
Sample Response	The response				
$v = \frac{2\pi r}{T}$ $= \frac{2\pi \times 0.8}{5 \div 12}$ $= 12.1 \text{ m s}^{-1}$ $a_c = \frac{v^2}{r}$ $= \frac{12.1^2}{0.8}$ $= 180 \text{ m s}^{-2}$ <p>Centripetal acceleration = 180 m s<sup>-2</sup> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to velocity in circular motion [1 mark]</li> <li>• centripetal acceleration [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• calculates the centripetal acceleration of the object [1 mark]</li> </ul>				
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">s_y = u_y t + \frac{1}{2} a t^2</math> <math display="block">4.3 = 0 + \frac{1}{2} \times 9.8 t^2</math> <math display="block">t = \sqrt{\frac{4.3}{4.9}}</math> <math display="block">= 0.94 \text{ s}</math> <math display="block">s_x = u_x t + \frac{1}{2} a t^2</math> <math display="block">= 12.1 \times 0.94 + \frac{1}{2} \times 0 \times 0.94^2</math> <math display="block">= 11.4 \text{ m}</math> <p>Horizontal displacement = 11 m (to two significant figures)</p> </td> <td> <ul style="list-style-type: none"> <li>• recognises the scenario relates to vertical component of projectile motion [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the time of flight [1 mark]</li> <li>• recognises the scenario relates to the horizontal component of projectile motion [1 mark]</li> <li>• calculates the total horizontal displacement [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	$s_y = u_y t + \frac{1}{2} a t^2$ $4.3 = 0 + \frac{1}{2} \times 9.8 t^2$ $t = \sqrt{\frac{4.3}{4.9}}$ $= 0.94 \text{ s}$ $s_x = u_x t + \frac{1}{2} a t^2$ $= 12.1 \times 0.94 + \frac{1}{2} \times 0 \times 0.94^2$ $= 11.4 \text{ m}$ <p>Horizontal displacement = 11 m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to vertical component of projectile motion [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the time of flight [1 mark]</li> <li>• recognises the scenario relates to the horizontal component of projectile motion [1 mark]</li> <li>• calculates the total horizontal displacement [1 mark]</li> </ul>
Sample Response	The response				
$s_y = u_y t + \frac{1}{2} a t^2$ $4.3 = 0 + \frac{1}{2} \times 9.8 t^2$ $t = \sqrt{\frac{4.3}{4.9}}$ $= 0.94 \text{ s}$ $s_x = u_x t + \frac{1}{2} a t^2$ $= 12.1 \times 0.94 + \frac{1}{2} \times 0 \times 0.94^2$ $= 11.4 \text{ m}$ <p>Horizontal displacement = 11 m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to vertical component of projectile motion [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the time of flight [1 mark]</li> <li>• recognises the scenario relates to the horizontal component of projectile motion [1 mark]</li> <li>• calculates the total horizontal displacement [1 mark]</li> </ul>				

<p><b>2021</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Gravity and motion</b></p>	<p>An object undergoes uniform circular motion in a path with a radius of <math>r</math>.</p> <p>Determine the effect on the radius if the mass of the object is doubled, but the centripetal force and velocity remain unchanged. [3 marks]</p>			
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">F = \frac{mv^2}{r}</math> <p>Let <math>R</math> be the radius of the new path</p> <math display="block">\frac{Mv^2}{r} = \frac{2Mv^2}{R}</math> <math display="block">\frac{1}{r} = \frac{2}{R}</math> <math display="block">R = 2r</math> <p>The radius will double.</p> </td> <td> <ul style="list-style-type: none"> <li>• recognises the scenario relates to uniform circular motion [1 mark]</li> <li>• provides correct reasoning [1 mark]</li> <li>• indicates that the radius will double [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	$F = \frac{mv^2}{r}$ <p>Let <math>R</math> be the radius of the new path</p> $\frac{Mv^2}{r} = \frac{2Mv^2}{R}$ $\frac{1}{r} = \frac{2}{R}$ $R = 2r$ <p>The radius will double.</p>
Sample Response	The response			
$F = \frac{mv^2}{r}$ <p>Let <math>R</math> be the radius of the new path</p> $\frac{Mv^2}{r} = \frac{2Mv^2}{R}$ $\frac{1}{r} = \frac{2}{R}$ $R = 2r$ <p>The radius will double.</p>	<ul style="list-style-type: none"> <li>• recognises the scenario relates to uniform circular motion [1 mark]</li> <li>• provides correct reasoning [1 mark]</li> <li>• indicates that the radius will double [1 mark]</li> </ul>			

**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]

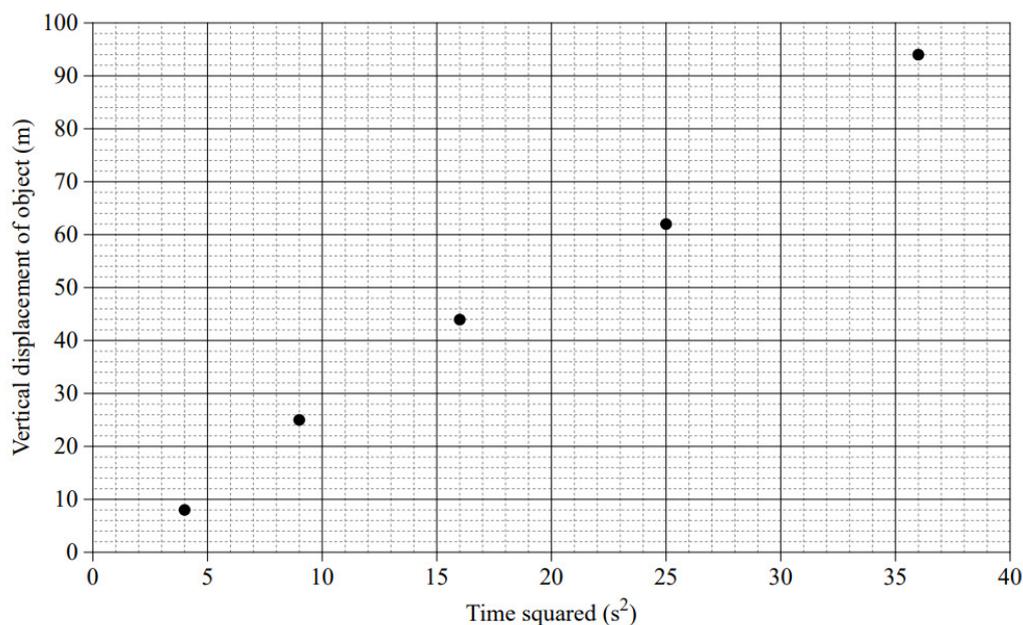
Sample Response	The response	Notes
$F_{g,net} = 0$ Therefore $ F_{g,A}  =  F_{g,B} $ $G \frac{m_s M_A}{r_A^2} = G \frac{m_s M_B}{r_B^2}$ $\frac{4M_B}{r_A^2} = \frac{M_B}{r_B^2}$ $4M_B \times r_B^2 = r_A^2 \times M_B$ $\frac{4M_B \times r_B^2}{M_B} = r_A^2$ $r_A^2 = 4r_B^2$ $r_A = 2r_B$ $120 = r_A + r_B$ $120 = 3r_B$ $r_B = 40$ Distance from Asteroid B = <b>40 km</b> (to the nearest whole number).	<ul style="list-style-type: none"> <li>• recognises the scenario relates to Newton's law of universal gravitation [1 mark]</li> <li>• recognises that no net force occurs when the forces are equivalent [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines distance from the asteroid [1 mark]</li> </ul>	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]

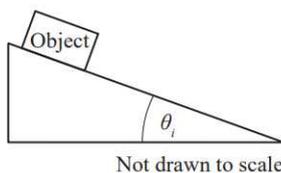
Sample Response	The response	Notes
<p>The mathematical proportionality is <math>s \propto t^2</math></p> <p>intercept = 0</p> <p>gradient = <math>\frac{y_2 - y_1}{x_2 - x_1}</math></p> <p>gradient = <math>\frac{94 - 0}{36 - 0}</math></p> <p>gradient = 2.6</p> <p><math>s = 2.6t^2</math></p>	<ul style="list-style-type: none"> <li>identifies the y-intercept [1 mark]</li> <li>determines the gradient of the graph [1 mark]</li> <li>identifies a mathematical relationship [1 mark]</li> </ul>	<p>For the gradient, accept between 2.5 and 2.7 inclusive.</p>

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

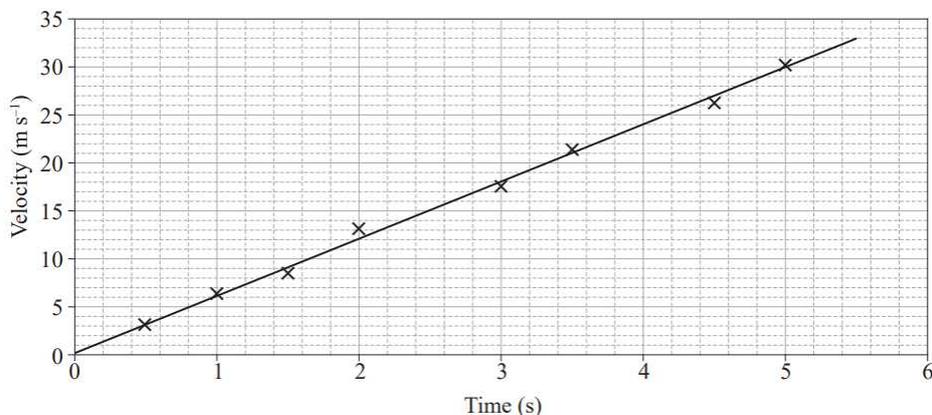
Sample Response	The response	Notes
<p><math>s = ut + \frac{1}{2}at^2</math></p> <p>Therefore <math>2.6t^2 = \frac{1}{2}at^2</math></p> <p>This means that <math>\frac{1}{2}a = 2.6</math></p> <p><math>a = 2 \times 2.6</math></p> <p><math>a = 5.2 \text{ m s}^{-2}</math></p> <p>Acceleration = 5.2 m s<sup>-2</sup> (to 2 significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the gradient can be used to find acceleration due to gravity [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the acceleration due to gravity [1 mark]</li> </ul>	<p>Allow FT error from Question 7a). Do not penalise for incorrect decimal places/significant figures.</p>

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.



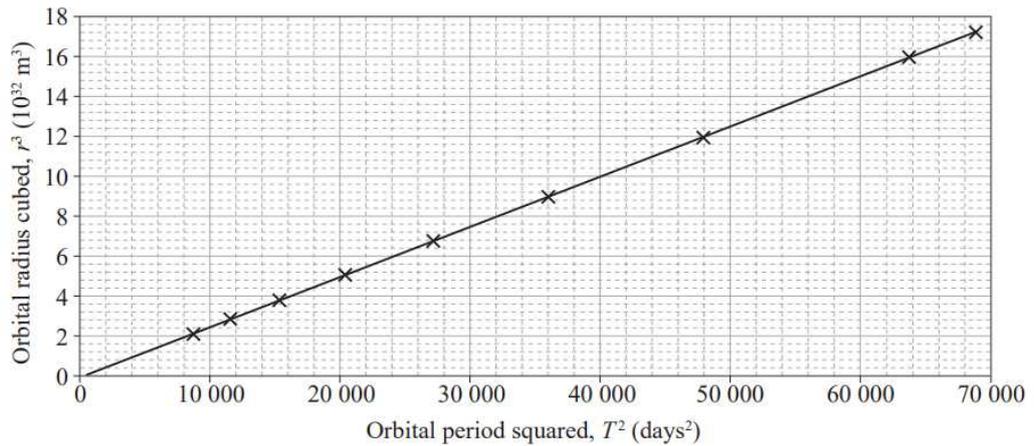
Determine the angle of incline,  $\theta_i$ , of the inclined plane. Show your working

Sample Response	The response	Notes
<p>Gradient of the graph = <math>6 \text{ m s}^{-2}</math> = acceleration                      The component of the acceleration due to gravity down the inclined plane is <math>g \sin \theta</math>                      Therefore  <math>g \sin \theta = 6</math>  <math>\theta_i = \sin^{-1}(6/9.8) = 38^\circ</math></p>	<ul style="list-style-type: none"> <li>arrives at a value for the gradient [1 mark]</li> <li>indicates an understanding of how the acceleration of the object is represented by the gradient of the graph [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed using the gradient value [1 mark]</li> <li>determines angle [1 mark]</li> </ul>	<p>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.</p> <p>In this case:                      Accept values inclusive between <math>37^\circ</math> and <math>38^\circ</math> for the angle.</p> <p>Allow FT error from the gradient value calculated.</p>

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,  $T^2$ .

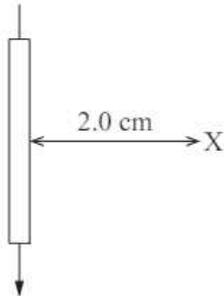


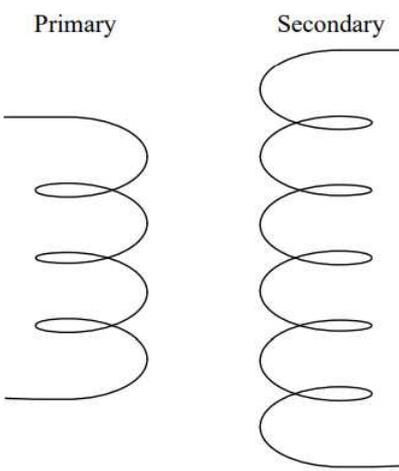
Determine the mass of the star. Show your working. [5 marks]

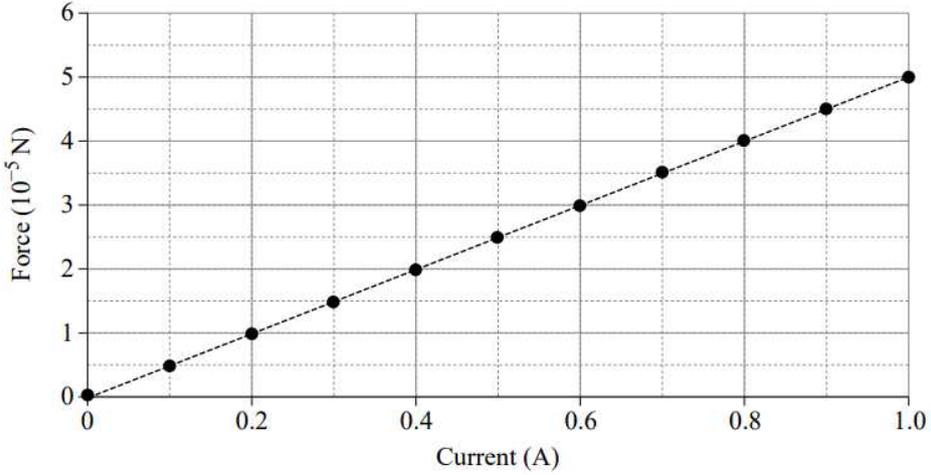
Sample Response	The response	Notes
<p>The gradient of the graph can be used to find <math>\frac{GM}{4\pi^2}</math>.</p> <p>The gradient of the graph can be found using the following two points: (0,0) and (40 000, 12).</p> <p>First, the x values will be converted to seconds<sup>2</sup> (0,0) and (2.985984 x10<sup>14</sup>, 12 x 10<sup>32</sup>).</p> <p>The gradient = 4.02 x 10<sup>18</sup></p> <p>Let the gradient be represented by the pronumeral V.</p> $V = \frac{GM}{4\pi^2}$ $M = \frac{V4\pi^2}{G}$ <p>Mass = 2.4 x 10<sup>30</sup> kg (to 1 decimal place)</p> <p>The gradient of the graph can be used to find <math>\frac{GM}{4\pi^2}</math>.</p> <p>The gradient of the graph can be found using the following two points: (0,0) and (40 000, 12).</p> <p>First, the x values will be converted to seconds<sup>2</sup> (0,0) and (2.985984 x10<sup>14</sup>, 12 x 10<sup>32</sup>).</p> <p>The gradient = 4.02 x 10<sup>18</sup></p> <p>Let the gradient be represented by the pronumeral V.</p> $V = \frac{GM}{4\pi^2}$ $M = \frac{V4\pi^2}{G}$ <p>Mass = 2.4 x 10<sup>30</sup> kg (to 1 decimal place)</p>	<ul style="list-style-type: none"> <li>indicates an understanding that the gradient represents <math>\frac{GM}{4\pi^2}</math> [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed to convert days<sup>2</sup> into seconds<sup>2</sup> [1 mark]</li> <li>arrives at a value for the gradient [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed using the gradient [1 mark]</li> <li>determines the mass [1 mark]</li> </ul>	<p>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.</p> <p>In this case: Accept values for the gradient inclusive between 3.6 x 10<sup>18</sup> and 4.1 x 10<sup>18</sup>. Accept values for the mass inclusive between 2.2 x 10<sup>30</sup> kg and 2.4 x 10<sup>30</sup> kg.</p> <p>Allow FT error for the mass.</p>

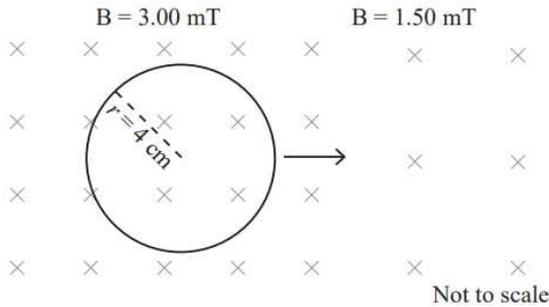
## Unit 3 – Topic 2: Electromagnetism

### Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b>  <b>Electromag.</b>	<p>A current-carrying wire is shown.</p>  <p>Not to scale <math>I = 0.5 \text{ A}</math></p> <p>Determine the magnetic field strength at X.</p> <p>(A) <math>5 \times 10^{-6} \text{ T}</math> out of the page (B) <math>5 \times 10^{-6} \text{ T}</math> into the page (C) <math>5 \times 10^{-8} \text{ T}</math> out of the page (D) <math>5 \times 10^{-8} \text{ T}</math> into the page</p>
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b>  <b>Electromag.</b>	<p>A magnet is passed through a solenoid comprising five turns and a cross-sectional area of <math>0.60 \text{ m}^2</math> to produce an EMF of <math>0.75 \text{ V}</math>.</p> <p>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.</p> <p>(A) <math>0.89 \text{ V}</math> (B) <math>1.1 \text{ V}</math> (C) <math>4.0 \text{ V}</math> (D) <math>4.5 \text{ V}</math></p>
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b>  <b>Electromag.</b>	<p>Coulomb's law describes the observation that</p> <p>(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.</p>
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b>  <b>Electromag.</b>	<p>A magnet moving through a coil of wire will induce a current with a magnetic field</p> <p>(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.</p>
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b>  <b>Electromag.</b>	<p>Calculate the electric field strength experienced at a distance of <math>2.8 \times 10^{-11} \text{ m}</math> from the centre of a helium nucleus.</p> <p>(A) <math>1.0 \times 10^2 \text{ N C}^{-1}</math> (B) <math>2.0 \times 10^2 \text{ N C}^{-1}</math> (C) <math>3.7 \times 10^{12} \text{ N C}^{-1}</math> (D) <math>7.3 \times 10^{12} \text{ N C}^{-1}</math></p>

<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b> <b>Electromag.</b></p>	<p><i>Electromotive force</i> is</p> <p>(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</p>
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b> <b>Electromag.</b></p>	<p>Which change would produce the greatest increase in magnetic field strength inside a current-carrying solenoid?</p> <p>(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</p>
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b> <b>Electromag.</b></p>	<p><i>Electric field strength</i> refers to the</p> <p>(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.</p>
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b> <b>Electromag.</b></p>	<p>A rectangular coil of 3000 turns and dimensions <math>0.1 \text{ m} \times 0.2 \text{ m}</math> is rotated in a uniform magnetic field of 2 mT.</p> <p>Calculate the minimum number of revolutions per second required to produce an average EMF of 6 V.</p> <p>(A) 1          (B) 3          (C) 13          (D) 50</p>
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 18</b> <b>Electromag.</b></p>	<p>The primary and secondary coils from a lossless transformer are shown.</p> <div style="text-align: center;">  </div> <p>Compared to the primary coil, the secondary coil will experience decreased</p> <p>(A) power.          (B) current.          (C) voltage.          (D) resistance.</p>

<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b></p> <p><b>Electromag.</b></p>	<p>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.</p> <p>The gradient of the line of best fit is proportional to the</p>  <p>(A) potential difference. (B) electromotive force. (C) resistance of the wire. (D) magnetic field strength.</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Electromag.</b></p>	<p>Electromagnetic radiation is</p> <p>(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.</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 14</b></p> <p><b>Electromag.</b></p>	<p>Moving electric charges in a magnetic field experience</p> <p>(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.</p>
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b></p> <p><b>Electromag.</b></p>	<p>Electrical potential energy is the</p> <p>(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.</p>

<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Electromag.</b></p>	<p>The diagram shows a current-carrying loop moving from one magnetic field to another magnetic field in 0.600 seconds.</p> <div style="text-align: center;">  <p style="text-align: center;">B = 3.00 mT                      B = 1.50 mT</p> <p style="text-align: right;">Not to scale</p> </div> <p>Calculate the magnitude of the EMF produced in the current-carrying loop.</p> <p>(A) <math>1.26 \times 10^{-6}</math> V  (B) <math>1.26 \times 10^{-5}</math> V  (C) <math>1.26 \times 10^{-1}</math> V  (D) <math>1.26 \times 10^2</math> V</p>
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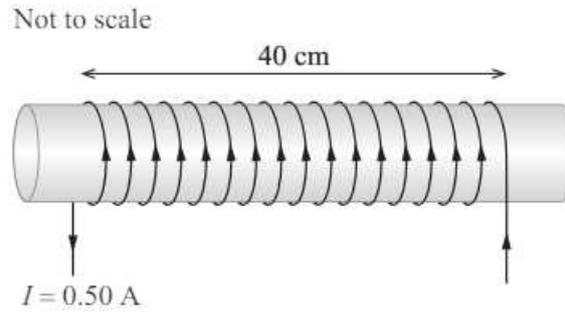
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b></p> <p><b>Electromag.</b></p>	<p>Which of the following is Lenz's Law?</p> <p>(A) The total electric charge of an isolated system remains constant regardless of changes within the system.  (B) The magnetic flux around a current-carrying 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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b></p> <p><b>Electromag.</b></p>	<p>The definition of <i>magnetic field</i> is</p> <p>(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.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b></p> <p><b>Electromag.</b></p>	<p>A solenoid with 24 loops of wire produces an EMF of 36 V during a magnetic flux change of 0.3 Wb.</p> <p>Calculate the period during which the magnetic flux varied.</p> <p>(A) 0.2 s  (B) 0.5 s  (C) 2.2 s  (D) 5.0 s</p>
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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)

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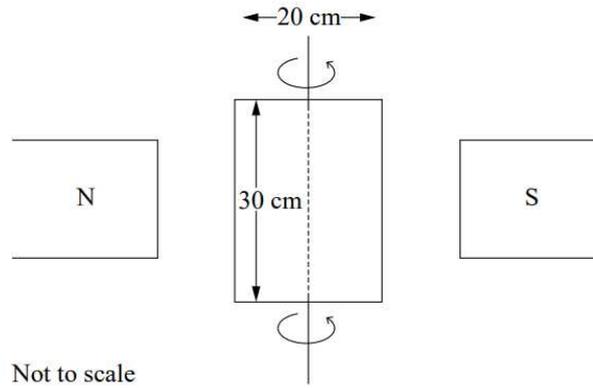
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Magnitude = \_\_\_\_\_ T (to two significant figures)

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  $60^\circ$  around the vertical axis. Show your working. [3 marks]

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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]

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<b>2021</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 21</b>  <b>Electromag.</b>	Explain how transformers work in terms of Faraday’s law and electromagnetic induction. [3 marks] <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/>
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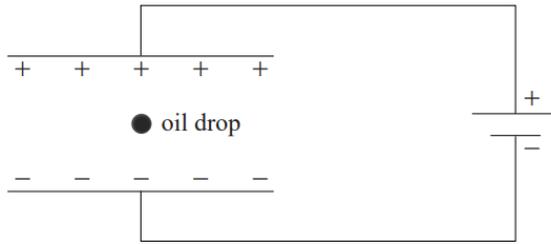

	$r = \text{_____ m (to two significant figures)}$



2022  
Paper 2  
Section 1  
Question 3

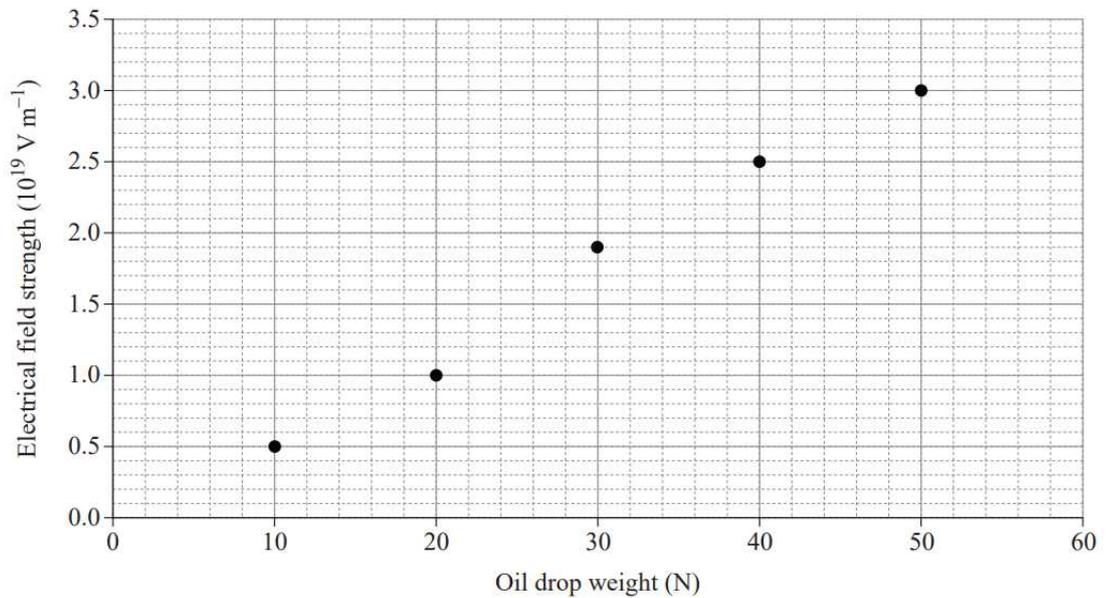
Electromag.

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]

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Average charge = \_\_\_\_\_ C (to two significant figures)

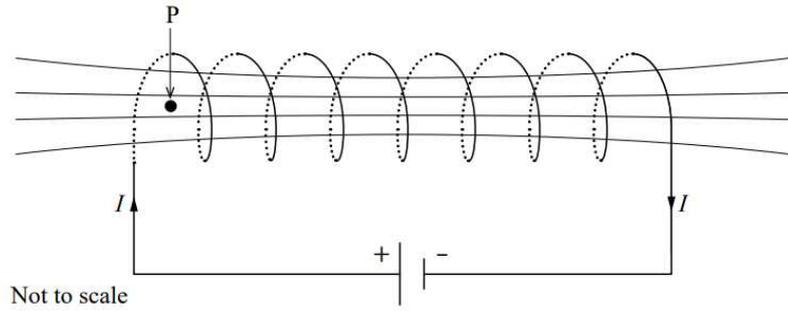
<p><b>2021 Paper 2 Section 1 Question 1</b></p> <p><b>Electromag.</b></p>	<p>Another oil drop was suspended between the plates with an electric field strength of <math>2.0 \times 10^{19} \text{ V m}^{-1}</math>.</p> <p>b) Determine the work done to move this oil drop a distance of 5 mm towards the negatively charged plate. Show your working. [4 marks]</p>
	<div style="border: 1px solid black; width: fit-content; margin: 0 auto; padding: 5px;">             Work done = _____ J (to two significant figures)           </div>

<p><b>2021 Paper 2 Section 1 Question 1</b></p> <p><b>Electromag.</b></p>	<p>A charge of <math>2.8 \times 10^{-7} \text{ C}</math> experiences an electrostatic force of <math>5.2 \times 10^{-1} \text{ N}</math> when placed near a charge of <math>3.2 \times 10^{-7} \text{ C}</math>.</p> <p>Calculate the distance between the two charges. [3 marks]</p>
	<div style="border: 1px solid black; width: fit-content; margin: 0 auto; padding: 5px;">             Distance = _____ m (to 2 significant figures)           </div>



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  $300 \mu\text{T}$  at Point P. [3 marks]

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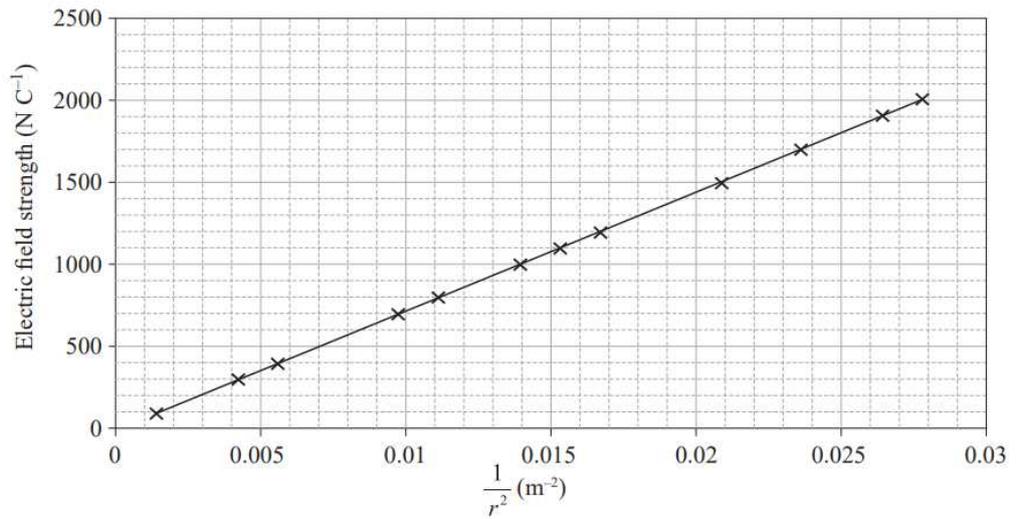
b) Determine the direction of the magnetic field produced by the solenoid. [1 mark]

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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]

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

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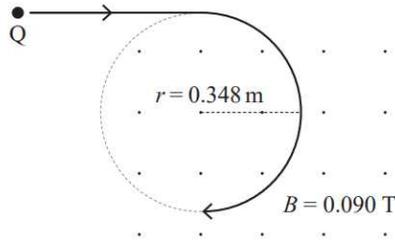
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Charge = \_\_\_\_\_ C (to 1 decimal place)



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  $1.5 \times 10^6 \text{ m s}^{-1}$ . 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	$-1.60 \times 10^{-19}$	$9.11 \times 10^{-31}$
2	$+1.60 \times 10^{-19}$	$9.11 \times 10^{-31}$
3	$+1.60 \times 10^{-19}$	$1.67 \times 10^{-27}$
4	$+1.60 \times 10^{-19}$	$3.34 \times 10^{-27}$
5	$-1.60 \times 10^{-19}$	$3.34 \times 10^{-27}$

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

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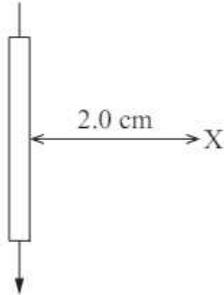
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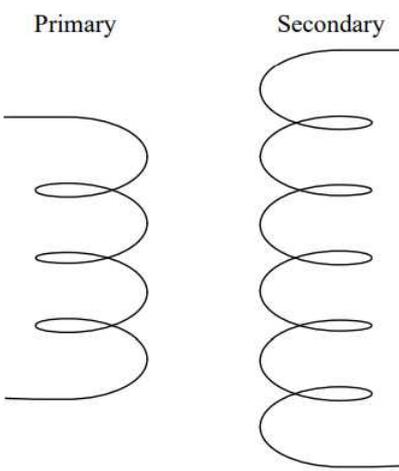


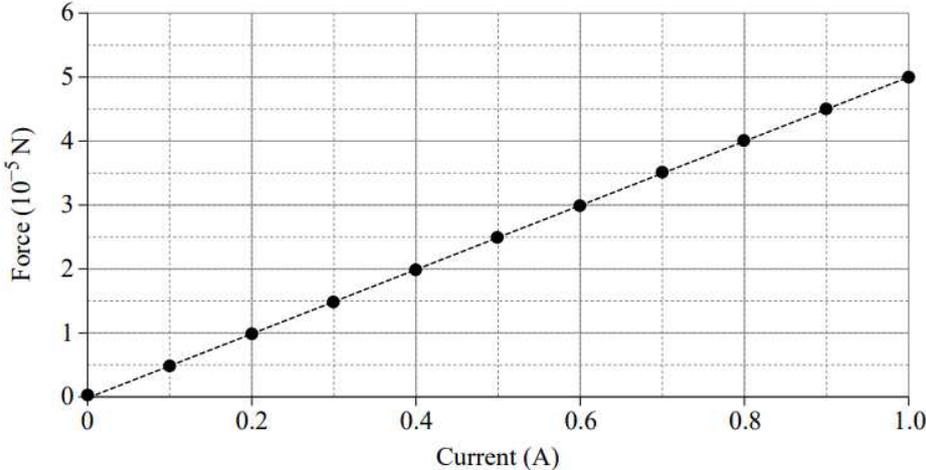
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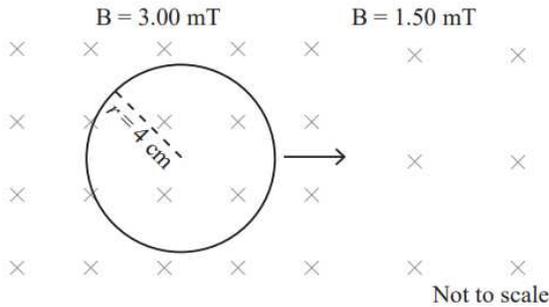
Particle Q = \_\_\_\_\_

**Marking Guide – Paper 1 Section 1**

<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Electromag.</b></p>	<p>A current-carrying wire is shown.</p>  <p style="text-align: center;">Not to scale <math>I = 0.5 \text{ A}</math></p> <p>Determine the magnetic field strength at X.</p> <p>(A) <math>5 \times 10^{-6} \text{ T}</math> out of the page – <b>Answer</b>            (B) <math>5 \times 10^{-6} \text{ T}</math> into the page            (C) <math>5 \times 10^{-8} \text{ T}</math> out of the page            (D) <math>5 \times 10^{-8} \text{ T}</math> into the page</p>
<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Electromag.</b></p>	<p>A magnet is passed through a solenoid comprising five turns and a cross-sectional area of <math>0.60 \text{ m}^2</math> to produce an EMF of <math>0.75 \text{ V}</math>.</p> <p>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.</p> <p>(A) <math>0.89 \text{ V}</math>  <b>(B) <math>1.1 \text{ V}</math> – Answer</b>            (C) <math>4.0 \text{ V}</math>            (D) <math>4.5 \text{ V}</math></p>
<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b></p> <p><b>Electromag.</b></p>	<p>Coulomb’s law describes the observation that</p> <p>(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.  <b>(D) like electric charges repel one another. – Answer</b></p>
<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b></p> <p><b>Electromag.</b></p>	<p>A magnet moving through a coil of wire will induce a current with a magnetic field</p> <p>(A) parallel to the electric field.  <b>(B) opposite in direction to the change in flux. – Answer</b>            (C) inversely proportional to the electromotive force.            (D) that will continue to fluctuate once the magnet is removed.</p>
<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b></p> <p><b>Electromag.</b></p>	<p>Calculate the electric field strength experienced at a distance of <math>2.8 \times 10^{-11} \text{ m}</math> from the centre of a helium nucleus.</p> <p>(A) <math>1.0 \times 10^2 \text{ N C}^{-1}</math>            (B) <math>2.0 \times 10^2 \text{ N C}^{-1}</math>  <b>(C) <math>3.7 \times 10^{12} \text{ N C}^{-1}</math> – Answer</b>            (D) <math>7.3 \times 10^{12} \text{ N C}^{-1}</math></p>

<p>2022 Paper 1 Section 1 Question 1 Electromag.</p>	<p><i>Electromotive force</i> is</p> <p>(A) the production of voltage across an electrical conductor due to its dynamic interaction with a magnetic field.  <b>(B) a difference in potential that tends to give rise to an electric current. – Answer</b>  (C) the repulsion experienced by two negatively charged particles.  (D) one of the four fundamental forces</p>
<p>2022 Paper 1 Section 1 Question 7 Electromag.</p>	<p>Which change would produce the greatest increase in magnetic field strength inside a current-carrying solenoid?</p> <p>(A) decreasing the thickness of the wire  (B) increasing the length of the solenoid  <b>(C) adding more turns of wire to the solenoid – Answer</b>  (D) using an alternating current instead of a direct current</p>
<p>2022 Paper 1 Section 1 Question 10 Electromag.</p>	<p><i>Electric field strength</i> refers to the</p> <p><b>(A) intensity of an electric field at a particular location. – Answer</b>  (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.</p>
<p>2022 Paper 1 Section 1 Question 13 Electromag.</p>	<p>A rectangular coil of 3000 turns and dimensions <math>0.1\text{ m} \times 0.2\text{ m}</math> is rotated in a uniform magnetic field of 2 mT.</p> <p>Calculate the minimum number of revolutions per second required to produce an average EMF of 6 V.</p> <p>(A) 1  (B) 3  <b>(C) 13 – Answer</b>  (D) 50</p>
<p>2022 Paper 1 Section 1 Question 18 Electromag.</p>	<p>The primary and secondary coils from a lossless transformer are shown.</p> <div style="text-align: center;">  </div> <p>Compared to the primary coil, the secondary coil will experience decreased</p> <p>(A) power.  <b>(B) current. – Answer</b>  (C) voltage.  (D) resistance.</p>

<p>2022 Paper 1 Section 1 Question 19</p> <p>Electromag.</p>	<p>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.</p> <p>The gradient of the line of best fit is proportional to the</p>  <p>(A) potential difference. (B) electromotive force. (C) resistance of the wire. <b>(D) magnetic field strength. – Answer</b></p>
<p>2021 Paper 1 Section 1 Question 6</p> <p>Electromag.</p>	<p>Electromagnetic radiation is</p> <p>(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. <b>(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</b></p>
<p>2021 Paper 1 Section 1 Question 14</p> <p>Electromag.</p>	<p>Moving electric charges in a magnetic field experience</p> <p>(A) a decrease in charge. (B) an increase in charge. (C) a force parallel to the direction of the magnetic field. <b>(D) a force perpendicular to the direction of the magnetic field. – Answer</b></p>
<p>2021 Paper 1 Section 1 Question 17</p> <p>Electromag.</p>	<p>Electrical potential energy is the</p> <p>(A) intensity of an electric field at a particular location. (B) difference in potential that tends to give rise to an electric current. <b>(C) capacity of electric charge carriers to do work due to their position in an electric circuit. – Answer</b> (D) work done on an electron in accelerating it through an electrical potential difference of one volt.</p>

<p>2020 Paper 1 Section 1 Question 4</p> <p>Electromag.</p>	<p>The diagram shows a current-carrying loop moving from one magnetic field to another magnetic field in 0.600 seconds.</p>  <p>Calculate the magnitude of the EMF produced in the current-carrying loop.</p> <p>(A) <math>1.26 \times 10^{-6}</math> V  <b>(B) <math>1.26 \times 10^{-5}</math> V – Answer</b>  (C) <math>1.26 \times 10^{-1}</math> V  (D) <math>1.26 \times 10^2</math> V</p>
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<p>2020 Paper 1 Section 1 Question 5</p> <p>Electromag.</p>	<p>Which of the following is Lenz's Law?</p> <p>(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.  <b>(C) The direction of an induced electric current always opposes the change in the circuit or magnetic field that produces it. – Answer</b>  (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.</p>
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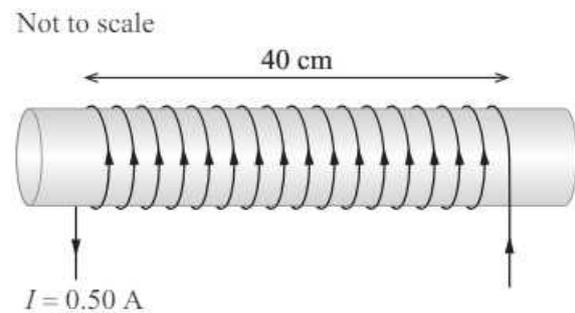
<p>2020 Paper 1 Section 1 Question 17</p> <p>Electromag.</p>	<p>The definition of <i>magnetic field</i> is</p> <p>(A) a region of space through which the total magnetic flux is measured.  (B) a region of space surrounding a body in which another body experiences a force of attraction.  (C) a region of space around an electrically charged particle or object within which a force would be exerted on other electrically charged particles or objects.  <b>(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</b></p>
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<p>2020 Paper 1 Section 1 Question 19</p> <p>Electromag.</p>	<p>A solenoid with 24 loops of wire produces an EMF of 36 V during a magnetic flux change of 0.3 Wb.</p> <p>Calculate the period during which the magnetic flux varied.</p> <p>(A) <b>0.2 s – Answer</b>  (B) 0.5 s  (C) 2.2 s  (D) 5.0 s</p>
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Marking Guide – Paper 1 Section 2

**2023**  
**Paper 1**  
**Section 2**  
**Question 24**  
**Electromag.**

A solenoid consisting of 1240 turns is shown.

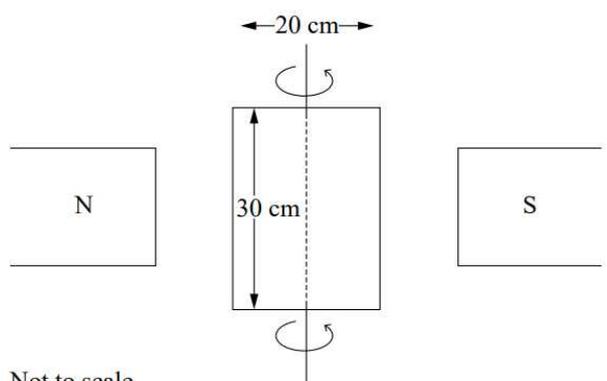


Determine the magnitude and direction of the magnetic field inside the solenoid. Show your working. (4 marks)

Sample response	The response
$n = \frac{1240}{0.4} = 3100 \text{ m}^{-1}$ $B = \mu_0 n I$ $= 4\pi \times 10^{-7} \times 3100 \times 0.5$ $= 0.0019 \text{ T}$ <p>Magnitude = 0.0019 T (to two significant figures) Direction = to the left</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to a magnetic field inside a solenoid [1 mark]</li> <li>calculates the number of turns per metre [1 mark]</li> <li>calculates the magnitude of the magnetic field [1 mark]</li> <li>identifies the direction of the magnetic field [1 mark]</li> </ul>

**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]

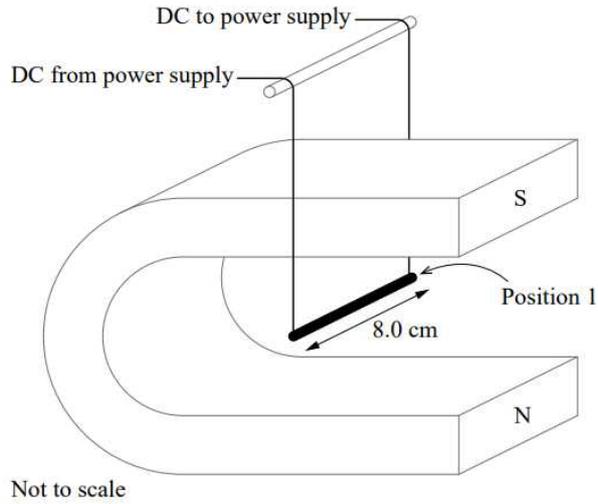
Sample Response	The response
<p>If loop is rotated 60°, angle of the loop perpendicular to the magnetic field is 90° – 60° = 30°</p> $\phi = BA \cos \theta$ $= 5 \times 10^{-3} \times 0.06 \times \cos 30^\circ$ $= 2.6 \times 10^{-4} \text{ Wb}$ <p>Change in flux = 2.6 × 10<sup>-4</sup> Wb (to two significant figures)</p>	<ul style="list-style-type: none"> <li>identifies the angle of the loop perpendicular to the magnetic field [1 mark]</li> <li>recognises the scenario relates to the amount of magnetic flux passing through an area [1 mark]</li> <li>calculates the change in flux [1 mark]</li> </ul>

<b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 25</b>  <b>Electromag.</b>	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.	<ul style="list-style-type: none"> <li>• describes the production of an induced magnetic field [1 mark]</li> <li>• describes formation of an induced electric field, perpendicular to the magnetic field [1 mark]</li> </ul>

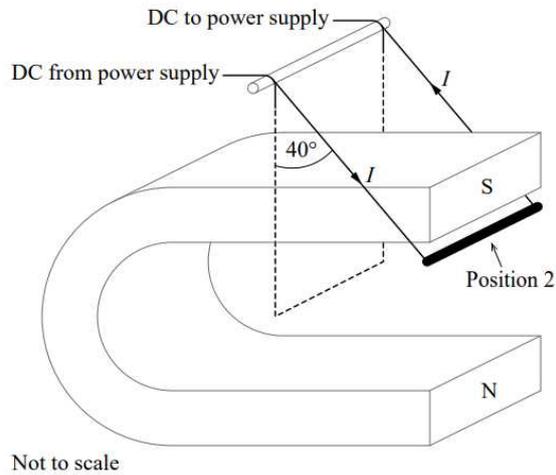
<b>2021</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 21</b>  <b>Electromag.</b>	Explain how transformers work in terms of Faraday's law and electromagnetic induction. [3 marks]		
	Sample Response	The response	Notes
	Alternating current passing through the first coil creates a magnetic flux. This magnetic 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.	<ul style="list-style-type: none"> <li>• recognises that alternating current creates a changing magnetic flux [1 mark]</li> <li>• recognises that EMF is induced in the second coil by the changing magnetic flux in the first coil [1 mark]</li> <li>• identifies that the induced EMF is proportional to the number of coils and the rate of change of magnetic flux [1 mark]</li> </ul>	For <i>magnetic flux</i> , accept <i>magnetic field</i> or <i>electromagnetic field</i> .

2021  
Paper 1  
Section 2  
Question 23  
Electromag.

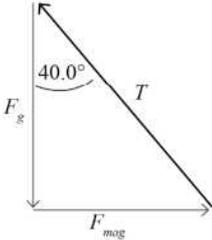
The diagram shows a metal rod with a mass of 10.0 g and a length of 8.0 cm suspended in a uniform magnetic field of 0.50 T. There is no electric current through the metal rod when it is in Position 1.



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

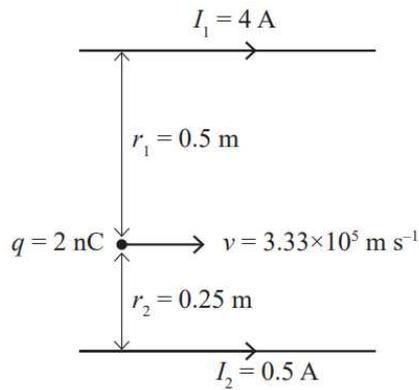


Determine the magnitude of the current required to move the metal rod into Position 2. [5 marks]

Sample Response	The response	Notes
<p>There are three forces acting on the wire and they are balanced, forming a vector triangle.</p>  <p>From the vector triangle:</p> $\tan \theta = \frac{F_{mag}}{F_g}$ <p>Therefore <math>F_{mag} = F_g \tan \theta</math></p> <p>Therefore <math>F_{mag} = mg \tan 40^\circ</math></p> <p>Sub in magnetic force formula on the left-hand side:</p> $BIL \sin \theta = mg \tan 40^\circ$ <p>The magnetic field is at right angles to the current:</p> $BIL \sin 90^\circ = mg \tan 40^\circ$ <p>Since <math>\sin 90^\circ = 1</math>, rearranging</p> $I = \frac{mg \tan 40^\circ}{BL}$ $I = \frac{(0.0100)(9.8) \tan 40^\circ}{(0.50)(0.080)}$ $I = 2.055\,794 \dots$ <p>Current = 2.1 A (to 1 decimal place)</p>	<ul style="list-style-type: none"> <li>• identifies the forces acting on the wire in the magnetic field [1 mark]</li> <li>• recognises that the force of gravity and the force of the magnetic field can be added to determine tension [1 mark]</li> <li>• identifies an equation for the relationship between <math>F_g</math> and <math>F_{mag}</math> [1 mark]</li> <li>• provides appropriate mathematical reasoning [1 mark]</li> <li>• determines the magnitude of the current [1 mark]</li> </ul>	<p>Allow FT marks due to error/s in prior working.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

2020  
Paper 1  
Section 2  
Question 28  
Electromag.

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



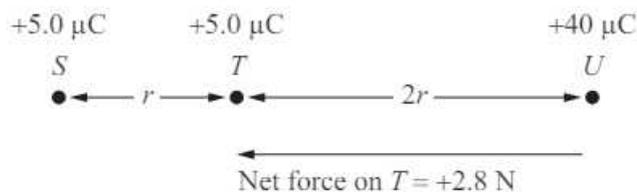
Calculate the magnitude of the magnetic force acting on the charged particle. [4 marks]

Sample Response	The response	Notes
$B_1 = \frac{\mu_0 I_1}{2\pi r_1} = 1.6 \times 10^{-6} \text{ T}$ $B_2 = \frac{\mu_0 I_2}{2\pi r_2} = 4 \times 10^{-7} \text{ T}$ The magnetic fields are going in different directions, so working out the difference gives an overall magnetic field of $B = 1.2 \times 10^{-6} \text{ T}$ The force on a moving charge in a magnetic field is given by $F = qvB \sin \theta$ 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 = $7.99 \times 10^{-10} \text{ N}$	<ul style="list-style-type: none"> <li>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]</li> <li>provides pertinent mathematical operation/s correctly performed to determine net magnetic field strength [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed [1 mark]</li> <li>determines the force on the charge [1 mark]</li> </ul>	Accept values inclusive between $7.99 \times 10^{-10} \text{ N}$ and $8 \times 10^{-10} \text{ N}$ .  Allow FT error for the magnetic field strength.  Do not penalise for incorrect decimal places/significant figures.

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
$E = \frac{F}{q}$ $= \frac{2.8}{5 \times 10^{-6}}$ $= 5.6 \times 10^5 \text{ N C}^{-1}$ <p>Electric field strength = <math>5.6 \times 10^5 \text{ N C}^{-1}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to force acting on a point within an electric field [1 mark]</li> <li>calculates the electric field strength at T [1 mark]</li> </ul>

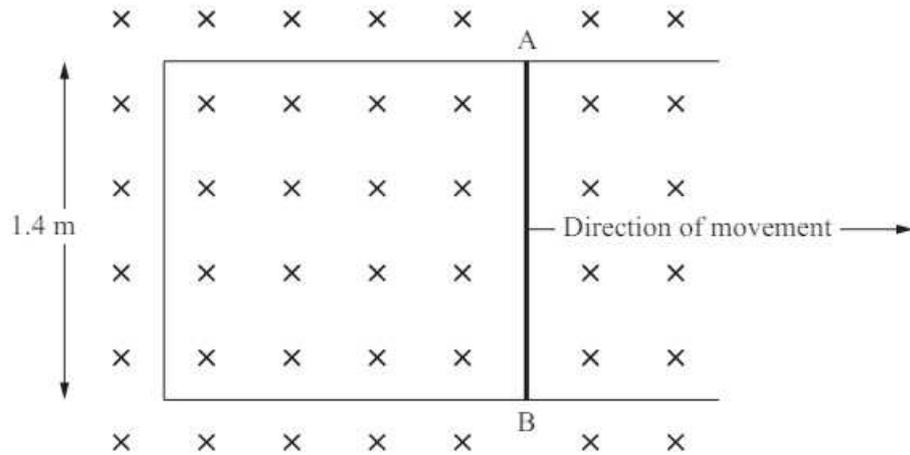
b) Determine the value of  $r$ . Show your working. [6 marks]

Sample response	The response
Using force Force between charges S and T: $F_{ST} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$ $= 9 \times 10^9 \times \frac{5 \times 10^{-6} \times 5 \times 10^{-6}}{r^2}$ $= \frac{0.225}{r^2}$	<ul style="list-style-type: none"> <li>recognises the scenario relates to forces between charges [1 mark]</li> </ul>
Force between charges T and U: $F_{TU} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$ $= 9 \times 10^9 \times \frac{5 \times 10^{-6} \times 40 \times 10^{-6}}{(2r)^2}$ $= \frac{1.8}{4r^2}$ $= \frac{0.45}{r^2}$	<ul style="list-style-type: none"> <li>identifies the relationship between force and distance for                             <ul style="list-style-type: none"> <li>charges S and T [1 mark]</li> <li>charges T and U [1 mark]</li> </ul> </li> </ul>
Equating the forces: $ F_{net}  =  F_{ST} - F_{TU} $ $ 2.8  = \left  \frac{0.225}{r^2} - \frac{0.45}{r^2} \right $ $r^2 = \left  \frac{-0.225}{2.8} \right $ $r = 0.28 \text{ m}$ <p><math>r = 0.28 \text{ m}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>identifies the vector relationship between forces [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> </ul>
	<ul style="list-style-type: none"> <li>calculates the value of <math>r</math> [1 mark]</li> </ul>

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  $40 \text{ m s}^{-1}$ , creating an induced EMF of  $23 \mu\text{V}$ .



Not to scale

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

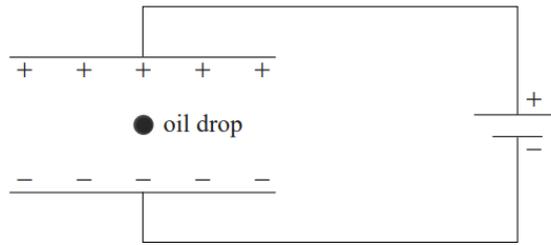
Sample response	The response
<p>The induced current is a result of the changing area of the enclosed loop.</p> $\Delta A = \Delta lw = wv\Delta t$ <p>Therefore:</p> $emf = -n \frac{\Delta(BA_{\perp})}{\Delta t}$ $emf = -1 \times \frac{Bwv\Delta t}{\Delta t}$ $23 \times 10^{-6} = -B \times 1.4 \times 40$ $B = \frac{23 \times 10^{-6}}{1.4 \times 40}$ $= 4.1 \times 10^{-7} \text{ T}$ <p>Magnetic field strength = <math>4.1 \times 10^{-7} \text{ T}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to Faraday's law and changing area [1 mark]</li> <li>identifies relationship for the change in area over time [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the magnitude of the magnetic field strength [1 mark]</li> </ul>

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

Sample response	The response
<p>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.</p>	<ul style="list-style-type: none"> <li>concludes the direction of the induced current in the loop is anticlockwise [1 mark]</li> <li>justifies the conclusion using Lenz's law [1 mark]</li> </ul>

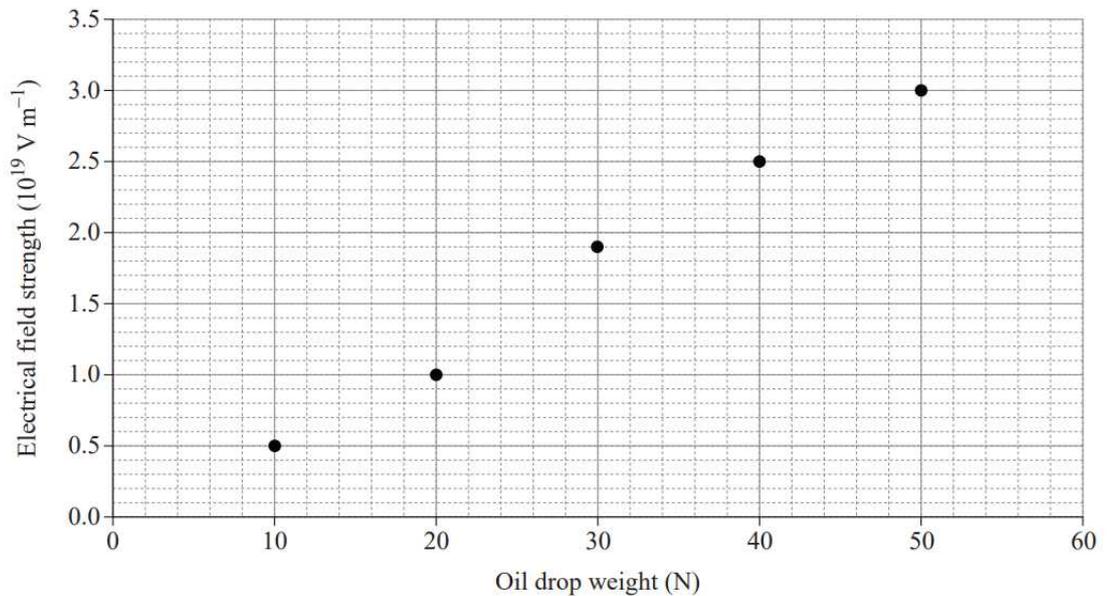
2022  
Paper 2  
Section 1  
Question 3  
Electromag.

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
<p>Since <math>E = \frac{F}{q}</math>, gradient of graph is equivalent to <math>\frac{1}{q}</math></p> $\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$ $= \frac{2.8 \times 10^{19} - 1.0 \times 10^{19}}{46 - 18}$ $= 6.43 \times 10^{17}$ $q = \frac{1}{6.43 \times 10^{17}}$ $= 1.6 \times 10^{-18}$ <p>Charge of electron = <math>1.6 \times 10^{-18} \text{ C}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to electric field strength and electron charge [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the gradient [1 mark]</li> <li>determines the average charge on the oil drops [1 mark]</li> </ul>

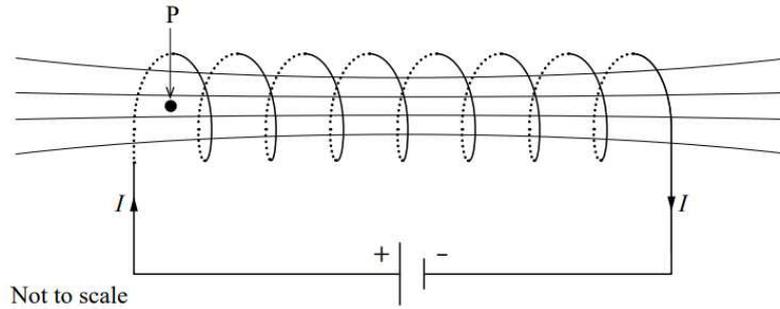
	Another oil drop was suspended between the plates with an electric field strength of $2.0 \times 10^{19} \text{ V m}^{-1}$ .				
	b) Determine the work done to move this oil drop a distance of 5 mm towards the negatively charged plate. Show your working. [4 marks]				
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td>           From the graph:  <math>F_g = 33 \text{ N}</math>  <math>\Delta U = W = F_s</math>  <math>= 33 \times 0.005</math>  <math>= 1.7 \times 10^{-1}</math>            Work done = 0.17 J (to two significant figures)         </td> <td> <ul style="list-style-type: none"> <li>determines the weight of the oil drop [1 mark]</li> <li>recognises the scenario relates to the work done in an electric field [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>determines the work done [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	From the graph: $F_g = 33 \text{ N}$ $\Delta U = W = F_s$ $= 33 \times 0.005$ $= 1.7 \times 10^{-1}$ Work done = 0.17 J (to two significant figures)	<ul style="list-style-type: none"> <li>determines the weight of the oil drop [1 mark]</li> <li>recognises the scenario relates to the work done in an electric field [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>determines the work done [1 mark]</li> </ul>
Sample Response	The response				
From the graph: $F_g = 33 \text{ N}$ $\Delta U = W = F_s$ $= 33 \times 0.005$ $= 1.7 \times 10^{-1}$ Work done = 0.17 J (to two significant figures)	<ul style="list-style-type: none"> <li>determines the weight of the oil drop [1 mark]</li> <li>recognises the scenario relates to the work done in an electric field [1 mark]</li> <li>demonstrates correct substitution [1 mark]</li> <li>determines the work done [1 mark]</li> </ul>				

<b>2021</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b>  <b>Electromag.</b>	A charge of $2.8 \times 10^{-7} \text{ C}$ experiences an electrostatic force of $5.2 \times 10^{-1} \text{ N}$ when placed near a charge of $3.2 \times 10^{-7} \text{ C}$ .						
	Calculate the distance between the two charges. [3 marks]						
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td> <math display="block">F = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}</math> <math display="block">r^2 = \frac{1}{4\pi\epsilon_0} \frac{Qq}{F}</math> <math display="block">r = \sqrt{\frac{1}{4\pi\epsilon_0} \frac{Qq}{F}}</math> <math display="block">= \sqrt{9 \times 10^9 \times \frac{2.8 \times 10^{-7} \times 3.2 \times 10^{-7}}{0.52}}</math>           Distance = 0.039 m (to 2 significant figures)         </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to Coulomb's law [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the distance [1 mark]</li> </ul> </td> <td>Do not penalise for incorrect decimal places/significant figures.</td> </tr> </tbody> </table>	Sample Response	The response	Notes	$F = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$ $r^2 = \frac{1}{4\pi\epsilon_0} \frac{Qq}{F}$ $r = \sqrt{\frac{1}{4\pi\epsilon_0} \frac{Qq}{F}}$ $= \sqrt{9 \times 10^9 \times \frac{2.8 \times 10^{-7} \times 3.2 \times 10^{-7}}{0.52}}$ Distance = 0.039 m (to 2 significant figures)	<ul style="list-style-type: none"> <li>recognises the scenario relates to Coulomb's law [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the distance [1 mark]</li> </ul>	Do not penalise for incorrect decimal places/significant figures.
Sample Response	The response	Notes					
$F = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$ $r^2 = \frac{1}{4\pi\epsilon_0} \frac{Qq}{F}$ $r = \sqrt{\frac{1}{4\pi\epsilon_0} \frac{Qq}{F}}$ $= \sqrt{9 \times 10^9 \times \frac{2.8 \times 10^{-7} \times 3.2 \times 10^{-7}}{0.52}}$ Distance = 0.039 m (to 2 significant figures)	<ul style="list-style-type: none"> <li>recognises the scenario relates to Coulomb's law [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the distance [1 mark]</li> </ul>	Do not penalise for incorrect decimal places/significant figures.					

<b>2021</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 5</b>  <b>Electromag.</b>	An alpha particle with a charge of $+3.2 \times 10^{-19} \text{ C}$ 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]						
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td>           The change in potential energy of an electric charge moving through an electric field is equivalent to the work done on the charge.  <math display="block">V = \frac{\Delta U}{q}</math> <math display="block">\Delta U = Vq</math> <math display="block">= 240 \times 3.2 \times 10^{-19}</math> <math display="block">= 7.68 \times 10^{-17} \text{ J} = W</math>             The work done on an object is equal to the change in kinetic energy.  <math display="block">E_k = \frac{1}{2}mv^2</math> <math display="block">7.68 \times 10^{-17} = \frac{1}{2} \times 6.64 \times 10^{-27} \times v^2</math> <math display="block">v^2 = \frac{7.68 \times 10^{-17}}{\frac{1}{2} \times 6.64 \times 10^{-27}}</math> <math display="block">v = \sqrt{\frac{7.68 \times 10^{-17}}{\frac{1}{2} \times 6.64 \times 10^{-27}}}</math>           Velocity = <math>1.5 \times 10^5 \text{ m s}^{-1}</math> (to 2 significant figures)         </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to work done on a moving charge in an electric field [1 mark]</li> <li>identifies that work done on the charge equates to its kinetic energy [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the velocity [1 mark]</li> </ul> </td> <td>           Allow FT marks due to error/s in prior working.             Do not penalise for incorrect decimal places/significant figures.         </td> </tr> </tbody> </table>	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. $V = \frac{\Delta U}{q}$ $\Delta U = Vq$ $= 240 \times 3.2 \times 10^{-19}$ $= 7.68 \times 10^{-17} \text{ J} = W$  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 = $1.5 \times 10^5 \text{ m s}^{-1}$ (to 2 significant figures)	<ul style="list-style-type: none"> <li>recognises the scenario relates to work done on a moving charge in an electric field [1 mark]</li> <li>identifies that work done on the charge equates to its kinetic energy [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the velocity [1 mark]</li> </ul>	Allow FT marks due to error/s in prior working.  Do not penalise for incorrect decimal places/significant figures.
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. $V = \frac{\Delta U}{q}$ $\Delta U = Vq$ $= 240 \times 3.2 \times 10^{-19}$ $= 7.68 \times 10^{-17} \text{ J} = W$  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 = $1.5 \times 10^5 \text{ m s}^{-1}$ (to 2 significant figures)	<ul style="list-style-type: none"> <li>recognises the scenario relates to work done on a moving charge in an electric field [1 mark]</li> <li>identifies that work done on the charge equates to its kinetic energy [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>determines the velocity [1 mark]</li> </ul>	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  $300 \mu\text{T}$  at Point P. [3 marks]

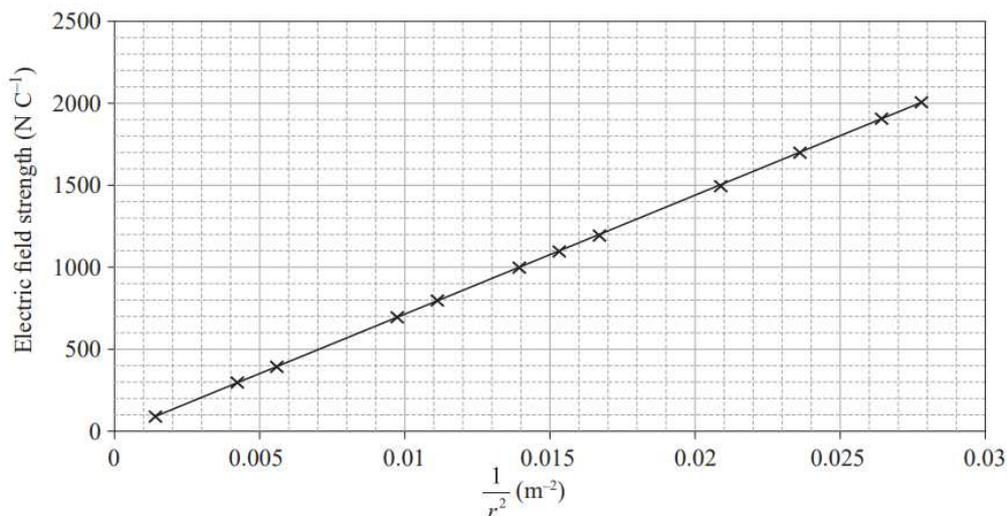
Sample Response	The response
$B = \mu_0 n I$ $n = \frac{B}{\mu_0 I}$ $n = \frac{300 \times 10^{-6}}{4\pi \times 10^{-7} \times 2} = 119 \text{ turns m}^{-1}$	<ul style="list-style-type: none"> <li>recognises the scenario relates to the magnetic field produced inside a solenoid [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the number of turns [1 mark]</li> </ul>

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

Sample Response	The response	Notes
Left to right	<ul style="list-style-type: none"> <li>determines the field goes from left to right [1 mark]</li> </ul>	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
$c = 0$ $m = \frac{2000 - 0}{0.0278 - 0} = 72\,000$ $E = 72\,000\left(\frac{1}{r^2}\right)$	<ul style="list-style-type: none"> <li>provides a correct value for the y-intercept [1 mark]</li> <li>provides a correct value for the gradient of the graph [1 mark]</li> <li>provides the equation [1 mark]</li> </ul>	<p>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:</p> <p>Accept values for the y-intercept between 50 NC<sup>-1</sup> and -50 NC<sup>-1</sup> inclusive.</p> <p>Accept values for the gradient between 70 000 and 72 500 inclusive.</p> <p>Allow FT error for the equation.</p>

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
$(E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2})$ equate the gradient to $kq$ . $q = 72\,000 / 9 \times 10^9 \text{ C} = 8 \times 10^{-6} \text{ C}$ Charge = $8.0 \times 10^{-6} \text{ C}$	<ul style="list-style-type: none"> <li>indicates an understanding of the physical scenario in relation to the gradient being used to find the charge [1 mark]</li> <li>provides pertinent mathematical operations correctly performed [1 mark]</li> <li>determines the charge [1 mark]</li> </ul>	<p>Allow FT error from part a).</p> <p>Allow FT error for the charge.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

**2020  
Paper 2  
Section 1  
Question 5**

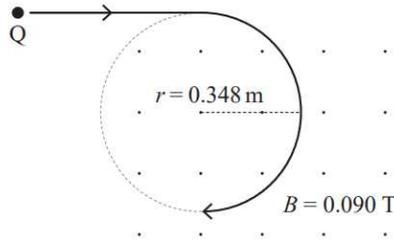
**Electromag.**

An electron is situated halfway between two nuclei that are separated from each other by a distance of  $4.5 \times 10^{-10}$  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
$F_2 = \frac{1}{4\pi\epsilon_0} \frac{Q_1 \times q_e}{r_1^2}$ $= 9 \times 10^9 \times \frac{3(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 1.3 \times 10^{-8} \text{N}$ $F_1 = \frac{1}{4\pi\epsilon_0} \frac{Q_2 \times q_e}{r_2^2}$ $= 9 \times 10^9 \times \frac{2(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 9.0 \times 10^{-9} \text{N}$ $ F_{net}  =  F_1  -  F_2 $ $= 1.4 \times 10^{-8} - 9.1 \times 10^{-9}$ <p>Force = <math>4.0 \times 10^{-9}</math> N (to 1 decimal place)</p>	<ul style="list-style-type: none"> <li>• indicates an understanding of the physical scenario in relation to Coulomb's law [1 mark]</li> <li>• provides pertinent mathematical operation/s correctly performed [1 mark]</li> <li>• determines the forces (or electric field strength) imposed by each nuclei on the electron [1 mark]</li> <li>• determines the correct net force [1 mark]</li> </ul>	<p>An understanding of the physical scenario of Coulomb's law may include:</p> <ul style="list-style-type: none"> <li>- the electron experiences two forces due to the two charges ...</li> </ul> <p>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.</p> <p>In this case: Accept values inclusive between: <math>1.3 \times 10^{-8}</math> N and <math>1.4 \times 10^{-8}</math> N for F2 <math>9.0 \times 10^{-9}</math> N and <math>9.1 \times 10^{-9}</math> N for F1.</p> <p>Allow FT error for all force calculations.</p>

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  $1.5 \times 10^6 \text{ m s}^{-1}$ . 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	$-1.60 \times 10^{-19}$	$9.11 \times 10^{-31}$
2	$+1.60 \times 10^{-19}$	$9.11 \times 10^{-31}$
3	$+1.60 \times 10^{-19}$	$1.67 \times 10^{-27}$
4	$+1.60 \times 10^{-19}$	$3.34 \times 10^{-27}$
5	$-1.60 \times 10^{-19}$	$3.34 \times 10^{-27}$

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

Sample Response	The response	Notes
<p>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.</p> $F_{mag} = F_{circular}$ $qvB \sin \theta = \frac{mv^2}{r}$ <p>Particle enters perpendicularly, therefore <math>\sin \theta = \sin 90^\circ = 1</math></p> $qvB = \frac{mv^2}{r}$ $m = \frac{qBr}{v}$ $m = \frac{(1.60 \times 10^{-19})(0.090)(3.48 \times 10^{-1})}{1.50 \times 10^6}$ $m = 3.34 \times 10^{-27} \text{ kg}$ <p>Therefore, Particle Q must be Particle 4.</p>	<ul style="list-style-type: none"> <li>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]</li> <li>provides pertinent mathematical operations correctly performed [1 mark]</li> <li>determines the mass [1 mark]</li> <li>identifies the correct particle using the mass and the charge of the particle [1 mark]</li> </ul>	<p>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:</p> <p>Accept answers inclusive between <math>3.33 \times 10^{-27} \text{ kg}</math> and <math>3.35 \times 10^{-27} \text{ kg}</math>.</p>

## Unit 4 Revolutions in modern physics

### Unit 4 – Topic 1: Special relativity

#### Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b>  <b>Special relativity</b>	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.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b>  <b>Special relativity</b>	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.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b>  <b>Special relativity</b>	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.
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b>  <b>Special relativity</b>	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.
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b>  <b>Special relativity</b>	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) $E = \frac{1}{2}mv^2$
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>Special relativity</b>	<i>Proper length</i> 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.

<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b></p> <p><b>Special relativity</b></p>	<p>A spaceship with a velocity of <math>9.0 \times 10^7 \text{ m s}^{-1}</math> is measured to be 125 m in length by an observer at rest.</p> <p>Calculate the length of the spaceship as measured by somebody on board the spaceship.</p> <p>(A) 119 m (B) 131 m (C) 137 m (D) 178 m</p>
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Special relativity</b></p>	<p>The definition of <i>relativistic momentum</i> is the</p> <p>(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.</p>
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b></p> <p><b>Special relativity</b></p>	<p>According to the theory of special relativity, the concept of <i>simultaneity</i> is best described as</p> <p>(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.</p>

**Paper 1 Section 2**

<p><b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 25</b></p> <p><b>Special relativity</b></p>	<p>An observer who is stationary relative to a moving spaceship measures the velocity of the spaceship to be <math>2.0 \times 10^8 \text{ m s}^{-1}</math>.</p> <p>Calculate the length of the spaceship if the observer records it as 18 m. Show your working. (3 marks)</p> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <div data-bbox="523 674 1254 775" style="border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"><p>Length = _____ m (to two significant figures)</p></div>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 23</b></p> <p><b>Special relativity</b></p>	<p>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.</p> <p>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]</p> <hr/>
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**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]

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Time = \_\_\_\_\_ years (to 1 decimal place)

**Paper 2 Section 1**

<p><b>2023</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Special relativity</b></p>	<p>Describe the effects of relativistic travel on an object. (3 marks)</p> <hr/>
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<p><b>2022</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Special relativity</b></p>	<p>Two spaceports are stationary relative to each other.</p> <p>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.</p> <p>Astronaut B is at a stationary position equally distant relative to each spaceport and observes the lights turn off one after the other.</p> <p>Explain why the astronauts view these events differently. [2 marks]</p> <hr/>
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<p><b>2020</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Special relativity</b></p>	<p>Explain why an object with mass cannot travel at the speed of light in a vacuum. [1 mark]</p> <hr/> <hr/> <hr/> <hr/> <hr/>
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## Marking Guide – Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b>  <b>Special relativity</b>	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. <b>(C) the object will gain infinite momentum. – Answer</b> (D) the inertia of the object will decrease.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b>  <b>Special relativity</b>	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. <b>(D) be shorter than the tunnel. – Answer</b>
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 17</b>  <b>Special relativity</b>	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. <b>(C) experiences time differently relative to the detector. – Answer</b> (D) cannot be accurately observed at relativistic speeds.
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b>  <b>Special relativity</b>	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. <b>(D) an observer. – Answer</b>
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b>  <b>Special relativity</b>	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) $E = \frac{1}{2}mv^2$  <b>Answer is A.</b>
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>Special relativity</b>	<i>Proper length</i> 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.

<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 19</b></p> <p><b>Special relativity</b></p>	<p>A spaceship with a velocity of <math>9.0 \times 10^7 \text{ m s}^{-1}</math> is measured to be 125 m in length by an observer at rest.</p> <p>Calculate the length of the spaceship as measured by somebody on board the spaceship.</p> <p>(A) 119 m <b>(B) 131 m – Answer</b> (C) 137 m (D) 178 m</p>
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Special relativity</b></p>	<p>The definition of <i>relativistic momentum</i> is the</p> <p>(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. <b>(C) momentum of an object when measured in the frame of reference in which the object is in motion. – Answer</b> (D) momentum of an object when measured in the frame of reference in which the object is stationary.</p>
<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 16</b></p> <p><b>Special relativity</b></p>	<p>According to the theory of special relativity, the concept of <i>simultaneity</i> is best described as</p> <p>(A) when two events occur at the same time. (B) when an observer sees two events occurring at the same time. <b>(C) two events observed to happen at the same time in a particular frame of reference. – Answer</b> (D) the relation between two events assumed to happen at the same time when observed from any frame of reference.</p>

Marking Guide – Paper 1 Section 2

<p><b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 25</b></p> <p><b>Special relativity</b></p>	<p>An observer who is stationary relative to a moving spaceship measures the velocity of the spaceship to be <math>2.0 \times 10^8 \text{ m s}^{-1}</math>.</p> <p>Calculate the length of the spaceship if the observer records it as 18 m. Show your working. (3 marks)</p>			
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <math display="block">L = L_0 \sqrt{1 - \frac{v^2}{c^2}}</math> <math display="block">18 = L_0 \sqrt{1 - \frac{(2.0 \times 10^8)^2}{(3.0 \times 10^8)^2}}</math> <math display="block">L_0 = 24 \text{ m}</math> <p>Length = 24 m (to two significant figures)</p> </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to an object experiencing length contraction [1 mark]</li> <li>correctly substitutes for relativistic length [1 mark]</li> <li>calculates the length of the spaceship [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$ $18 = L_0 \sqrt{1 - \frac{(2.0 \times 10^8)^2}{(3.0 \times 10^8)^2}}$ $L_0 = 24 \text{ m}$ <p>Length = 24 m (to two significant figures)</p>
Sample response	The response			
$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$ $18 = L_0 \sqrt{1 - \frac{(2.0 \times 10^8)^2}{(3.0 \times 10^8)^2}}$ $L_0 = 24 \text{ m}$ <p>Length = 24 m (to two significant figures)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to an object experiencing length contraction [1 mark]</li> <li>correctly substitutes for relativistic length [1 mark]</li> <li>calculates the length of the spaceship [1 mark]</li> </ul>			

<p><b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 23</b></p> <p><b>Special relativity</b></p>	<p>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.</p> <p>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]</p>						
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td rowspan="2"> <p>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.</p> </td> <td> <p>[2 marks]</p> <ul style="list-style-type: none"> <li>provides an explanation of why the twins will no longer be the same age</li> <li>supports the explanation using the theory of special relativity</li> <li>provides a conclusion about the respective ages of the twins that indicates an understanding of the twin paradox</li> </ul> </td> <td rowspan="2"> <p>Support using the theory of special relativity may include:</p> <ul style="list-style-type: none"> <li>the concept of time dilation/length contraction</li> <li>relevant calculations.</li> </ul> </td> </tr> <tr> <td> <p>[1 mark]</p> <ul style="list-style-type: none"> <li>provides an explanation of why the twins will no longer be the same age</li> <li>supports the explanation using the theory of special relativity</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>provides an explanation of why the twins will no longer be the same age</li> <li>provides a conclusion about the respective ages of the twins that indicates an understanding of special relativity</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	Notes	<p>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.</p>	<p>[2 marks]</p> <ul style="list-style-type: none"> <li>provides an explanation of why the twins will no longer be the same age</li> <li>supports the explanation using the theory of special relativity</li> <li>provides a conclusion about the respective ages of the twins that indicates an understanding of the twin paradox</li> </ul>	<p>Support using the theory of special relativity may include:</p> <ul style="list-style-type: none"> <li>the concept of time dilation/length contraction</li> <li>relevant calculations.</li> </ul>
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**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
$t = \frac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}}$ $4.0 = \frac{t_o}{\sqrt{1 - \frac{(0.90c)^2}{c^2}}}$ $t_o = 1.7 \text{ years}$ <p>Time = 1.7 years (to 1 decimal place)</p>	<ul style="list-style-type: none"> <li>• indicates an understanding of the physical scenario in relation to time dilation, or other relevant physical concept/s [1 mark]</li> <li>• indicates an understanding that the time provided in the question represents relativistic time [1 mark]</li> <li>• provides pertinent mathematical operation/s correctly performed [1 mark]</li> <li>• determines the time [1 mark]</li> </ul>	<p>Only two marks can be awarded if the response confuses proper time and relativistic time.</p> <p>Accept answers between 1.7 years and 1.8 years inclusive.</p> <p>Do not penalise for incorrect decimal places/significant figures.</p>

**Marking Guide – Paper 2 Section 1**

<b>2023</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b>  <b>Special relativity</b>	Describe the effects of relativistic travel on an object. (3 marks)				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>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.</p> <p>Finally, an object moving at relativistic speeds would be observed to decrease in length in the direction of its travel.</p> </td> <td> <ul style="list-style-type: none"> <li>describes the effect of                             <ul style="list-style-type: none"> <li>time dilation [1 mark]</li> <li>length contraction [1 mark]</li> <li>relativistic momentum [1 mark]</li> </ul> </li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>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.</p> <p>Finally, an object moving at relativistic speeds would be observed to decrease in length in the direction of its travel.</p>	<ul style="list-style-type: none"> <li>describes the effect of                             <ul style="list-style-type: none"> <li>time dilation [1 mark]</li> <li>length contraction [1 mark]</li> <li>relativistic momentum [1 mark]</li> </ul> </li> </ul>
Sample response	The response				
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<b>2022</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b>  <b>Special relativity</b>	Two spaceports are stationary relative to each other.					
	<p>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.</p> <p>Astronaut B is at a stationary position equally distant relative to each spaceport and observes the lights turn off one after the other.</p> <p>Explain why the astronauts view these events differently. [2 marks]</p>					
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>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.</p> </td> <td> <ul style="list-style-type: none"> <li>explains simultaneity from the perspective of astronaut A [1 mark]</li> <li>explains the loss of simultaneity for astronaut B [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	<p>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.</p>	<ul style="list-style-type: none"> <li>explains simultaneity from the perspective of astronaut A [1 mark]</li> <li>explains the loss of simultaneity for astronaut B [1 mark]</li> </ul>	
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<b>2020</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 1</b>  <b>Special relativity</b>	Explain why an object with mass cannot travel at the speed of light in a vacuum. [1 mark]							
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td> <p>An object with mass cannot travel at the speed of light because as its velocity approaches <math>1c</math>, its momentum approaches infinity.</p> </td> <td> <ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the object's momentum approaches infinity [1 mark]</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the energy required to accelerate the object approaches infinity [1 mark]</li> </ul> </td> <td> <ul style="list-style-type: none"> <li>Equivalent statements may include:                             <ul style="list-style-type: none"> <li>as velocity approaches <math>c</math></li> <li>...</li> </ul> </li> <li>No mark is to be awarded if the response only indicates that the object's mass increases to infinity.</li> <li>Equivalent mathematical explanations are acceptable, e.g.  <math display="block">E_r = \sqrt{(m_0c^2)^2 + (pc)^2}</math> </li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	Notes	<p>An object with mass cannot travel at the speed of light because as its velocity approaches <math>1c</math>, its momentum approaches infinity.</p>	<ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the object's momentum approaches infinity [1 mark]</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the energy required to accelerate the object approaches infinity [1 mark]</li> </ul>	<ul style="list-style-type: none"> <li>Equivalent statements may include:                             <ul style="list-style-type: none"> <li>as velocity approaches <math>c</math></li> <li>...</li> </ul> </li> <li>No mark is to be awarded if the response only indicates that the object's mass increases to infinity.</li> <li>Equivalent mathematical explanations are acceptable, e.g.  <math display="block">E_r = \sqrt{(m_0c^2)^2 + (pc)^2}</math> </li> </ul>	
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<p>An object with mass cannot travel at the speed of light because as its velocity approaches <math>1c</math>, its momentum approaches infinity.</p>	<ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the object's momentum approaches infinity [1 mark]</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>states that as velocity approaches the speed of light (or equivalent), the energy required to accelerate the object approaches infinity [1 mark]</li> </ul>	<ul style="list-style-type: none"> <li>Equivalent statements may include:                             <ul style="list-style-type: none"> <li>as velocity approaches <math>c</math></li> <li>...</li> </ul> </li> <li>No mark is to be awarded if the response only indicates that the object's mass increases to infinity.</li> <li>Equivalent mathematical explanations are acceptable, e.g.  <math display="block">E_r = \sqrt{(m_0c^2)^2 + (pc)^2}</math> </li> </ul>						

## Unit 4 – Topic 2: Quantum theory

### Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b>  <b>Quantum theory</b>	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.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>Quantum theory</b>	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.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b>  <b>Quantum theory</b>	Incident light with a frequency of $1.70 \times 10^{15}$ Hz is shone onto a metal surface with a work function of $1.00 \times 10^{-18}$ J.  Determine the kinetic energy of a photoelectron ejected from the metal surface.  (A) $7.9 \times 10^{-1}$ eV (B) $1.7 \times 10^{-15}$ eV (C) $1.3 \times 10^{-19}$ eV (D) $2.0 \times 10^{-38}$ eV
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>Quantum theory</b>	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) $6.3 \times 10^{14}$ Hz (B) $2.1 \times 10^6$ Hz (C) $4.8 \times 10^{-7}$ Hz (D) $1.6 \times 10^{-15}$ Hz
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 20</b>  <b>Quantum theory</b>	The energy level diagram for a simple atom is shown.  <p>Not to scale</p> What transition is allowed for an electron that absorbs a photon with a frequency of $6.3 \times 10^{14}$ Hz?  (A) $n = 1$ to $n = 3$ (B) $n = 1$ to $n = 4$ (C) $n = 2$ to $n = 3$ (D) $n = 3$ to $n = 4$

<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b>  <b>Quantum theory</b>	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
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b>  <b>Quantum theory</b>	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.
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b>  <b>Quantum theory</b>	Determine the wavelength of an electromagnetic wave with an energy of $2.4 \times 10^{-23}$ J. (A) $7.2 \times 10^{-15}$ m (B) $2.8 \times 10^{-11}$ m (C) $8.3 \times 10^{-3}$ m (D) $1.2 \times 10^2$ m
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 11</b>  <b>Quantum theory</b>	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.
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b>  <b>Quantum theory</b>	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
<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 20</b>  <b>Quantum theory</b>	A photoelectron with a kinetic energy of $2.5 \times 10^{-19}$ J is ejected when a photon with a frequency of $1.3 \times 10^{15}$ Hz is incident on the metal plate. Calculate the threshold frequency of light required to eject the photoelectron from the metal plate. (A) $6.1 \times 10^{-19}$ Hz (B) $3.7 \times 10^{14}$ Hz (C) $9.2 \times 10^{14}$ Hz (D) $1.7 \times 10^{15}$ Hz
<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b>  <b>Quantum theory</b>	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.

<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b>  <b>Quantum</b> <b>theory</b>	<p>The Rutherford atomic model describes an atom</p> <p>(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.</p>
<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 20</b>  <b>Quantum</b> <b>theory</b>	<p>Calculate the frequency of light that would be required to eject a photoelectron at a velocity of <math>1.90 \times 10^6 \text{ m s}^{-1}</math> from a metal plate with a work function of 4.73 eV.</p> <p>(A) <math>1.14 \times 10^{15} \text{ Hz}</math>  (B) <math>1.34 \times 10^{15} \text{ Hz}</math>  (C) <math>2.48 \times 10^{15} \text{ Hz}</math>  (D) <math>3.62 \times 10^{15} \text{ Hz}</math></p>

**Paper 1 Section 2**

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

<b>2023 Paper 1 Section 2 Question 26</b>  <b>Quantum theory</b>	Calculate the energy (in electron volts) of a photon with a wavelength of 405 nm. Show your working. (4 marks)
	<div style="border: 1px solid black; padding: 10px; width: fit-content; margin: 0 auto;">Energy = _____ eV (to three significant figures)</div>

**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]

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**2022  
Paper 1  
Section 2  
Question 23**

**Quantum theory**

The diagram shows the electron energy levels for hydrogen.

	Ionisation	
n = 6	_____	-0.38 eV
n = 5	_____	-0.54 eV
n = 4	_____	-0.85 eV
n = 3	_____	-1.51 eV
n = 2	_____	-3.40 eV
n = 1	_____	-13.60 eV
	Ground level	

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

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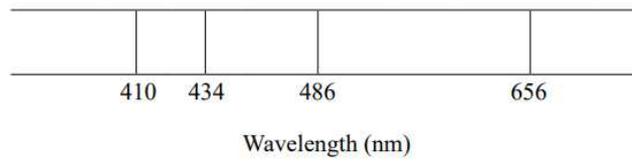
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Energy released = \_\_\_\_\_ J (to three significant figures)

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]

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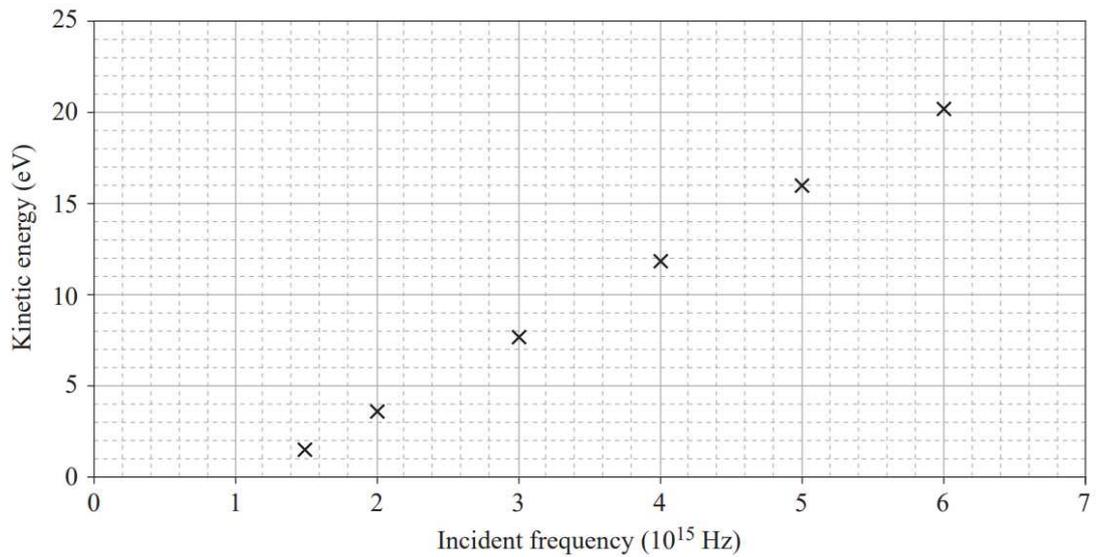


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**2020  
Paper 1  
Section 2  
Question 26**

**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]

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Metal = \_\_\_\_\_

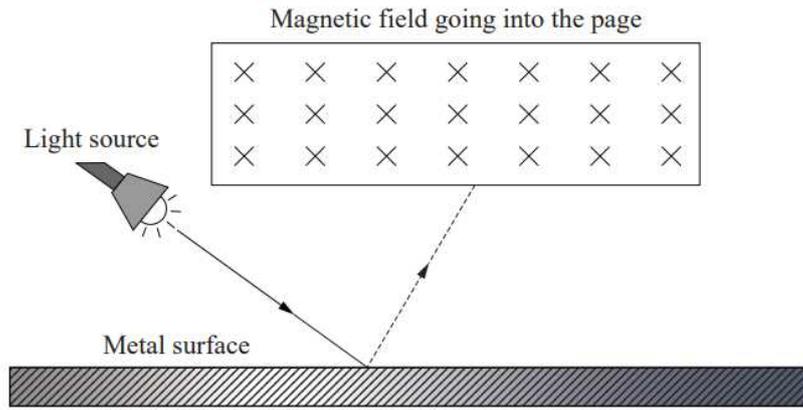






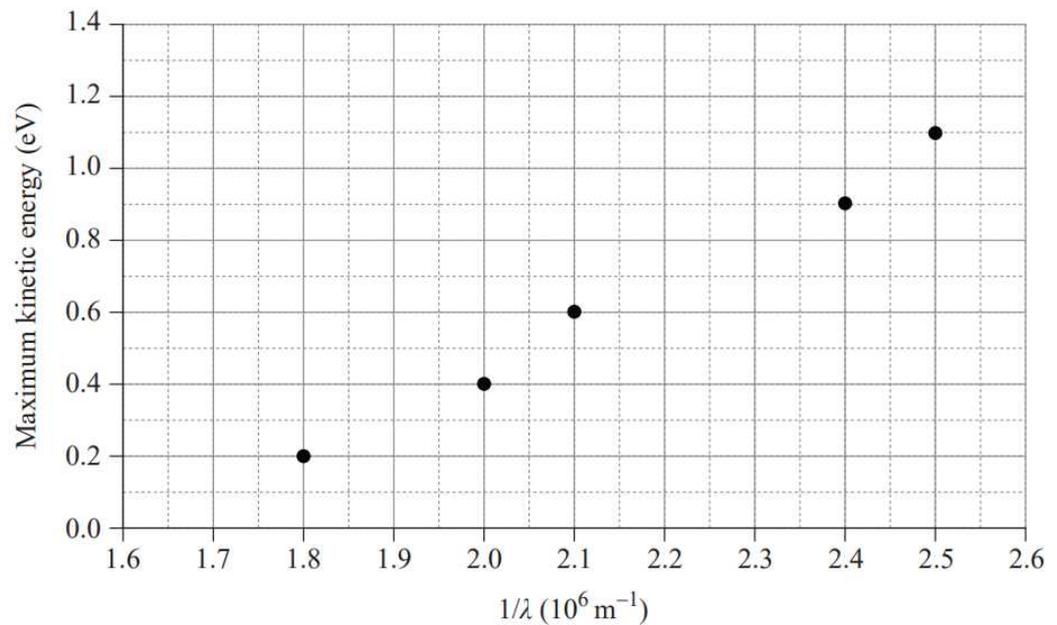

2022  
Paper 2  
Section 1  
Question 6  
  
Quantum  
theory

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]

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]

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Work function = \_\_\_\_\_ J (to two significant figures)

c) If the strength of the magnetic field is  $5 \mu\text{T}$ , 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)



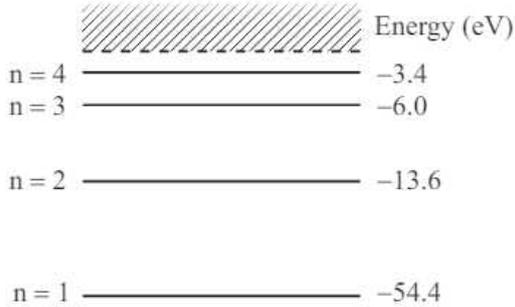




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<b>2020 Paper 2 Section 1 Question 7  Quantum theory</b>	<p>A photoelectric effect experiment is conducted by shining different frequencies of light on a sample of aluminium. The kinetic energy of the ejected photoelectrons was measured. The data is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

<p>2023 Paper 1 Section 1 Question 2</p> <p>Quantum theory</p>	<p>Photons are</p> <p>(A) <b>gauge bosons that exhibit wave characteristics.</b> – Answer (B) particles that can only travel in a medium. (C) mediators of the weak nuclear force. (D) leptons with no charge.</p>
<p>2023 Paper 1 Section 1 Question 5</p> <p>Quantum theory</p>	<p>Young’s double slit experiment demonstrates that light</p> <p>(A) behaves differently in different frames of reference. (B) <b>shares characteristics with mechanical waves.</b> – Answer (C) is a longitudinal wave. (D) acts like a particle.</p>
<p>2023 Paper 1 Section 1 Question 8</p> <p>Quantum theory</p>	<p>Incident light with a frequency of <math>1.70 \times 10^{15}</math> Hz is shone onto a metal surface with a work function of <math>1.00 \times 10^{-18}</math> J.</p> <p>Determine the kinetic energy of a photoelectron ejected from the metal surface.</p> <p>(A) <b><math>7.9 \times 10^{-1}</math> eV</b> – Answer (B) <math>1.7 \times 10^{-15}</math> eV (C) <math>1.3 \times 10^{-19}</math> eV (D) <math>2.0 \times 10^{-38}</math> eV</p>
<p>2023 Paper 1 Section 1 Question 10</p> <p>Quantum theory</p>	<p>A black body at a temperature of 6040 K produces photons across a range of frequencies.</p> <p>Calculate the frequency at which the maximum number of photons is produced.</p> <p>(A) <b><math>6.3 \times 10^{14}</math> Hz</b> – Answer (B) <math>2.1 \times 10^6</math> Hz (C) <math>4.8 \times 10^{-7}</math> Hz (D) <math>1.6 \times 10^{-15}</math> Hz</p>
<p>2023 Paper 1 Section 1 Question 20</p> <p>Quantum theory</p>	<p>The energy level diagram for a simple atom is shown.</p> <div style="text-align: center;">  <p>Energy (eV)</p> <p>n = 4 ————— -3.4</p> <p>n = 3 ————— -6.0</p> <p>n = 2 ————— -13.6</p> <p>n = 1 ————— -54.4</p> <p>Not to scale</p> </div> <p>What transition is allowed for an electron that absorbs a photon with a frequency of <math>6.3 \times 10^{14}</math> Hz?</p> <p>(A) n = 1 to n = 3 (B) n = 1 to n = 4 (C) n = 2 to n = 3 (D) <b>n = 3 to n = 4</b> – Answer</p>

<p>2022 Paper 1 Section 1 Question 2</p> <p>Quantum theory</p>	<p>A photon is described as</p> <p>(A) a continuous wave of light energy. (B) a particle that can only propagate in a medium. <b>(C) a quantum of all forms of electromagnetic energy. – Answer</b> (D) a particle that mediates the forces between protons</p>
<p>2022 Paper 1 Section 1 Question 6</p> <p>Quantum theory</p>	<p>After coherent light has been passed through a double slit, the observation of an interference pattern on a screen is explained by the</p> <p><b>(A) wave nature of light. – Answer</b> (B) equal width of the slits. (C) discrete packets of photons. (D) distance from the slits to the screen.</p>
<p>2022 Paper 1 Section 1 Question 8</p> <p>Quantum theory</p>	<p>Determine the wavelength of an electromagnetic wave with an energy of <math>2.4 \times 10^{-23}</math> J.</p> <p>(A) <math>7.2 \times 10^{-15}</math> m (B) <math>2.8 \times 10^{-11}</math> m <b>(C) <math>8.3 \times 10^{-3}</math> m – Answer</b> (D) <math>1.2 \times 10^2</math> m</p>
<p>2022 Paper 1 Section 1 Question 11</p> <p>Quantum theory</p>	<p>The maximum kinetic energy of an electron ejected from a metallic surface can be increased by</p> <p>(A) using a positively ionised metal. (B) using a metal with a larger work function. (C) increasing the intensity of the incident light. <b>(D) decreasing the wavelength of the incident light. – Answer</b></p>
<p>2021 Paper 1 Section 1 Question 9</p> <p>Quantum theory</p>	<p>The Bohr atomic model describes an atom as</p> <p>(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. <b>(D) a small positive nucleus surrounded by negative electrons in set orbits of fixed energy – Answer</b></p>
<p>2021 Paper 1 Section 1 Question 20</p> <p>Quantum theory</p>	<p>A photoelectron with a kinetic energy of <math>2.5 \times 10^{-19}</math> J is ejected when a photon with a frequency of <math>1.3 \times 10^{15}</math> Hz is incident on the metal plate.</p> <p>Calculate the threshold frequency of light required to eject the photoelectron from the metal plate.</p> <p>(A) <math>6.1 \times 10^{-19}</math> Hz (B) <math>3.7 \times 10^{14}</math> Hz (C) <math>9.2 \times 10^{14}</math> Hz <b>(D) <math>1.7 \times 10^{15}</math> Hz – Answer</b></p>
<p>2020 Paper 1 Section 1 Question 7</p> <p>Quantum theory</p>	<p>A quantum of any form of electromagnetic radiation is also known as</p> <p><b>(A) a photon. – Answer</b> (B) an X-ray. (C) a positron. (D) an electron.</p>

<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 13</b>  <b>Quantum</b> <b>theory</b>	The Rutherford atomic model describes an atom  (A) as the smallest particle of any substance. <b>(B) with a small, dense nucleus surrounded by orbiting electrons. – Answer</b> (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.
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 20</b>  <b>Quantum</b> <b>theory</b>	Calculate the frequency of light that would be required to eject a photoelectron at a velocity of $1.90 \times 10^6 \text{ m s}^{-1}$ from a metal plate with a work function of 4.73 eV.  (A) $1.14 \times 10^{15} \text{ Hz}$ (B) $1.34 \times 10^{15} \text{ Hz}$ (C) $2.48 \times 10^{15} \text{ Hz}$ <b>(D) <math>3.62 \times 10^{15} \text{ Hz}</math> – Answer</b>
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Marking Guide – Paper 1 Section 2

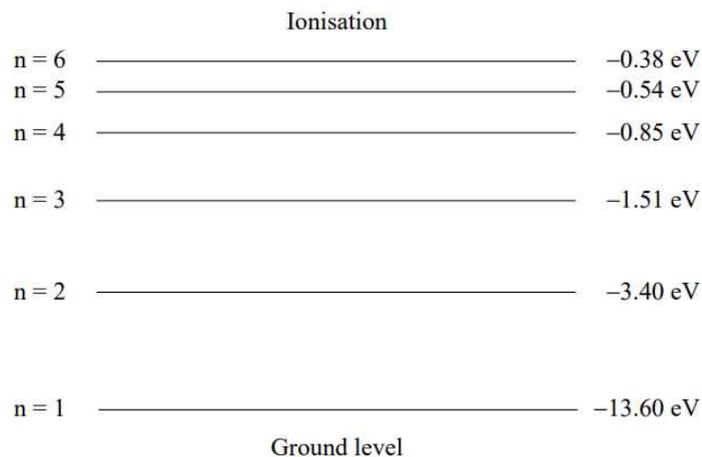
<p>2023 Paper 1 Section 2 Question 21</p> <p>Quantum theory</p>	Describe how the atomic model proposed by Bohr addresses the limitation of Rutherford’s model. (4 marks)	
	<p><b>Sample response</b></p> <p>The Rutherford model provided evidence for the presence of electrons around the nucleus of an atom, while the Bohr atomic model described how electrons orbit the nucleus.</p> <p>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.</p>	<p><b>The response</b></p> <ul style="list-style-type: none"> <li>describes Rutherford's atomic model [1 mark]</li> <li>describes Bohr's atomic model [1 mark]</li> <li>describes a limitation of Rutherford's atomic model [1 mark]</li> <li>describes significance of quantised energy levels [1 mark]</li> </ul>

<p>2023 Paper 1 Section 2 Question 26</p> <p>Quantum theory</p>	Calculate the energy (in electron volts) of a photon with a wavelength of 405 nm. Show your working. (4 marks)	
	<p><b>Sample response</b></p> $f = \frac{c}{\lambda}$ $= \frac{3 \times 10^8}{405 \times 10^{-9}}$ $= 7.41 \times 10^{14} \text{ Hz}$ $E = hf$ $= 6.626 \times 10^{-34} \times 7.41 \times 10^{14}$ $= 4.91 \times 10^{-19} \text{ J}$ $= 3.07 \text{ eV}$ <p>Energy = 3.07 eV (to three significant figures)</p>	<p><b>The response</b></p> <ul style="list-style-type: none"> <li>recognises the scenario relates to conversion of wavelength to frequency [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the energy of photon [1 mark]</li> <li>converts energy into eV [1 mark]</li> </ul>

<p>2022 Paper 1 Section 2 Question 21</p> <p>Quantum theory</p>	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]	
	<p><b>Sample Response</b></p> <p>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 <math>\lambda_{max} = \frac{b}{T}</math>.</p> <p>As the temperature increases, the peak wavelength will be shorter and this is observed by the colour change from red to orange.</p>	<p><b>The response</b></p> <ul style="list-style-type: none"> <li>describes the scenario in terms of black-body radiation [1 mark]</li> <li>uses Wien's Law to explain the colour change in the iron bar [1 mark]</li> </ul>

2022  
Paper 1  
Section 2  
Question 23  
  
Quantum  
theory

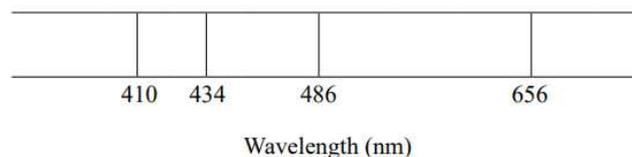
The diagram shows the electron energy levels for hydrogen.



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
$\Delta E = E_f - E_i$ $= -13.60 - (-1.51)$ $= -12.09 \text{ eV}$ $= -1.93 \times 10^{-18} \text{ J or } 1.93 \times 10^{-18} \text{ J released}$ Energy released = $1.93 \times 10^{-18} \text{ J}$ (to three significant figures)	<ul style="list-style-type: none"> <li>• recognises the scenario relates to the change in electron energy as it moves between energy levels [1 mark]</li> <li>• determines the energy released [1 mark]</li> <li>• converts energy from electronvolts to joules [1 mark]</li> </ul>

The visible light emission spectrum for hydrogen is shown.

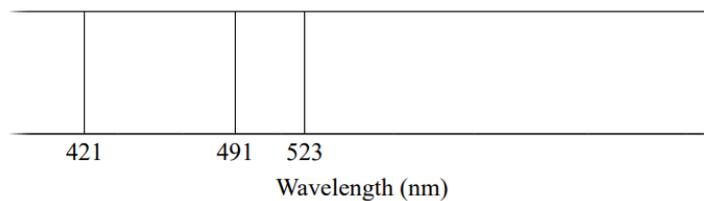


b) Explain why hydrogen only has four emission spectrum lines in the visible (i.e. 400–700 nm) spectrum. [3 marks]

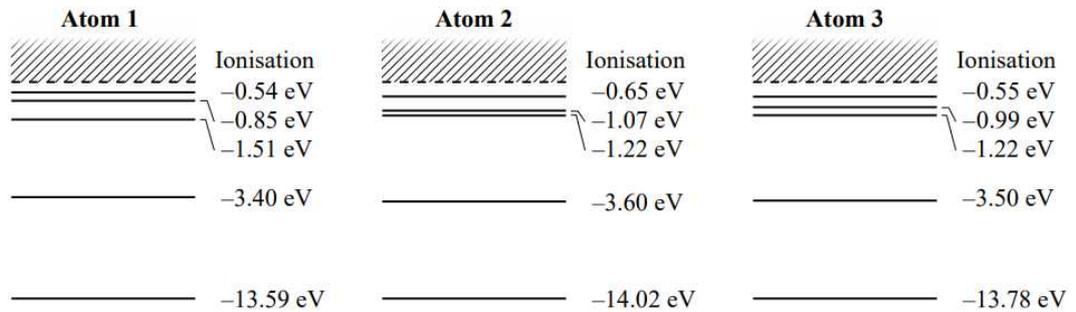
Sample Response	The response
Emission spectrum lines relate to the wavelength of light produced by the release of energy as an electron moves from a higher energy level to a lower energy level within an atom. Since light in the visible spectrum corresponds to wavelengths between 400–700 nm, only energy emitted with wavelengths within this range will be observed. This corresponds to electrons moving between levels where $n = 2, 3$ or $4$ .	<ul style="list-style-type: none"> <li>• explains the relationship between emission lines and orbital energies [1 mark]</li> <li>• identifies that only transitions occurring between orbitals where the energy difference corresponds to wavelengths between 400–700 nm would emit visible light [1 mark]</li> <li>• identifies specific aspects of the energy level diagram to support the explanation [1 mark]</li> </ul>

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

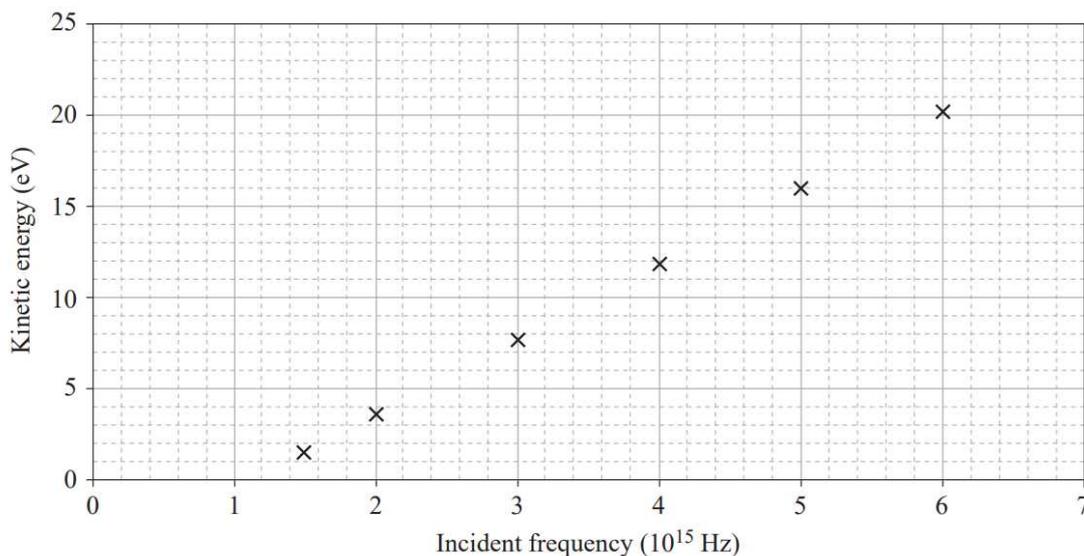
Determine which atom is most likely to be the unknown atom. [5 marks]

Sample Response	The response	Notes
<p>Each wavelength of light corresponds to a quantum of energy, which can be worked out using the following equation:</p> $E = hf = \frac{hc}{\lambda}$ <p>The energies that have produced the three wavelengths of light are:</p> <p>Line 1: 421 nm  <math>E = 4.72 \times 10^{-19} \text{ J} = 2.95 \text{ eV}</math></p> <p>Line 2: 491 nm  <math>E = 4.05 \times 10^{-19} \text{ J} = 2.53 \text{ eV}</math></p> <p>Line 3: 523 nm  <math>E = 3.8 \times 10^{-19} \text{ J} = 2.38 \text{ eV}</math></p> <p>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.</p>	<ul style="list-style-type: none"> <li>recognises how absorption spectra relate to energy level diagrams [1 mark]</li> <li>determines the energy of photons absorbed by the atom [1 mark]</li> <li>converts from joules to eV [1 mark]</li> <li>identifies energy level transitions corresponding to absorbed photons [1 mark]</li> <li>determines the atom [1 mark]</li> </ul>	<p>Allow FT marks for error/s in prior working.</p>

**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.

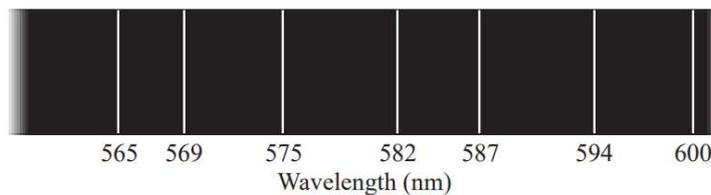
Metal	Work function (eV)
potassium	2.30
copper	4.70
osmium	5.93

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

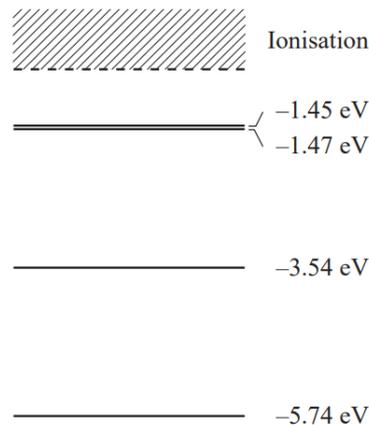
Sample Response	The response	Notes
<p>x-intercept = <math>1.13 \times 10^{15}</math> Hz  <math>W_0 = hf_0 = 6.626 \times 10^{-34} \times 1.13 \times 10^{15} / 1.6 \times 10^{-19}</math>  <math>= 4.7</math> eV            Unknown metal = copper</p>	<ul style="list-style-type: none"> <li>identifies a relevant value or feature of the graph [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed or sound mathematical reasoning [1 mark]</li> <li>identifies the unknown metal [1 mark]</li> </ul>	<p>Relevant values/features of the graph may include:</p> <ul style="list-style-type: none"> <li>x-intercept</li> <li>y-intercept</li> <li>...</li> </ul> <p>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.</p> <p>Students may annotate graph, but this is not essential to marking.</p>

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:				<ul style="list-style-type: none"> <li>provides pertinent mathematical operation/s correctly performed to determine the differences between the energy levels in the energy level diagram [1 mark]</li> <li>provides pertinent mathematical operation/s to convert eV to joules [1 mark]</li> <li>indicates wavelengths produced by Element A that are also included in the emission spectra [1 mark]</li> <li>provides an answer that indicates the possibility that Element A is one of the gases comprising the gas mixture [1 mark]</li> </ul>	Allow FT error for the final answer.
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	$-3.2 \times 10^{-21}$	62 100		
1.45–3.54	-2.09	$-3.344 \times 10^{-19}$	594		
1.45–5.74	-4.29	$-6.864 \times 10^{-19}$	290		
1.47–3.54	-2.07	$-3.312 \times 10^{-19}$	600		
1.47–5.74	-4.28	$-6.848 \times 10^{-19}$	290		
3.54–5.74	-2.2	$-3.52 \times 10^{-19}$	565		
It is possible that Element A is one of the gases comprising the gas mixture.					

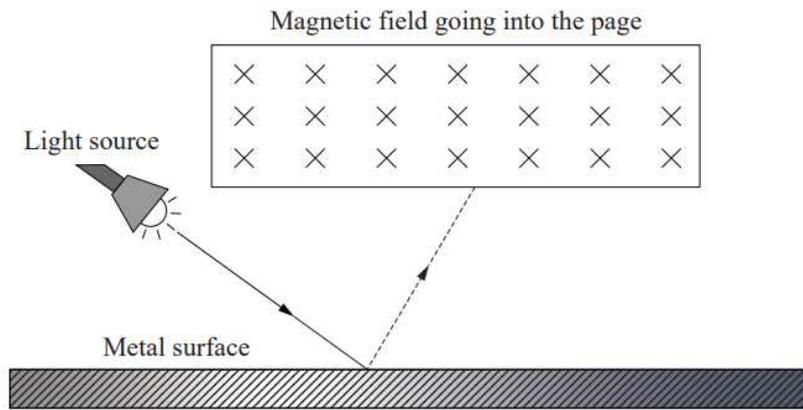
Marking Guide – Paper 2 Section 1

<p>2023 Paper 2 Section 1 Question 5</p> <p>Quantum theory</p>	Describe what happens when light is shone onto a metallic surface in the context of the photoelectric effect. (4 marks)	
	<p style="text-align: center;"><b>Sample response</b></p> <p>Light with energy equivalent to <math>hf</math> has the ability to produce photoelectrons from a metallic surface.</p> <p>When the frequency of light is below the threshold frequency for the metallic surface, the light will be reflected with no transfer of energy.</p> <p>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.</p> <p>The intensity of incident light is proportional to the number of photoelectrons for frequencies greater than the threshold frequency.</p>	<p style="text-align: center;"><b>The response</b></p> <ul style="list-style-type: none"> <li>• identifies incident light has energy equivalent to <math>hf</math> [1 mark]</li> <li>• describes transfer of energy when frequency of light is             <ul style="list-style-type: none"> <li>– below the threshold frequency [1 mark]</li> <li>– above the threshold frequency [1 mark]</li> </ul> </li> <li>• identifies relationship between intensity of incident light and resultant photoelectrons [1 mark]</li> </ul>

<p>2023 Paper 2 Section 1 Question 7</p> <p>Quantum theory</p>	Discuss the nature of light by describing evidence from two key experiments. (7 marks)	
	<p style="text-align: center;"><b>Sample response</b></p> <p>Young's double slit experiment and black-body radiation both provide evidence for the behaviour of light.</p> <p>In Young's double slit experiment, the interference patterns formed as light passed between the two slits demonstrates the wave nature of light.</p> <p>In contrast, black-body radiation demonstrates the quantised nature of light as electrons can only absorb or emit energy in discrete amounts.</p> <p>Therefore, light has some wave properties and some particle properties.</p>	<p style="text-align: center;"><b>The response</b></p> <ul style="list-style-type: none"> <li>• identifies evidence for the nature of light comes from             <ul style="list-style-type: none"> <li>– Young's double slit experiment [1 mark]</li> <li>– black-body radiation [1 mark]</li> </ul> </li> <li>• describes evidence for wave nature of light [1 mark]</li> <li>• describes evidence for photons [1 mark]</li> <li>• concludes light has the properties of both waves and particles [1 mark]</li> </ul>

2022  
Paper 2  
Section 1  
Question 6  
  
Quantum  
theory

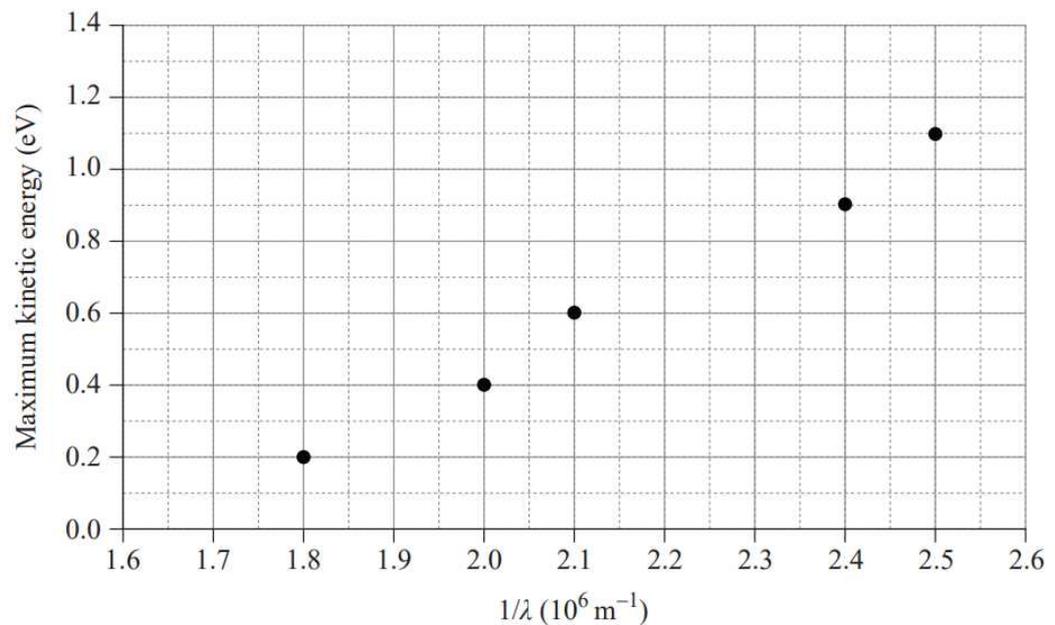
A light was shone onto a metallic surface and the subsequently released photoelectron passed through a magnetic field.



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
<p>The x-intercept corresponds to the threshold frequency for the metal. Therefore, based on the line of best fit, the corresponding wavelength is <math>\frac{1}{1.65 \times 10^6} = 606 \text{ nm}</math>.</p> $f_0 = \frac{c}{\lambda}$ $= \frac{3.00 \times 10^8}{606 \times 10^{-9}}$ $= 4.95 \times 10^{14} \text{ Hz}$ $W = hf_0$ $= 6.626 \times 10^{-34} \times 4.95 \times 10^{14}$ $= 3.3 \times 10^{-19} \text{ J}$ <p>Work function = <math>3.3 \times 10^{-19} \text{ J}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>determines the threshold frequency [1 mark]</li> <li>recognises the scenario relates to work function [1 mark]</li> <li>provides appropriate reasoning [1 mark]</li> <li>determines the work function [1 mark]</li> </ul>

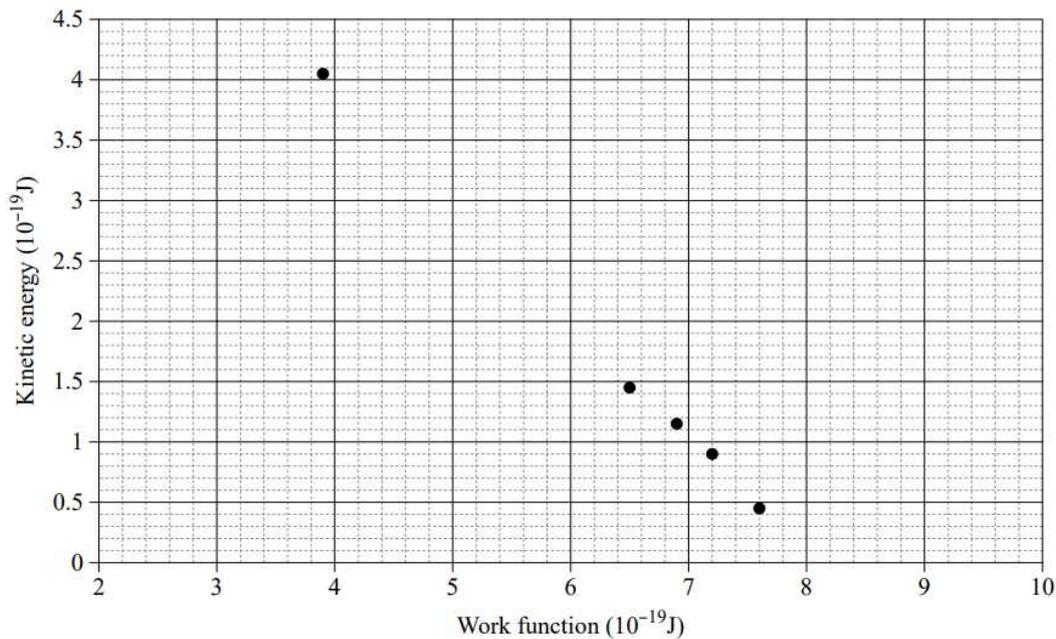
c) If the strength of the magnetic field is  $5 \mu\text{T}$ , determine the maximum radius of the photoelectron's path through the magnetic field, when light of wavelength  $450 \text{ nm}$  was shone onto the metallic surface. Show your working. [9 marks]

Sample Response	The response
<p>Inverse of wavelength = <math>\frac{1}{450 \times 10^{-9}} = 2.2 \times 10^6 \text{ m}^{-1}</math></p> <p>Maximum kinetic energy of photoelectron:</p> $E_k = 0.7 \times 1.6 \times 10^{-19} = 1.12 \times 10^{-19} \text{ J}$ <p>Maximum velocity of photoelectron:</p> $E_k = \frac{1}{2}mv^2$ $1.12 \times 10^{-19} = \frac{1}{2} \times 9.109 \times 10^{-31} v^2$ $v = \sqrt{\frac{1.12 \times 10^{-19}}{4.55 \times 10^{-31}}}$ $= 5.0 \times 10^5 \text{ m s}^{-1}$ <p>Force acting on photoelectron in the magnetic field:</p> $F = qvB \sin \theta$ $= 1.6 \times 10^{-19} \times 5.0 \times 10^5 \times 5.0 \times 10^{-6} \times \sin 90$ $= 4.0 \times 10^{-19} \text{ N}$ <p>Radius of photoelectron's path:</p> $F = \frac{mv^2}{r}$ $4.0 \times 10^{-19} = \frac{9.109 \times 10^{-31} \times (5.0 \times 10^5)^2}{r}$ $r = 0.57 \text{ m}$ <p>Radius of photoelectron's path = <math>0.57 \text{ m}</math> (to two significant figures)</p>	<ul style="list-style-type: none"> <li>determines the corresponding inverse of wavelength [1 mark]</li> <li>determines the maximum kinetic energy of the photoelectron [1 mark]</li> <li>recognises the scenario relates to velocity of photoelectrons [1 mark]</li> <li>determines the maximum velocity of the photoelectron [1 mark]</li> <li>recognises the scenario relates to force on photoelectrons [1 mark]</li> <li>determines the force on the photoelectron [1 mark]</li> <li>recognises the scenario relates to the radius of the circular path [1 mark]</li> <li>provides appropriate mathematical reasoning to determine radius [1 mark]</li> <li>determines the maximum radius of the photoelectron's path [1 mark]</li> </ul>

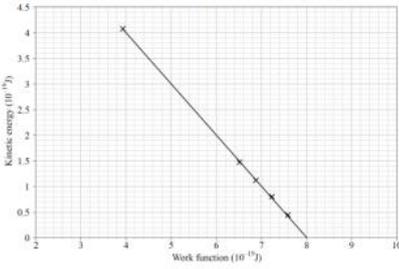
2021  
Paper 2  
Section 1  
Question 8

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
<p> <math>E_k = hf - W</math>  <math>E_k = -W + hf</math>                      The y-intercept of the line will be <math>hf</math> </p>  <p> <math>y = mx + c</math>                      To determine the gradient, the data (6, 2) and (8, 0) were used                 </p> $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0 - 2}{8 - 6} = -1$ <p>Therefore <math>y = -1x + c</math> Substitute (8, 0)</p> $0 = -1 \times 8 + c$ $c = 8$ <p>Therefore</p> $hf = c$ $f = \frac{c}{h} = \frac{8 \times 10^{-19}}{6.626 \times 10^{-34}} \approx 1.2 \times 10^{15} \text{ Hz}$ <p>Wavelength = 248 nm (to the nearest whole number)</p>	<ul style="list-style-type: none"> <li>recognises the scenario relates to <math>E_k = hf - W</math> [1 mark]</li> <li>uses appropriate features of the graph to determine a value for <math>hf</math> [1 mark]</li> <li>provides correct reasoning [1 mark]</li> <li>determines wavelength [1 mark]</li> </ul>	<p>Appropriate features of the graph include:</p> <ul style="list-style-type: none"> <li>the x-intercept</li> <li>a point on the line of best fit</li> <li>or any other relevant feature.</li> </ul> <p>Do not penalise for incorrect decimal places/significant figures.</p>

<b>2021</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 9</b>  <b>Quantum theory</b>	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.	<ul style="list-style-type: none"> <li>describes the results of Young's double slit experiment [1 mark]</li> <li>recognises that Young's experiment involves constructive and destructive interference [1 mark]</li> <li>states that the result is similar to that of a mechanical wave [1 mark]</li> </ul>	For <i>mechanical wave</i> accept other suitable responses consistent with a reasonable understanding of a transverse wave.

<b>2020</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 3</b>  <b>Quantum theory</b>	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. $E = hf$ $= \frac{hc}{\lambda}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9}}$ $= 4.9695 \times 10^{-19} \text{ J}$ $E = \frac{4.9695 \times 10^{-19}}{1.60 \times 10^{-19}}$ $\approx 3.106 \text{ eV}$ The largest transition below 3.106 eV is between -2.7 eV and -5.6 eV. $E = -2.7 - -5.6$ $= 2.9 \text{ eV}$ In joules, $E = 2.9 \times 1.60 \times 10^{-19}$ $= 4.64 \times 10^{-19} \text{ J}$ $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{4.64 \times 10^{-19}}$ Wavelength = 428 nm	Solution 1 <ul style="list-style-type: none"> <li>indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram [1 mark]</li> <li>provides pertinent mathematical operation/s correctly performed to move between values for wavelength and energy [1 mark]</li> <li>identifies the largest allowable energy transition for visible light to be emitted (consequentially correct) [1 mark]</li> <li>identifies the consequentially correct transition to produce the shortest wavelength of visible light [1 mark]</li> </ul>	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.  Do not penalise for incorrect decimal places/significant figures.	

		<ul style="list-style-type: none"> <li>• determines the wavelength of light [1 mark]</li> </ul> OR Solution 2 <ul style="list-style-type: none"> <li>• indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram [1 mark]</li> <li>• provides pertinent mathematical operation/s correctly performed to calculate all energy differences [1 mark]</li> <li>• provides pertinent mathematical operation/s correctly performed to identify all possible wavelengths emitted by the atom [1 mark]</li> <li>• identifies the consequentially correct wavelengths within the visible spectrum [1 mark]</li> <li>• determines the wavelength of light [1 mark]</li> </ul>	
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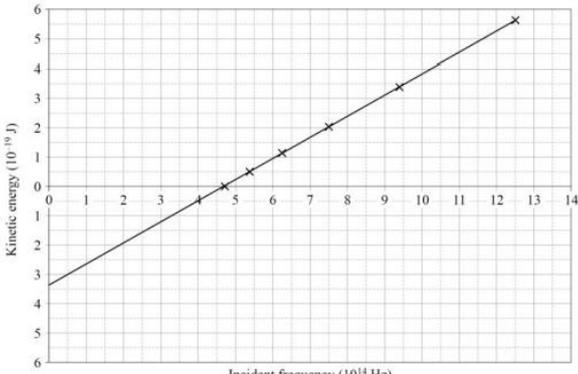
<p><b>2020</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Quantum theory</b></p>	Describe how experiments on the photoelectric effect provide evidence of the quantised nature of photons. [4 marks]		
	Sample Response	The response	Notes
	The photoelectric effect experiment demonstrates 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.	<ul style="list-style-type: none"> <li>• identifies that the intensity of light is proportional to the number of photoelectrons [1 mark]</li> <li>• identifies that the proportionality between intensity and the number of photoelectrons provides evidence that light is made of photons/packets [1 mark]</li> <li>• identifies that the frequency of light relates to a set/quantised/packet of energy [1 mark]</li> <li>• identifies that the kinetic energy of the emitted electron is related to the energy per photon (or equivalent) [1 mark]</li> <li>• identifies that the increase of kinetic energy as the frequency of incident light increases suggests the quantised nature of photons [1 mark]</li> </ul>	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
 <p> <math display="block">\text{Gradient} = \frac{\Delta E_K}{\Delta f} = \frac{5.6 \times 10^{-19} - 1.5 \times 10^{-21}}{1.25 \times 10^{15} - 4.68 \times 10^{14}} = 7.2 \times 10^{-34}</math> </p> <p> <math display="block">\text{Work function} = \text{y-intercept} = 3.3 \times 10^{-19} \text{ J}</math> </p> <p> <math display="block">E_K = 7.2 \times 10^{-34} \times f - 3.3 \times 10^{-19}</math> </p>	<ul style="list-style-type: none"> <li>• provides a correct value for the <math>y</math>-intercept [1 mark]</li> <li>• provides a correct value for the gradient of the graph [1 mark]</li> <li>• provides the equation [1 mark]</li> </ul>	<p>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.</p> <p>In this case: Accept values inclusive between: <math>7.1 \times 10^{-34}</math> and <math>7.3 \times 10^{-34}</math> for the gradient. <math>3.3 \times 10^{-19}</math> and <math>3.5 \times 10^{-19}</math> for the <math>y</math>-intercept.</p> <p>Students may annotate graph, but this is not essential to marking.</p> <p>Allow FT error for the equation.</p>

## Unit 4 – Topic 3: The Standard Model

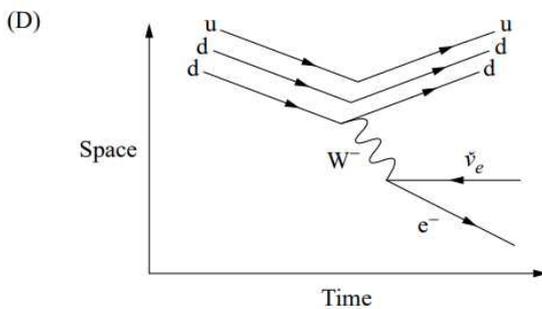
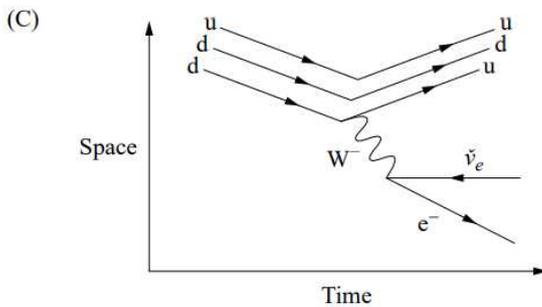
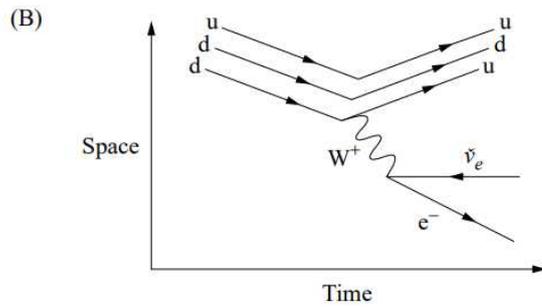
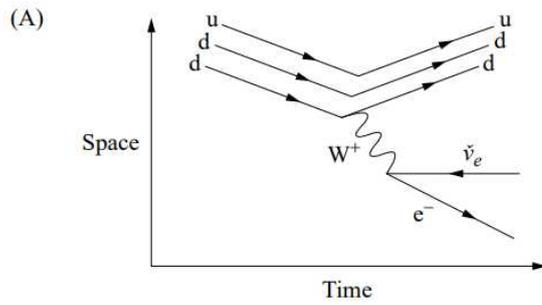
### Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 14</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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.
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>The</b> <b>Standard</b> <b>Model</b>	<i>Tau</i> 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?



2022  
Paper 1  
Section 1  
Question 20

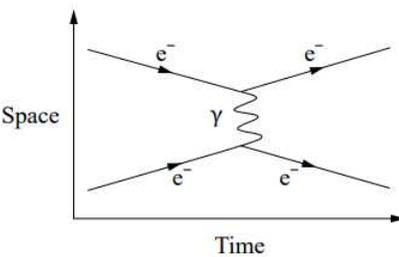
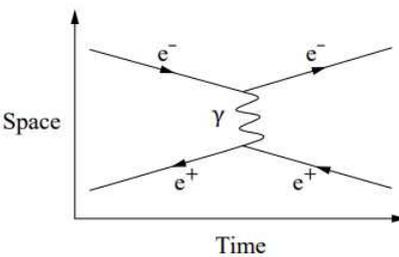
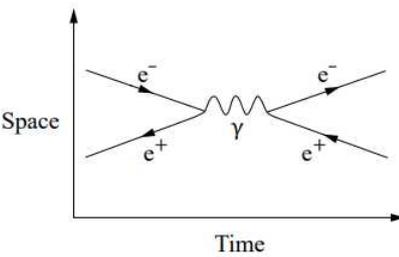
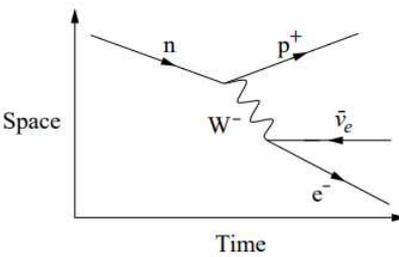
The  
Standard  
Model

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

<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b>  <b>The</b> <b>Standard</b> <b>Model</b>	Leptons do not experience the (A) weak force. (B) strong force. (C) gravitational force. (D) electromagnetic force.
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<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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.
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<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b>  <b>The</b> <b>Standard</b> <b>Model</b>	Which Feynman diagram shows an electron interacting with another electron? (A)  (B)  (C)  (D) 
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>The</b> <b>Standard</b> <b>Model</b>	The force that quarks experience that leptons do not is the (A) weak force. (B) strong force. (C) normal force. (D) electromagnetic force.
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<b>2020 Paper 1 Section 1 Question 14  The Standard Model</b>	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
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**Paper 1 Section 2**

<p><b>2023 Paper 1 Section 2 Question 22</b></p> <p><b>The Standard Model</b></p>	<p>Particles move at a rate of <math>1.3 \times 10^6</math> times per second around a circular particle accelerator with a radius of 35 m.</p> <p>Calculate the average speed of the particles. Show your working. (3 marks)</p> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <div data-bbox="461 741 1318 842" style="border: 1px solid black; padding: 10px; margin: 20px auto; width: fit-content;"><p>Average speed = _____ <math>\text{m s}^{-1}</math> (to two significant figures)</p></div>
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<p><b>2023 Paper 1 Section 2 Question 23</b></p> <p><b>The Standard Model</b></p>	<p>List the forces that can be experienced by leptons (1 mark)</p> <hr/> <hr/> <hr/>
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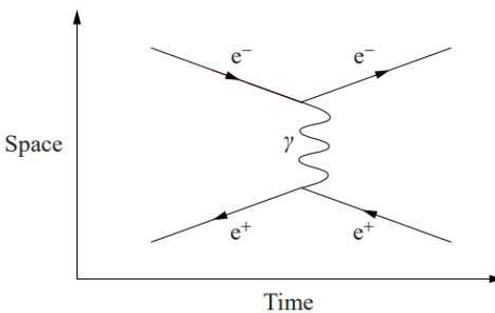
<p><b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 22</b></p> <p style="text-align: center;"><b>The Standard Model</b></p>	<p>A collection of mesons was observed by a detector to move an average distance of 11.0 m when travelling at 95% of the speed of light. However, based on their properties, the mesons were expected to travel an average distance of 3.4 m.</p> <p>Explain the difference between the observed and expected average distances. [2 marks]</p> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 26</b></p> <p style="text-align: center;"><b>The Standard Model</b></p>	<p>Carbon-14 undergoes nuclear decay to nitrogen-14.</p> ${}^1_6\text{C} \rightarrow {}^{14}_7\text{N} + e^{-} + \bar{\nu}_e$ <p>List the two types of particles whose total number must be conserved in this reaction. [1 mark]</p> <hr/> <hr/>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 22</b></p> <p style="text-align: center;"><b>The Standard Model</b></p>	<p>List the six types of leptons. [1 mark]</p> <p>1. <hr/></p> <p>2. <hr/></p> <p>3. <hr/></p> <p>4. <hr/></p> <p>5. <hr/></p> <p>6. <hr/></p>
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**Paper 2 Section 1**

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

<b>2022 Paper 2 Section 1 Question 5</b>  <b>The Standard Model</b>	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.

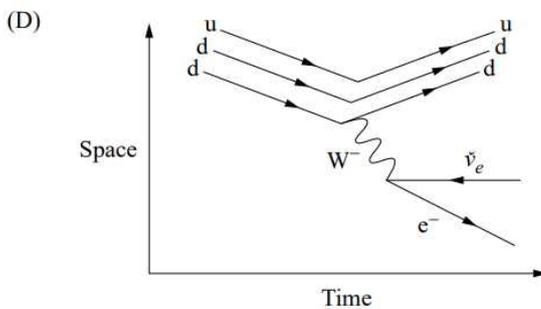
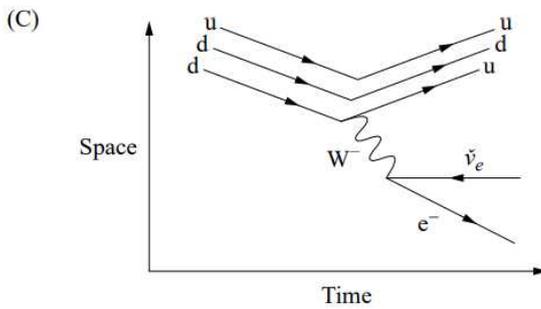
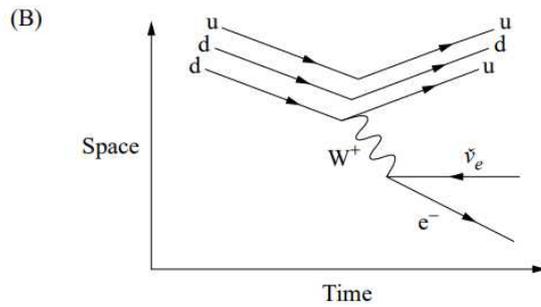
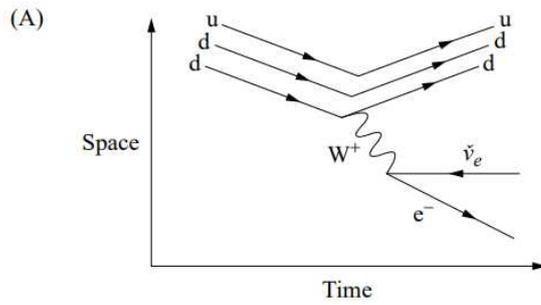
## Marking Guide – Paper 1 Section 1

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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. <b>(C) the lepton number does not change. – Answer</b> (D) the number of particles will decrease.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 12</b>  <b>The</b> <b>Standard</b> <b>Model</b>	What is a consequence of symmetry in particle interactions?  <b>(A) The law of conservation of momentum is obeyed. – Answer</b> (B) Charges on particles will always be different. (C) Antiparticles travel backwards through time. (D) Total mass of the particles will decrease.
<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 14</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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. <b>(D) particle whose interactions can be mediated by photons. – Answer</b>
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>The</b> <b>Standard</b> <b>Model</b>	<i>Tau</i> particles are classified as  (A) bosons. <b>(B) leptons. – Answer</b> (C) mesons. (D) baryons

2022  
Paper 1  
Section 1  
Question 14

The  
Standard  
Model

Which Feynman diagram correctly depicts neutron decay?



Answer is C.

2022  
Paper 1  
Section 1  
Question 20

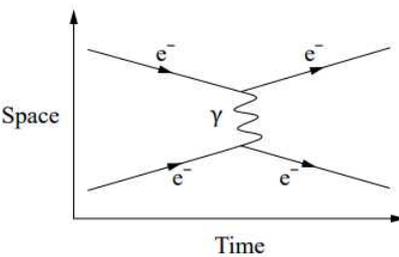
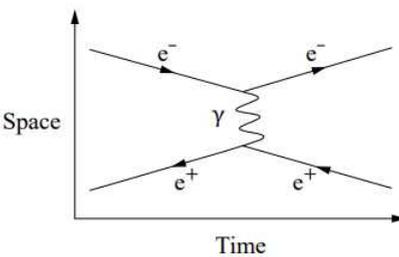
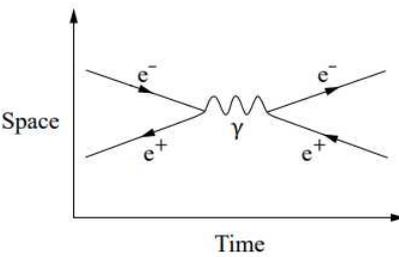
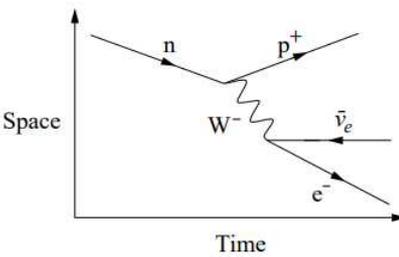
The  
Standard  
Model

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

<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b>  <b>The</b> <b>Standard</b> <b>Model</b>	Leptons do not experience the (A) weak force. <b>(B) strong force. – Answer</b> (C) gravitational force. (D) electromagnetic force.
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<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>The</b> <b>Standard</b> <b>Model</b>	Mesons are <b>(A) subatomic particles composed of one quark and one antiquark. – Answer</b> (B) elementary particles that are classified as leptons. (C) elementary particles exchanged between quarks. (D) subatomic particles composed of three quarks.
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<b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 15</b>  <b>The</b> <b>Standard</b> <b>Model</b>	Which Feynman diagram shows an electron interacting with another electron? (A)  (B)  (C)  (D)  <b>Answer is A.</b>
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<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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 <b>(C) up, down, charm, strange, top and bottom – Answer</b> (D) charm, strange, right, left, top and bottom
---	--

<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>The</b> <b>Standard</b> <b>Model</b>	The force that quarks experience that leptons do not is the (A) weak force. <b>(B) strong force. – Answer</b> (C) normal force. (D) electromagnetic force.
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<b>2020 Paper 1 Section 1 Question 14  The Standard Model</b>	Select the list that contains only gauge bosons.  (A) gluon, photon, meson and hadron (B) lepton, baryon, meson and hadron <b>(C) gluon, photon, Z boson and W boson – Answer</b> (D) Z boson, W boson, photon and lepton
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**Marking Guide – Paper 1 Section 2**

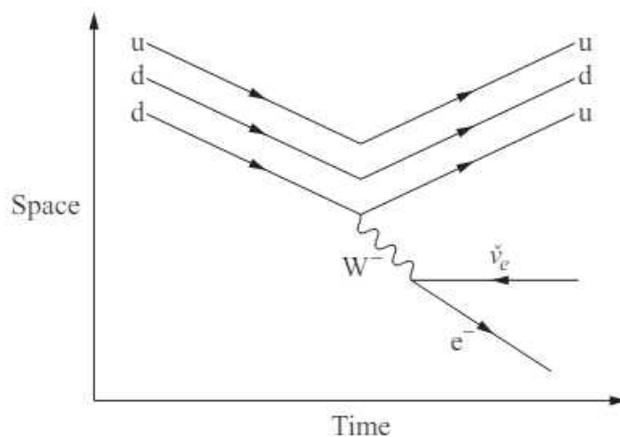
<p><b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 22</b></p> <p><b>The</b> <b>Standard</b> <b>Model</b></p>	<p>Particles move at a rate of <math>1.3 \times 10^6</math> times per second around a circular particle accelerator with a radius of 35 m.</p> <p>Calculate the average speed of the particles. Show your working. (3 marks)</p>			
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <math>C = 2\pi r = 2 \times \pi \times 35 \approx 219.91 \text{ m}</math>  <math>f = \frac{1}{T}</math>  <math>\therefore v = \frac{2\pi r}{T} = 219.91 \times 1.3 \times 10^6 = 2.86 \times 10^8 \text{ m s}^{-1}</math>                      Average speed = <math>2.9 \times 10^8 \text{ m s}^{-1}</math> (to two significant figures)                 </td> <td> <ul style="list-style-type: none"> <li>recognises the scenario relates to average speed of objects in uniform circular motion [1 mark]</li> <li>provides appropriate mathematical reasoning [1 mark]</li> <li>calculates the average speed of the particles [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	$C = 2\pi r = 2 \times \pi \times 35 \approx 219.91 \text{ m}$ $f = \frac{1}{T}$ $\therefore v = \frac{2\pi r}{T} = 219.91 \times 1.3 \times 10^6 = 2.86 \times 10^8 \text{ m s}^{-1}$ Average speed = $2.9 \times 10^8 \text{ m s}^{-1}$ (to two significant figures)
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<p><b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 23</b></p> <p><b>The</b> <b>Standard</b> <b>Model</b></p>	<p>List the forces that can be experienced by leptons (1 mark)</p>			
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td>                     Weak nuclear force                      Electromagnetic force                      Gravitational force                 </td> <td> <ul style="list-style-type: none"> <li>identifies the forces [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	Weak nuclear force Electromagnetic force Gravitational force
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Weak nuclear force Electromagnetic force Gravitational force	<ul style="list-style-type: none"> <li>identifies the forces [1 mark]</li> </ul>			

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.	<ul style="list-style-type: none"> <li>identifies conservation of lepton number / symmetry of the interaction [1 mark]</li> <li>describes conservation of mass [1 mark]</li> </ul>

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.

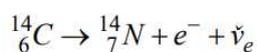
Explain the difference between the observed and expected average distances. [2 marks]

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.	<ul style="list-style-type: none"> <li>identifies that an object at relativistic speed experiences time dilation [1 mark]</li> <li>explains the relationship between time travelled and observed distance [1 mark]</li> </ul>

2022  
Paper 1  
Section 2  
Question 26

The  
Standard  
Model

Carbon-14 undergoes nuclear decay to nitrogen-14.



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

Sample Response	The response
Baryons Leptons	<ul style="list-style-type: none"> <li>identifies baryons and leptons [1 mark]</li> </ul>

<b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 22</b>  <b>The</b> <b>Standard</b> <b>Model</b>	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	<ul style="list-style-type: none"> <li>• identifies the six leptons [1 mark]</li> </ul>	<p>Listing the respective antiparticles is permitted but only in addition to, not in place of, the leptons listed in the sample response.</p> <p>Listing the symbols (<math>e</math>, <math>\nu_e</math>, <math>\nu_\mu</math>, <math>\mu</math>, <math>\nu_\tau</math>, <math>\tau</math>) in addition to, or in place of, lepton names is permitted. If both are provided then the symbol must match the name.</p> <p>Misspelling of lepton names is permitted as long as the error does not impede meaning.</p>	

**Marking Guide – Paper 2 Section 1**

<p><b>2022</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>The Standard Model</b></p>	<p>Contrast the properties of up quarks and tau particles. [2 marks]</p>				
	<table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>Up quarks are fundamental particles that experience the strong nuclear force and may be combined with other quarks to form mesons and baryons.</p> <p>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.</p> </td> <td> <ul style="list-style-type: none"> <li>identifies a difference between the nature of particles [1 mark]</li> <li>interaction forces [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample Response	The response	<p>Up quarks are fundamental particles that experience the strong nuclear force and may be combined with other quarks to form mesons and baryons.</p> <p>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.</p>	<ul style="list-style-type: none"> <li>identifies a difference between the nature of particles [1 mark]</li> <li>interaction forces [1 mark]</li> </ul>
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<p><b>2022</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 5</b></p> <p><b>The Standard Model</b></p>	<p>The Feynman diagram for a particle interaction is shown.</p>				
	<div style="text-align: center;"> </div> <p>Describe the particle interaction taking place. [3 marks]</p> <table border="1"> <thead> <tr> <th>Sample Response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>The Feynman diagram represents the interaction between an electron and a positron through Bhabha 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.</p> </td> <td> <ul style="list-style-type: none"> <li>identifies that the interaction involves an electron and a positron [1 mark]</li> <li>identifies that a photon is exchanged [1 mark]</li> <li>describes that both particles change velocity due to the interaction [1 mark]</li> </ul> </td> </tr> </tbody> </table>		Sample Response	The response	<p>The Feynman diagram represents the interaction between an electron and a positron through Bhabha 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.</p>
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<p><b>2021</b> <b>Paper 2</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>The Standard Model</b></p>	<p>List the four gauge bosons in the Standard Model. [1 mark]</p>							
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