AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 1

Friday 24 May 2024 Morning Time allowed: 2 hours

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8–32	
TOTAL	

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 . 1 State the names of the four fundamental interactions.

[1 mark]

1 _____

2 _____

3 _____

4 _____

0 1 . 2 State the products of the decay of a free neutron.

[1 mark]

_____

0 1 . 3 Explain which of the fundamental interactions is responsible for the decay of the neutron.

[2 marks]

_____

_____

_____

_____

0 1 . 4 The forces between two moving electrons cause their paths to change.

Explain, using the concept of exchange particles, why the electron paths change.

[3 marks]

_____

_____

_____

_____

_____

_____

7

Do not write outside the box

0 2 A positive pion collides with a neutron and the following interaction is observed:

$$\pi^+ + n \rightarrow K^+ + \Sigma^0$$

Σ^0 is a neutral sigma particle with a strangeness of -1

The interaction can be used to deduce the classifications of the Σ^0.

0 2 . 1 Identify the classifications of each particle in **Table 1**.
Tick (✓) the appropriate boxes for each particle.

[2 marks]

Table 1

Particle	Baryon	Hadron	Lepton	Meson
π^+				
n				
K^+				
Σ^0				

0 2 . 2 A conservation rule predicts that the following interaction **cannot** occur:

$$\pi^- + n \rightarrow K^- + \Sigma^0$$

State the conservation rule.
Go on to explain your answer.

[3 marks]

Question 2 continues on the next page

Do not write outside the box

One way in which neutral pions decay is

$$\pi^0 \rightarrow e^- + e^+ + \gamma$$

0 2 . 3 Compare the rest energies of the particles involved in this decay.

[2 marks]

0 2 . 4 The decay of the neutral pion leads to the production of further gamma photons.

Explain why.

[1 mark]

0 2 . 5 The Standard Model is a theory that classifies elementary particles.
Evidence for the theory has been collected since about 1950. However, the term Standard Model has only been used since 1973.

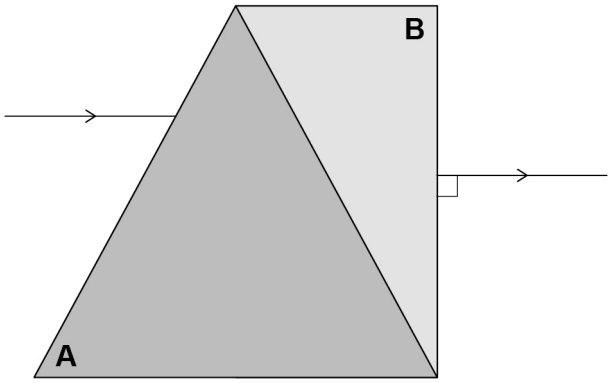
Suggest why progress in particle physics is slow.

[1 mark]

9

0 3 **Figure 1** shows two prisms **A** and **B** of different refractive indices joined to make a block.
A ray of monochromatic light is shown entering and then leaving the block.

Figure 1



0 3 . 1 Complete, on **Figure 1**, the path of the ray of light inside the block.

[1 mark]

0 3 . 2 Deduce which prism, **A** or **B**, has the greater refractive index.

[2 marks]

The block is used with a telescope to investigate stars.
The block can be replaced with a diffraction grating.

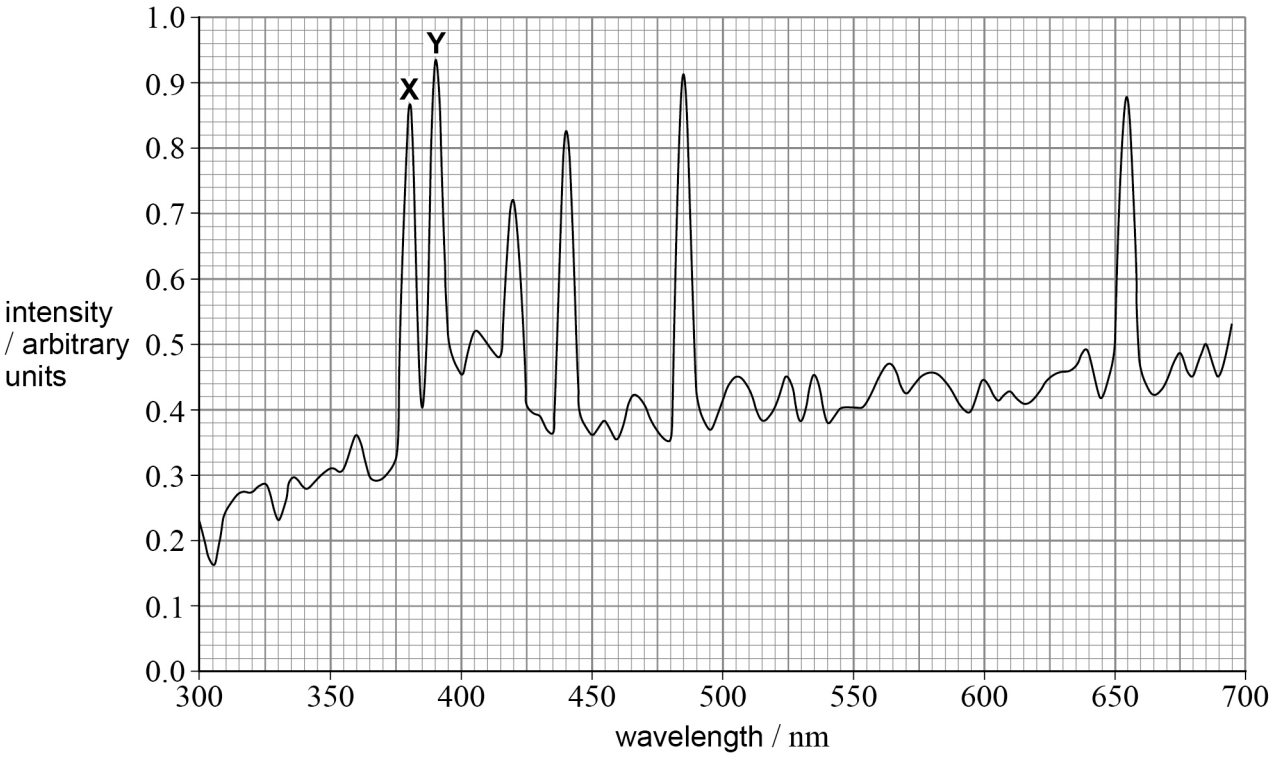
0 3 . 3 Describe **one** non-astronomical application of a diffraction grating.

[1 mark]

Question 3 continues on the next page

0 3 . 4 **Figure 2** shows a spectrum of light. Two lines in the spectrum are labelled **X** and **Y**.

Figure 2



The light passes at normal incidence through a diffraction grating. The number of lines per metre for the grating is G.

The first-order diffraction angle of **X** is at $28.2°$ to the normal.

Calculate G.

[3 marks]

$G =$ _____ m^{-1}

Do not write outside the box

0 3 . 5 A scientist wants to obtain an accurate value for the difference in wavelength between line **X** and line **Y**.

She has two options:

- option 1: to analyse the second-order spectrum from the original grating
- option 2: to analyse the first-order spectrum from a grating with $2G$ lines per metre.

Discuss which option she should choose.

[3 marks]

10

Turn over for the next question

0 4 The deuterium–tritium (D–T) reaction is a nuclear reaction between two isotopes of hydrogen.
The D–T reaction is

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathrm{n}$$

The energy from this reaction is transferred to the kinetic energy of the helium nucleus and the kinetic energy of the neutron.
Assume that the kinetic energies of the hydrogen nuclei are zero just before the reaction occurs.

0 4 . 1 Show that the kinetic energy of the neutron represents approximately 80% of the total energy transferred.

[2 marks]

0 4 . 2 The combined kinetic energy of the helium nucleus and the neutron is 2.82×10^{-12} J.

Calculate the initial speed of the neutron.

[2 marks]

initial speed = _____ $\mathrm{m\ s^{-1}}$

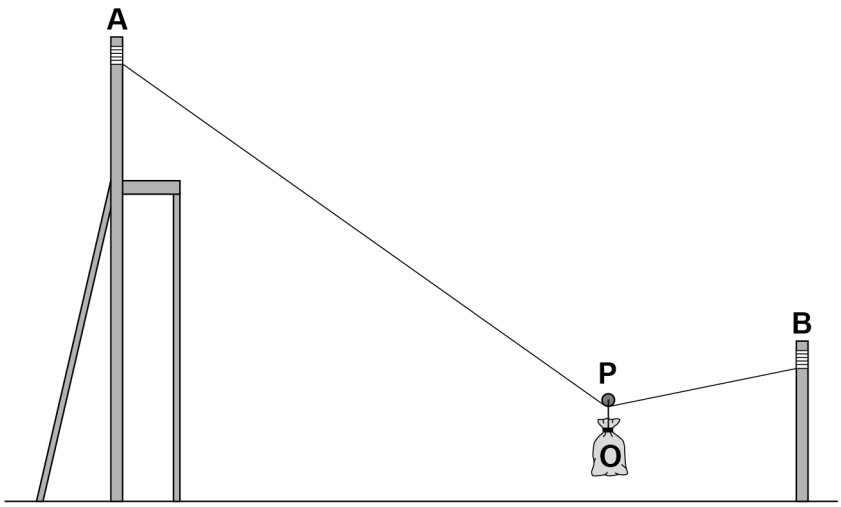
4

0 5 A cable system is to be used to transfer supplies across a river. A model of the proposed system is built in order to test its performance.

The model consists of a cable attached to two vertical posts **A** and **B**, as shown in **Figure 3**.
A pulley **P** of negligible mass is attached to the cable.

In this question the length of the cable does not change and the weight of the cable can be ignored.

Figure 3



An object **O** is attached to **P**. In one test, **O** and **P** are at rest in the position shown in **Figure 3**.
The weight of **O** is 350 N.

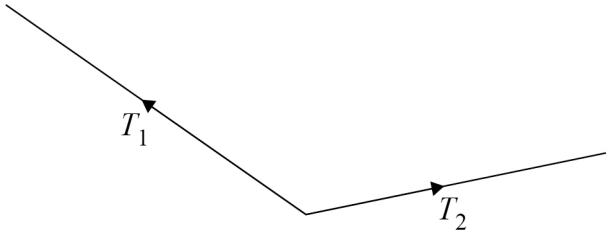
Question 5 continues on the next page

0 5 . 1 **Figure 4** is a force diagram drawn to scale. It represents the magnitudes and directions of the tensions T_1 and T_2 in the cable when **O** is at rest in the position shown in **Figure 3**. At this position, resistive forces are zero.

Complete the force diagram.
Go on to determine, using your diagram, the magnitudes of T_1 and T_2.

[4 marks]

Figure 4



$T_1 =$ _____ N

$T_2 =$ _____ N

Do not write outside the box

0 5 . 2 In a second test, pulley **P** with **O** attached is released from **A**.
P and **O** move along the cable to **B**.

The change in height of the centre of mass of **O** between **A** and **B** is $4.5\ \text{m}$.
The distance travelled along the cable is $18\ \text{m}$.

The speed of **O** when it reaches **B** is $6.5\ \text{m s}^{-1}$.

Calculate the average resistive force on **O** and **P** as they move from **A** to **B**.

[5 marks]

average resistive force = _____ N

Question 5 continues on the next page

0 5 . 3 **O** contains a fragile item packed in suitable material.

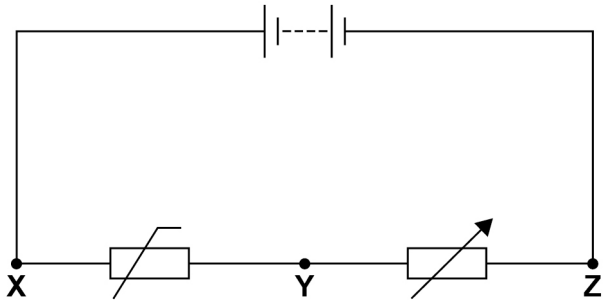
Explain how the material can prevent damage to the fragile item when **O** stops suddenly at **B**.

[3 marks]

12

0 6 The circuit in **Figure 5** is used as part of a temperature sensor.
The battery has an emf of 6.5 V and negligible internal resistance.

Figure 5



The initial temperature of the thermistor is 22 °C.
At this temperature the resistance of the thermistor is 350 Ω and the circuit current is 12 mA.

0 6 . 1 Calculate the resistance of the variable resistor.

[2 marks]

resistance = _____ Ω

Question 6 continues on the next page

Do not write outside the box

0 6 . 2 The resistance R of the thermistor at temperature θ in K is given by:

$$R = R_0 e^{B\left(\frac{1}{\theta} - \frac{1}{\theta_0}\right)}$$

where R_0 is the resistance at the initial temperature θ_0 in K, and B is a constant.

The temperature of the thermistor is increased to 318 K.
The variable resistor is adjusted so that the circuit current is again 12 mA.
The potential difference across the thermistor is now 3.2 V.

Determine B.
State an appropriate unit for your answer.

[5 marks]

$B =$ _____ unit = _____

Do not write outside the box

0 6 . 3 Explain why the current in the thermistor needs to be controlled.

[2 marks]

0 6 . 4 Explain how ammeters and voltmeters can be used in the circuit in **Figure 5** to demonstrate the conservation of charge and the conservation of energy.

Refer to points **X**, **Y** and **Z** in your answer.

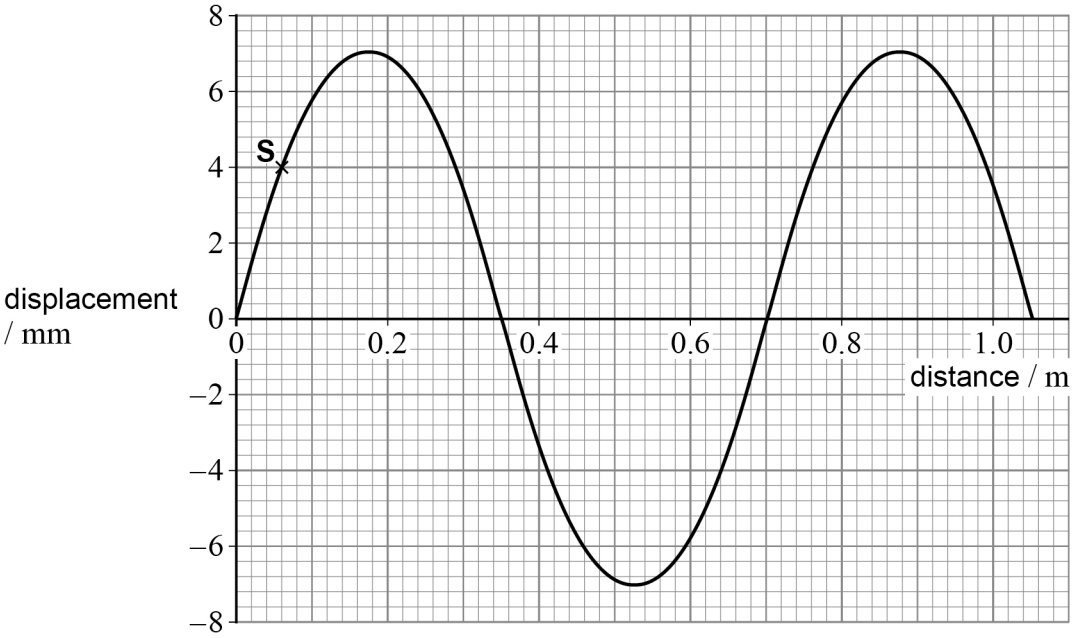
[2 marks]

11

0 7 An experiment is done to investigate stationary waves on a string.
A string of length 1.05 m is attached between a clamp stand and a vibration generator. A stationary wave is formed on the string when the vibration generator frequency is 625 Hz.

Figure 6 shows the variation of displacement with distance from one end of the string at time $t = 0$
At this time all points on the string have their maximum displacement.
S is one point on the string.

Figure 6



The stationary wave is produced by two progressive waves travelling in opposite directions on the string.

0 7 . 1 Deduce the amplitude of one of the progressive waves.

[1 mark]

amplitude = _____ mm

Do not write outside the box

0 7 . 2 Determine, in $\mathrm{m\ s^{-1}}$, the speed of one of the progressive waves.

[2 marks]

speed = _____ $\mathrm{m\ s^{-1}}$

0 7 . 3 State the phase relationship between the two waves when $t = 0$

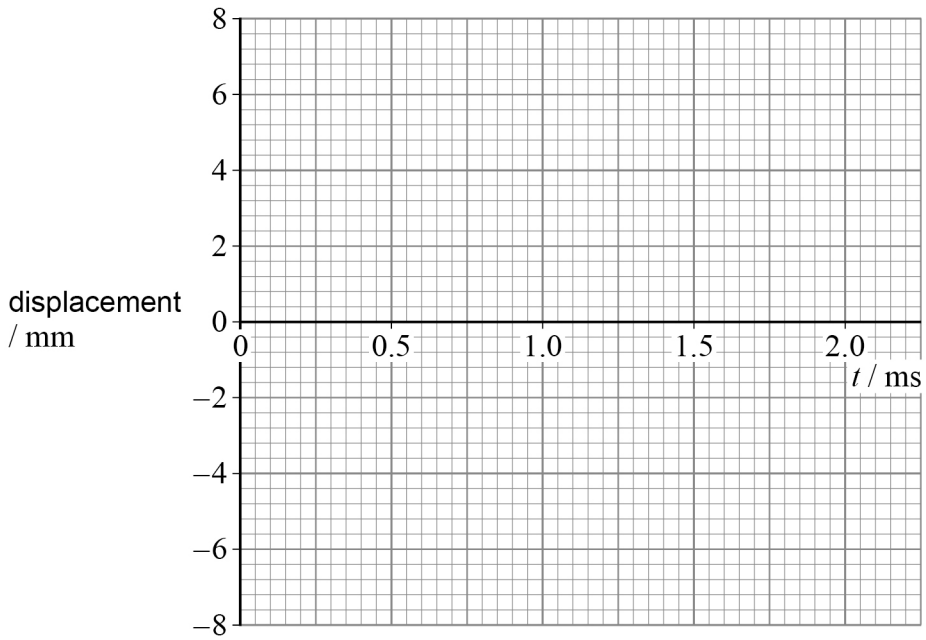
[1 mark]

_____

0 7 . 4 Sketch, on **Figure 7**, a graph to show how the displacement of **S** varies with t.

[3 marks]

Figure 7



7

END OF SECTION A

Do not write outside the box

Section B

Each of Questions **08** to **32** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD 

WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked. Do **not** use additional sheets for this working.

0 8 Which nuclear change results in the nucleus with the greatest specific charge?

[1 mark]

A the alpha decay of a $^{209}_{82}\mathrm{Po}$ nucleus

B the beta-minus decay of a $^{28}_{12}\mathrm{Mg}$ nucleus

C the beta-plus decay of a $^{39}_{20}\mathrm{Ca}$ nucleus

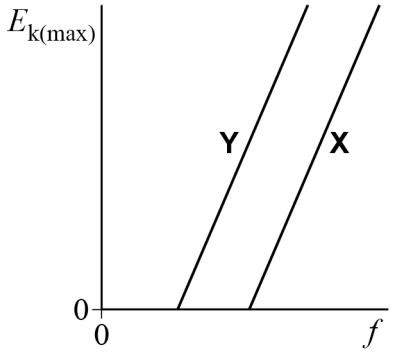
D electron capture by a $^{105}_{47}\mathrm{Ag}$ nucleus

0 9 In two separate experiments, electromagnetic radiation of variable frequency f is incident on the surfaces of plates made from metals **X** and **Y**.
The work function of **X** is greater than the work function of **Y**.

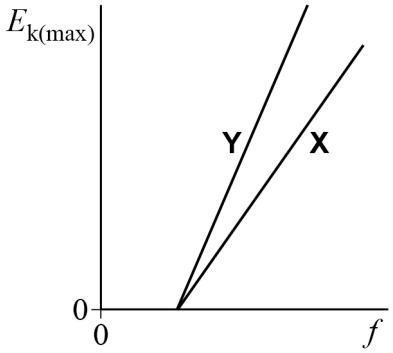
Which graph shows how the maximum kinetic energy $E_{k(max)}$ of photoelectrons emitted from the surfaces of the plates varies with f?

[1 mark]

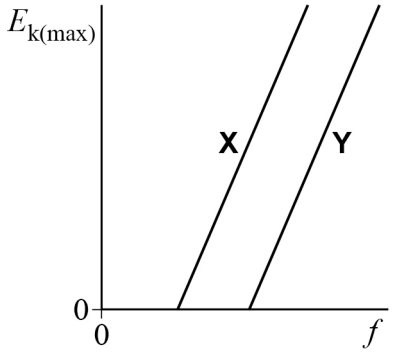
A



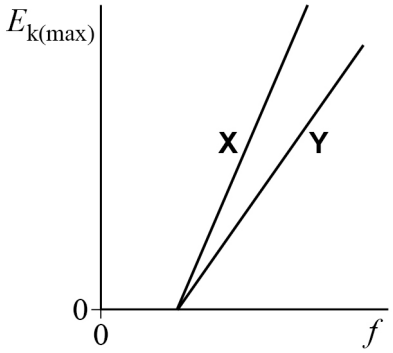
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 0 Monochromatic light is incident on a metal surface in a vacuum and photoelectrons are emitted from the surface. The photoelectric current I is the rate of flow of charge from the surface.
The maximum kinetic energy of the photoelectrons is $E_{k(max)}$.
$E_{k(max)}$ and I are measured.

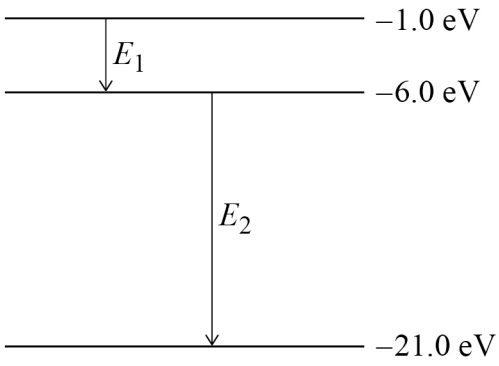
The frequency of the light is then increased. There is no change to the rate at which energy is incident on the surface.

What happens to $E_{k(max)}$ and I when the frequency is increased?

[1 mark]

	$E_{k(max)}$	I	
A	increases	decreases	⬭
B	increases	no change	⬭
C	no change	no change	⬭
D	no change	decreases	⬭

1 1 Three energy levels for an atom are shown.



Energy change E_1 leads to the emission of a photon of wavelength λ_1.
Energy change E_2 leads to the emission of a photon of wavelength λ_2.

What is $\frac{\lambda_1}{\lambda_2}$?

[1 mark]

A $\frac{1}{4}$ ⬭

B $\frac{1}{3}$ ⬭

C 3 ⬭

D 4 ⬭

1 2 An electron and a proton move with the same speed.

What is $\frac{\text{de Broglie wavelength of electron}}{\text{de Broglie wavelength of proton}}$?

[1 mark]

A 5.5×10^{-4} ⬭

B 2.3×10^{-2} ⬭

C 42 ⬭

D 1800 ⬭

Do not write outside the box

1 3 A laser emits light of wavelength $600\ \text{nm}$ for $10\ \text{ns}$.

What is the number of complete waves emitted by the laser?

[1 mark]

A 5×10^{17} ⬭

B 5×10^{12} ⬭

C 5×10^{8} ⬭

D 5×10^{6} ⬭

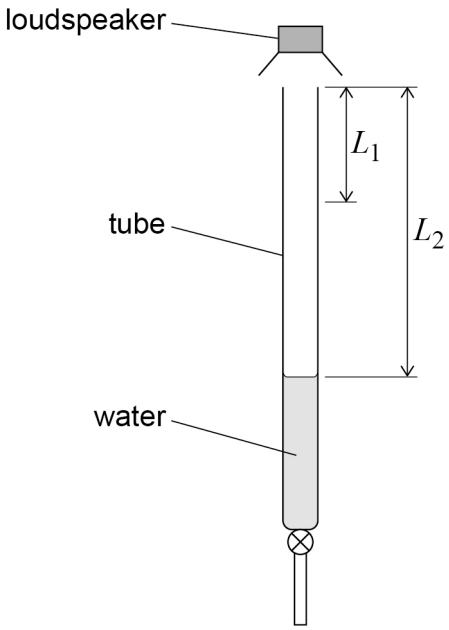
1 4 A detector measures the intensity of light from a source S_1.
Polaroid material is placed between source S_1 and the detector. When the material is rotated through a small angle, the detected intensity does not change.
When this procedure is repeated for a source S_2, the detected intensity decreases.

Which is correct?

[1 mark]

	Light waves from S_1	**Light waves from S_2**	
A	unpolarised	polarised	⬭
B	unpolarised	unpolarised	⬭
C	polarised	polarised	⬭
D	polarised	unpolarised	⬭

1 5 A loudspeaker producing a single-frequency sound is mounted above a tube filled with water. A tap at the bottom of the tube is opened to allow the water to run out.



A student observes the change in loudness of the sound emitted by the tube as the water runs out.

When the length of the column of air in the tube reaches L_1, the loudness is at its first maximum.

The next maximum is reached when the length of the column of air is L_2.

What is the wavelength of the sound emitted by the loudspeaker?

[1 mark]

A L_2 ⬭

B $2L_1$ ⬭

C $L_2 - L_1$ ⬭

D $2(L_2 - L_1)$ ⬭

1 6 Point sources of sound of the same frequency are placed at S_1 and S_2.

A sound detector is moved slowly along the line **PQ**. Consecutive maxima of sound intensity are detected at **W** and **Y** and consecutive minima are detected at **X** and **Z**.

What is the wavelength of the sound?

[1 mark]

A $(S_1Y - S_2Y) - (S_1W - S_2W)$ ⬭

B $(S_1X - S_2X) - (S_1W - S_2W)$ ⬭

C $(S_1Y - S_2Y) - (S_1X - S_2X)$ ⬭

D $(S_1Z - S_2Z) - (S_1W - S_2W)$ ⬭

1 7 Monochromatic light is used in a Young's double-slit interference experiment after passing through a single slit. The resulting fringe pattern is observed on a screen.

The separation of the fringes can be increased by

[1 mark]

A using monochromatic light of lower frequency. ⬭

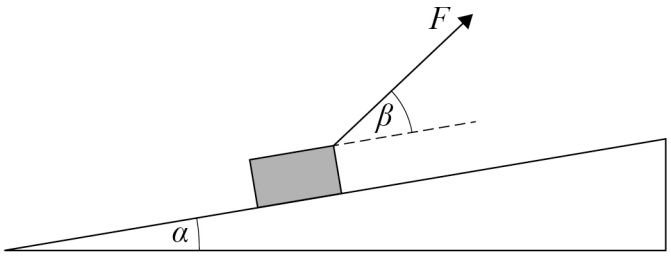
B decreasing the width of the single slit. ⬭

C increasing the separation of the double slits. ⬭

D decreasing the distance between the double slits and the screen. ⬭

Do not write outside the box

1 8 A force of magnitude F acts on a box of mass m that moves along a frictionless slope. The slope is at an angle α to the horizontal and the force acts at an angle β to the slope.



What is the magnitude of the acceleration of the block along the slope?

[1 mark]

A $\frac{F}{m}\sin\alpha - g\sin\beta$ ⬭

B $\frac{F}{m}\cos\beta - g\sin\alpha$ ⬭

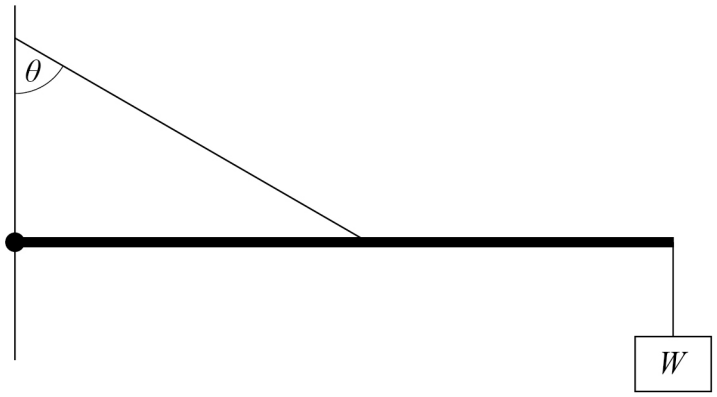
C $\frac{F}{m}\cos(\alpha+\beta) - g\cos\beta$ ⬭

D $\frac{F}{m}\cos(\alpha+\beta) - g\sin\beta$ ⬭

Turn over for the next question

1 9 The weight of a uniform bar is W.
An object also of weight W is attached to one end.
The bar is pivoted at the other end and held horizontal by a rope attached to its centre.
The tension in the rope is $4W$.

not to scale



What is angle θ?

[1 mark]

A 41° ⬭

B 45° ⬭

C 60° ⬭

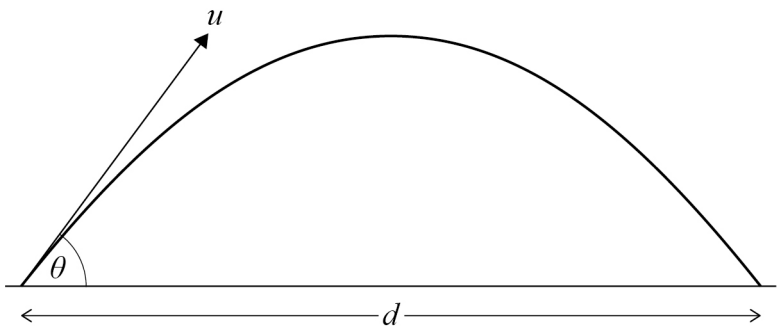
D 71° ⬭

Do not write outside the box

2 0 A projectile is fired from ground level over horizontal ground.

Its initial velocity is u at an angle θ to the horizontal.

The range of the projectile is d.



A second projectile is fired with a velocity $2u$ at the same angle.

What is the range of this projectile?
Assume that air resistance is negligible.

[1 mark]

A $\sqrt{2}d$ ⬭

B $2d$ ⬭

C $2\sqrt{2}d$ ⬭

D $4d$ ⬭

2 1 A particle travelling horizontally at $1.0 \times 10^{7}\ \text{m s}^{-1}$ enters a region where it has a constant vertical acceleration of $4 \times 10^{14}\ \text{m s}^{-2}$.

What is the horizontal distance the particle has travelled in the region when its vertical displacement is 8×10^{-2} m?

[1 mark]

A 0.2 m ⬭

B 0.1 m ⬭

C 2×10^{-8} m ⬭

D 0.4×10^{-9} m ⬭

Turn over ►

Do not write outside the box

2 2 An object is thrown vertically upwards at time $t = 0$

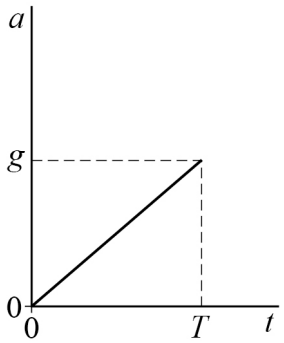
The object reaches its maximum height when $t = T$ and reaches its terminal speed on the way down.

The magnitude of the object's acceleration is a.

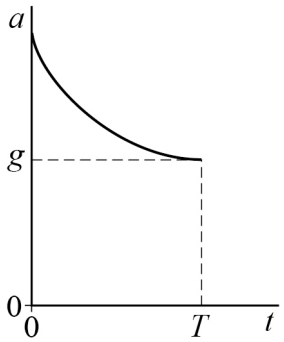
Which graph shows the variation of a with t?

[1 mark]

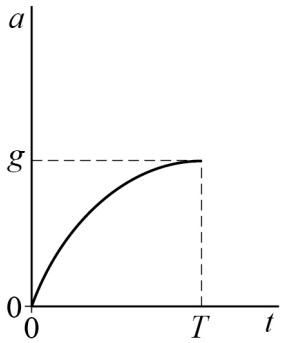
A



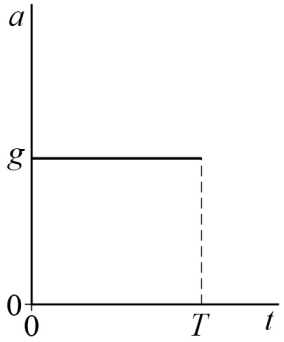
B



C



D



Do not write outside the box

2 3 A man has a mass of $75.0\ \text{kg}$.
He stands on weighing scales in a lift that accelerates upwards at $2.60\ \text{m s}^{-2}$.

What is the reading on the scales during the acceleration?

[1 mark]

A $195\ \text{N}$ ⬭

B $541\ \text{N}$ ⬭

C $736\ \text{N}$ ⬭

D $931\ \text{N}$ ⬭

2 4 An average force of $42\ \text{kN}$ acts on the air passing through a jet engine. This force causes the speed of the air to increase by $540\ \text{m s}^{-1}$.

What mass of air passes through the engine in one minute?

[1 mark]

A $7.7 \times 10^{-2}\ \text{kg}$ ⬭

B $4.7\ \text{kg}$ ⬭

C $78\ \text{kg}$ ⬭

D $4700\ \text{kg}$ ⬭

2 5 A uniform wire is stretched by a load F.
The elastic strain energy stored in the wire is E.

The load is increased from F to $2F$.
The wire obeys Hooke's law.

What is the increase in the elastic strain energy stored in the wire?

[1 mark]

A E ⬭

B $2E$ ⬭

C $3E$ ⬭

D $4E$ ⬭

Do not write outside the box

2 6 A spring is compressed by a force F. The spring has stiffness k and its length changes by ΔL during the compression. When the force is removed the spring returns to its original length in time t.

What is the average power developed by the spring as it returns to its original length?

[1 mark]

A $\frac{k\Delta L}{2t}$ ⬭

B $\frac{k\Delta L}{t}$ ⬭

C $\frac{k(\Delta L)^2}{2t}$ ⬭

D $\frac{k(\Delta L)^2}{t}$ ⬭

2 7 A $12\ \Omega$ resistor is connected across the terminals of a battery of emf $2.0\ \text{V}$ and internal resistance $4.0\ \Omega$.

What is the pd across the resistor?

[1 mark]

A $0.25\ \text{V}$ ⬭

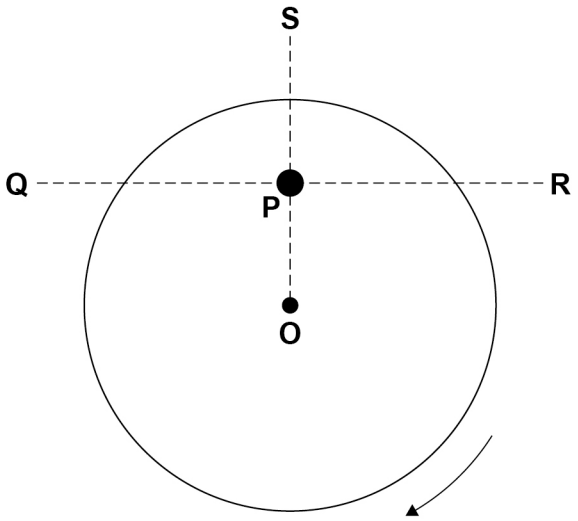
B $0.75\ \text{V}$ ⬭

C $1.30\ \text{V}$ ⬭

D $1.50\ \text{V}$ ⬭

2 8 A small mass is placed at **P** on a horizontal turntable. The turntable rotates clockwise with a constant angular speed about a vertical axis through its centre **O**.

view of turntable from above



The mass remains at rest relative to the turntable.

What is the direction of the frictional force on the mass at the instant shown?

[1 mark]

A from **P** to **O** ⬭

B from **P** to **Q** ⬭

C from **P** to **R** ⬭

D from **P** to **S** ⬭

Turn over for the next question

2 9 A particle of mass m moves in a circle of radius r. The number of revolutions completed per second is f.

What is the kinetic energy of the particle?

[1 mark]

A $4\pi^2 mf^2 r^2$ ⬭

B $2\pi^2 mf^2 r^2$ ⬭

C $\dfrac{mf^2r^2}{4\pi^2}$ ⬭

D $\dfrac{mf^2r^2}{2}$ ⬭

3 0 A body is in simple harmonic motion of amplitude $0.60\ \text{m}$ and period 2π seconds.

What is its speed when its displacement is $0.20\ \text{m}$?

[1 mark]

A $0.32\ \text{m s}^{-1}$ ⬭

B $0.57\ \text{m s}^{-1}$ ⬭

C $0.63\ \text{m s}^{-1}$ ⬭

D $22\ \text{m s}^{-1}$ ⬭

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3 1 When a mass **M** is suspended from a spring, the spring extends by a distance x.
M is displaced vertically and, when released, it oscillates with a period T.

M is removed and suspended from a different spring. The spring extends by a distance $\frac{x}{2}$.

M is again displaced vertically and released.

What is the new period of oscillations of **M**?

[1 mark]

A $\frac{T}{2}$ ⬭

B $\frac{T}{\sqrt{2}}$ ⬭

C $T\sqrt{2}$ ⬭

D $2T$ ⬭

3 2 A mass–spring system and a simple pendulum have identical periods of oscillation T when at the surface of the Earth.

Both are taken to planet **X** where the acceleration due to gravity is $\frac{g}{2}$.

What are the periods of the mass–spring system and the simple pendulum on **X**?

[1 mark]

	Period of mass–spring system	Period of simple pendulum	
A	$\frac{T}{2}$	$T\sqrt{2}$	⬭
B	T	$2T$	⬭
C	T	$T\sqrt{2}$	⬭
D	$T\sqrt{2}$	T	⬭

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END OF QUESTIONS

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