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

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	
7–31	
TOTAL	

JUN2174081O1   IB/M/Jun21/E8

7408/1

Section A

Answer **all** questions in this section.

0 1 Cosmic rays are high-energy particles that come from space. Most of these particles are protons. There are other particles in cosmic rays, including atomic nuclei.

Table 1 gives the data for one particular nucleus **X**.

Table 1

Mass / kg	8.02×10^{-26}
Specific charge / $C\,kg^{-1}$	4.39×10^7
Kinetic energy / MeV	215

0 1 . 1 Determine the number of neutrons in nucleus **X**.

[3 marks]

Charge on protons = 1.6×10^{-19} C

Total charge in X

= Specific charge × mass

= $\frac{C}{kg} \times kg$

= C

$= 4.39 \times 10^7 \times 8.02 \times 10^{-26}$

$= 3.52 \times 10^{-18}$ C

No. of protons $= \dfrac{3.52 \times 10^{-18} C}{1.6 \times 10^{-19} C}$

$= 22$

Nucleons $= \dfrac{8.02 \times 10^{-26}}{1.67 \times 10^{-27}} = 48$

number of neutrons = $48 - 22 = \underline{26}$

0 1 . 2 Calculate the speed of **X**.
Ignore relativistic effects. (x moving with speed higher than speed of light)

[3 marks]

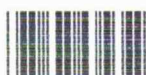$E_k = (215 \times 10^6 \times 1.6 \times 10^{-19})$ J

$= 3.44 \times 10^{-11}$ J

$E_k = \frac{1}{2}mv^2$

$v = \sqrt{\dfrac{2 \times E_k}{m}}$

$v = \sqrt{\dfrac{2 \times 3.44 \times 10^{-11}}{8.02 \times 10^{-26}}}$

$= 29,289,168$ m s^{-1}

$= 2.9 \times 10^7$ m s^{-1}

speed = 2.9×10^7 m s^{-1}

Do not write outside the box

A pion (π^+) and a kaon (K^+) are produced when cosmic rays interact with the upper atmosphere.

0 1 . 3 The π^+ decays to produce a positron and an electron neutrino.

Show how the conservation laws apply to this decay.

[2 marks]

$$\pi^+ \longrightarrow e^+ + \nu_e \quad \text{Baryon Number}$$

$$+1 \qquad +1 \qquad 0 \qquad 0 = 0 + 0 \quad (\text{Conserved})$$

Charge is Conserved | Lepton Number

$$+1 = +1 + 0 \qquad 0 = -1 + (+1)$$

$$\Rightarrow +1 = +1 \qquad 0 = 0 \quad (\text{Conserved})$$

0 1 . 4 The K^+ decays to produce an anti-muon and a muon neutrino.

Explain how strangeness applies in this decay.

[2 marks]

$$K^+ \longrightarrow \mu^+ + \nu_\mu$$

$$+1 = 0 + 0 \quad (\text{strangeness})$$

- This is a weak interaction, so strangeness can change.
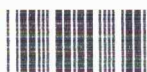
0 1 . 5 Write an equation for a K^+ decay that involves only hadrons.

[2 marks]

$$K^+ \longrightarrow \pi^+ + \pi^0$$

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Turn over ▶

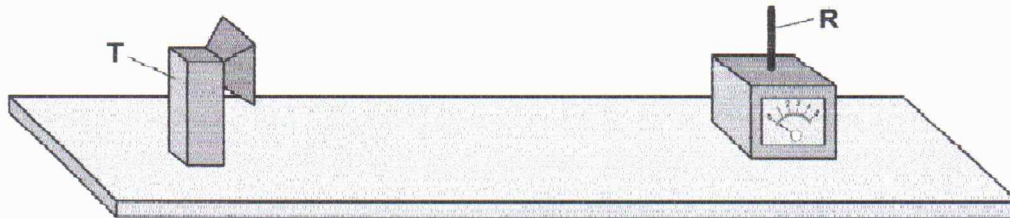**0 2**   **Figure 1** shows apparatus used to investigate the properties of microwaves.
The microwaves from the transmitter **T** are vertically polarised and have a wavelength
of about 3 cm.
The microwaves are detected at the receiver by a vertical metal rod **R**.
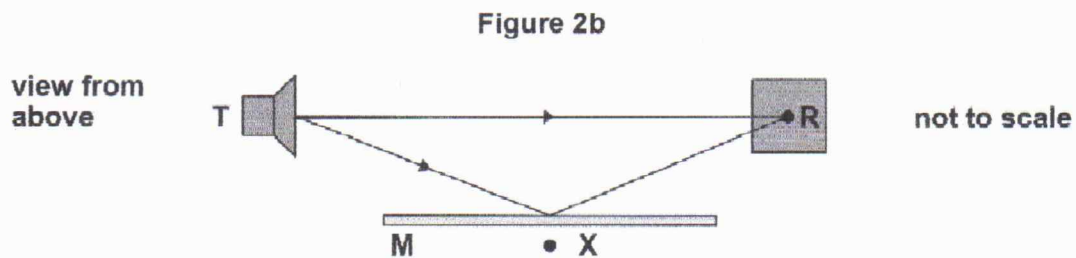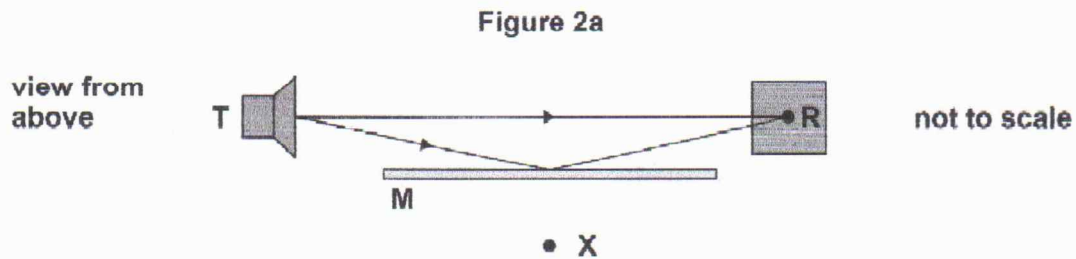
Figure 1

0 2 . 1   Explain how the apparatus can be used to demonstrate that the waves from **T** are
vertically polarised.

[3 marks]

– When aerial is rotated in vertical
plane, the signal maximum is detected.
– When aerial is rotated in horizontal
plane, a minimum is detected.
– Maximum occurs when aerial is
aligned with plane of polarisation
of the microwave.
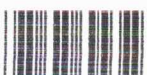
Figures 2a and **2b** show **T** and **R** and two different positions of a metal plate **M** that reflects microwaves. **M** is vertical and parallel to the direct transmission from **T** to **R**.

Figure 2a

view from
above   **T** ....→............... **R**   not to scale

M

• **X**

Figure 2b

view from
above   **T** ....→............... **R**   not to scale

M   • **X**

In an experiment, **T** and **R** are about two metres apart. **M** is moved slowly towards **X**.
Figure 2a shows the initial position of **M**.
Figure 2b shows **M** when it has been moved a few centimetres.

The arrowed lines show the path of waves that reach **R** directly and the path of waves that reach **R** by reflection from **M**.

0 2 . 2   Explain what happens to the signal detected by **R** as **M** is moved slowly towards **X**.
[4 marks]

— The reflected and the direct waves will interfere at R.
— So the received signal will have a series of max and min as the path difference increases as plate is moved towards X.
— This changes the phase difference between reflected and direct wave and so the signal strength at R changes.
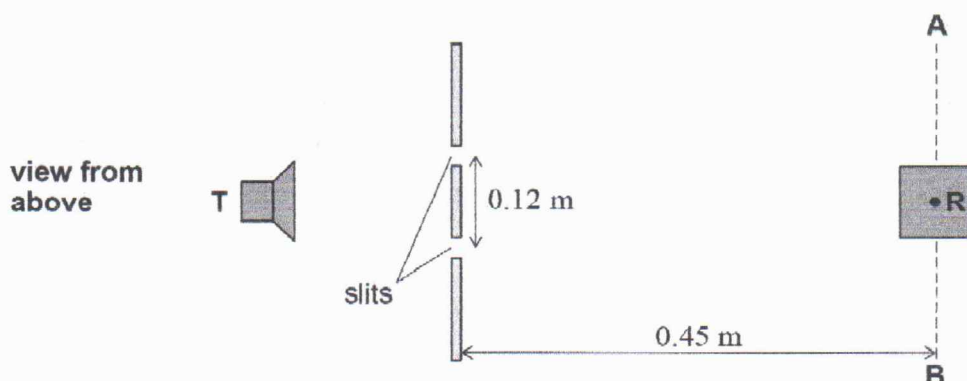
Question 2 continues on the next page

Turn over ▶

Figure 3 shows an arrangement used in a different experiment to try to determine the wavelength of the microwaves.

Figure 3

A double-slit arrangement is placed between **T** and **R**.

The initial position of **R** is the same distance from each slit and is 0.45 m from the midpoint of the two slits.
AB is a line perpendicular to the line between **T** and the initial position of **R**.
R can be moved 0.25 m towards **A** and 0.25 m towards **B** along **AB**.

The two slits act as two coherent sources with a separation of 0.12 m.

| 0 | 2 | . | 3 | Suggest why Young's double-slit equation should **not** be used to determine the wavelength.

[1 mark]

- The screen distance should be much greater than the slit seperation for the equation $\lambda = \frac{ws}{D}$ to be used.

0 2 . 4   The wavelength is known to be about 3 cm.

Deduce whether this practical arrangement is suitable for a determination of a value for the wavelength.

[3 marks]

Max path length
for 1st slit
$$= \sqrt{0.45^2 + (0.25 - 0.06^2}$$
$$= 0.49 m.$$

max path length for
2nd slit
$$= \sqrt{0.45^2 + (0.25 + 0.06)^2}$$
$$= 0.55 m$$

Path difference
$$= 0.55 - 0.49$$
$$= 0.06 m.$$
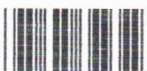
$$0.03 \div 2 = 0.015 m$$

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Since 0.06 is greater than $0.03 \div 2 = 0.015 m$ then yes the arrangement is suitable for determining value of λ.

Turn over for the next question

0 3 Figure 4 shows a ray of monochromatic light incident at angle A from air onto the end of a straight optical fibre.

This ray undergoes total internal reflection at the core–cladding boundary. A ray that enters the optical fibre at an angle greater than A will only be partially reflected at the core–cladding boundary.
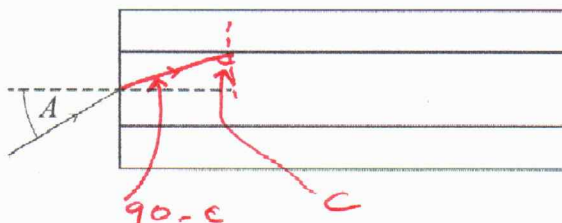
Figure 4

Table 2 shows some properties of the optical fibre.

Table 2

	Refractive index
cladding	1.41
core	1.47

0 3 . 1 Calculate the speed of the light ray in the optical fibre.

[1 mark]

$n = \dfrac{\text{speed in vacuum}}{\text{speed in fibre}}$

$\text{Speed in fibre} = \dfrac{3.0 \times 10^8}{1.47}$

$= 2.04 \times 10^8$

speed = _____2.0 × 10⁸_____ m s⁻¹
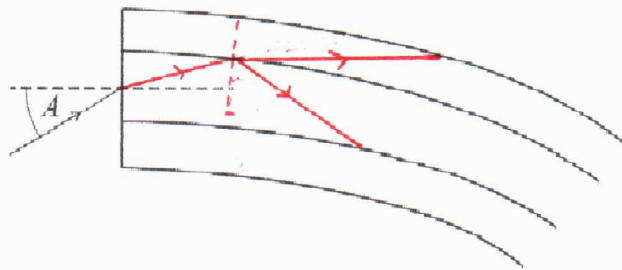
0 3 . 2   Calculate A, in degrees, for the optical fibre shown in **Figure 4**.

[3 marks]

the critical angle c;

$$\sin_i = \frac{n_2}{n_1}$$

$$= \frac{1.41}{1.47}$$

$$= 0.96$$

$$= \sin^{-1}(0.96)$$

$$c = 73.6°$$

angle of refraction

$$= 90 - 73.6$$

$$= 16.4$$

$$n = \frac{\sin A}{\sin r}$$

$$A = \sin^{-1}(1.47 \sin 16.4°)$$

$$= 24.5°$$

$A =$ _____ 24.5° _____ degrees

0 3 . 3   A ray is incident on the optical fibre at angle A. The optical fibre is now bent, as shown in **Figure 5**.

Figure 5

Draw, on **Figure 5**, what happens to the ray within the optical fibre.
Explain your answer.

[3 marks]

- Since the fibre is bent, the critical angle is greater than the angle of incidence.

- So some light will be refracted in the cladding.
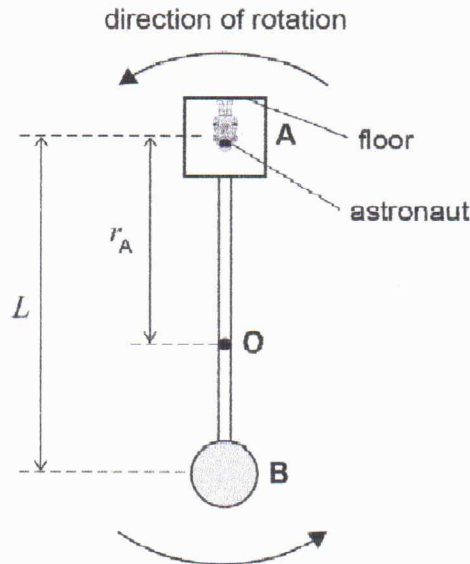
- Some will undergo partial reflected into the core.

7

Turn over ▶

0 4 Figure 6 shows a rotating spacecraft that is proposed to carry astronauts to Mars.

Figure 6

direction of rotation

The spacecraft consists of two parts **A** and **B** connected by a rigid cylindrical rod. When the spacecraft is travelling, **A** and **B** rotate at a constant angular speed about their common centre of mass **O**.

L is the distance between the centre of mass of **A** and the centre of mass of **B**. r_A is the distance from **O** to the centre of mass of **A**.

0 4 . 1 As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why.

[2 marks]

— As it rotates a centripetal force acts on the astronaut and is directed towards the centre of rotation.
— This force is similar to gravity.

0 4 . 2 The forces exerted on **A** and **B** by the connecting rod have the <u>same</u> magnitude.

m_A is the mass of **A**

m_B is the mass of **B**

Show, by considering the centripetal forces acting on **A** and **B**, that r_A is given by

$$r_A = \frac{m_B L}{m_A + m_B}$$

[2 marks]

$F_A = m_A r_A \omega^2$

but $r_B = L - r_A$

$\therefore m_A r_A \omega^2 = m_B (L - r_A) \omega^2$

$F_B = m_B (L - r_A) \omega^2$

$m_A r_A = m_B L - m_B r_A$

$m_A r_A + m_B r_A = m_B L$

Remember

$F_A = F_B$

$r_A (m_A + m_B) = m_B L$

$$r_A = \frac{m_B L}{m_A + m_B}$$

0 4 . 3 In this spacecraft $m_A < m_B$.

<u>Deduce</u> whether the centre of mass of **A** or the centre of mass of **B** rotates with a greater linear speed.

[2 marks]

— Both A and B have same angular velocity.　　　　(ω is same)

— Since $V = r\omega$ and r_A is greater than r_B, then $V_A = r_A \omega$ is greater than $V_B = r_B \omega$.

— So velocity of A is greater than that of B.

Question 4 continues on the next page

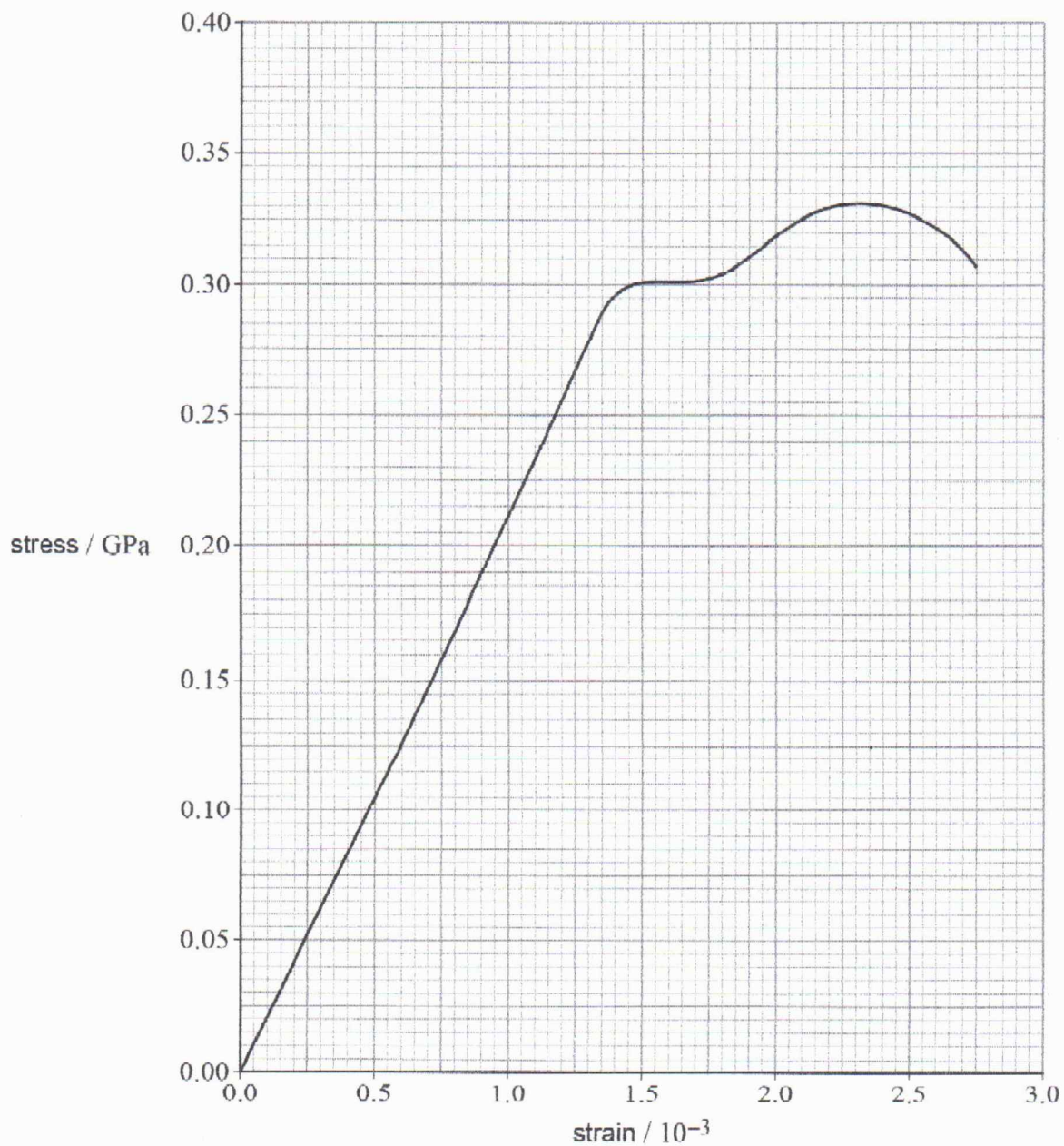The astronauts live in **A** and the cargo is stored in **B**.

When loaded,

$$m_A = 1.32 \times 10^6 \text{ kg}$$

$$m_B = 3.30 \times 10^6 \text{ kg}.$$

The spacecraft imitates the gravity of Mars where $g = 3.7 \text{ m s}^{-2}$.

Figure 7 shows a stress–strain curve for the metal used for the rigid rod.

Figure 7

stress / GPa

strain / 10^{-3}

0 4 . 4 Suggest a suitable diameter for the rod.
Justify your answer.

[5 marks]

$f = m \times a$

$= 1.32 \times 10^6 \times 3.7$

$= 4.9 \times 10^6 N.$

$\text{Stress} = \dfrac{\text{Force}}{\text{Area}}$

$\text{Area} = \pi r^2$

$= \pi \left(\dfrac{d}{2}\right)^2$

$\therefore \quad = \dfrac{\pi d^2}{4}$

$\therefore \quad d = \sqrt{\dfrac{4 \times \text{area}}{\pi}}$

$\text{Area} = \dfrac{4.9 \times 10^6 N}{0.3 \times 10^9 N m^{-2}}$

$= 0.0163 m^2$

$d = \sqrt{\dfrac{4 \times 0.0163}{\pi}}$

$= 0.144 m$

At a stress of 0.3 GPa
the metal undergoes plastic
deformation

- So for safety conserns
the diameter should be
greater than 0.144m
for the metal to withstand
a stress of 0.3 GPa
$d = 0.2m$

diameter = _____0.2_____ m

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0 5   **Figure 8** shows the H-shaped posts used in a game of rugby.

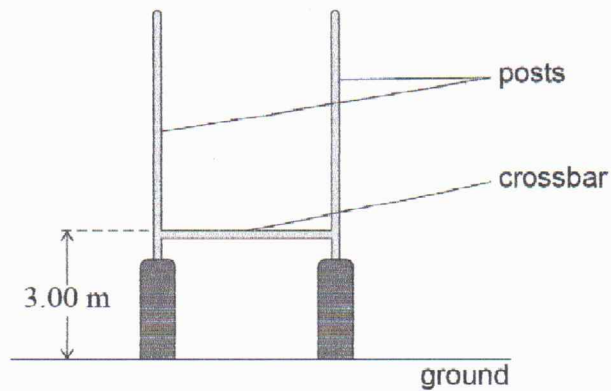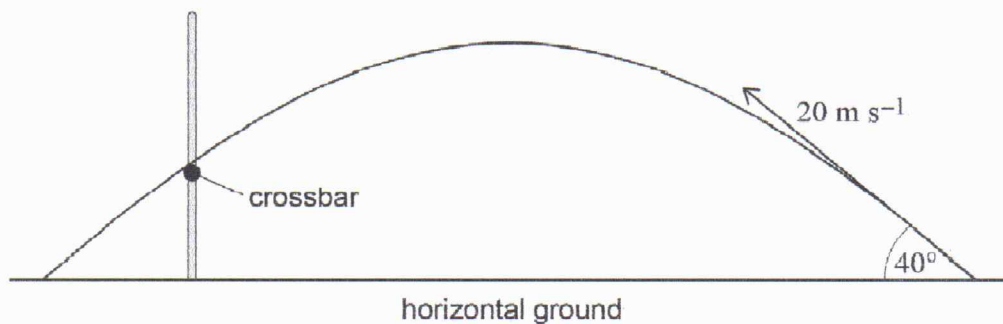**Figure 8**

posts

crossbar

3.00 m

ground

Figure 9 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is 20.0 m s^{-1} at an angle of 40.0° to the ground.

You should consider air resistance to be negligible and treat the ball as a simple projectile.
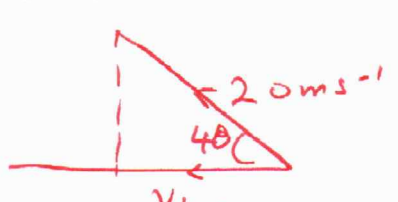
Figure 9

20 m s^{-1}

crossbar

40°

horizontal ground

The top of the crossbar is 3.00 m above the horizontal ground.

0 5 . 1 Show that the minimum speed of the ball in flight is about 15 m s^{-1}.

Explain your answer.

[2 marks]

V_h is horizontal velocity of ball.

$V_h = 20 \cos 40°$

$= 15.3$ m s^{-1}

$\cos 40° = \dfrac{V_h}{20}$

— Since air resistance is negligible and horizontally the ball is not acted by gravity, so 15.3 ms^{-1} is constant.

0 5 . 2 The ball just passes over the crossbar at a time t after it is kicked.

Show that t must satisfy the following equation:

$$4.91t^2 - 12.9t + 3.00 = 0$$

[2 marks]

Vertical velocity (initial).

$V_v = 20 \sin 40°$

$= 12.9$ m s^{-1}

$s = ut + \frac{1}{2}gt^2$

$s = 3.0$ m (displacement)
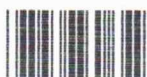
$u = 12.5$ ms^{-1}

$g = 9.81$ ms^{-1}

$t = t$

$-3 = -12.9t + \frac{1}{2} \times 9.81 t^2$

$= 12.9t + 4.91t^2$

$4.91t^2 - 12.9t + 3 = 0$

Question 5 continues on the next page

Turn over ▶

0 5 . 3 There are two solutions to the equation

$$4.91t^2 - 12.9t + 3.00 = 0$$

$a \qquad b \qquad c$

Discuss which of the two solutions is the time taken for the ball to pass over the crossbar from when it is kicked.

In your answer you should

$a = 4.91$
$b = -12.9$

* state the value for t given by each solution
* explain the physical significance of the other solution.

$c = 3.00$

[4 marks]

Use

$$a = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

to solve to t

$$t = \frac{-(-12.9) \pm \sqrt{(-12.9)^2 - (4 \times 4.91 \times 3)}}{2 \times 4.91}$$

$$t = 0.258 \text{ s}$$

or

$$t = 2.37 \text{ s}$$

solution 1 = _____ 0.258 _____ s

solution 2 = _____ 2.37 _____ s

– The answer is 2.37s for the ball to pass over the cross bar.

– It took the ball 0.258s to move a distance of 3.0m going up.

– To cross the bar, the ball is going down after reaching it max height.

0 5 . 4 Another attempt is made to kick the ball over the crossbar. The initial velocity of the ball is the same as in the first attempt.
This kick is made from a horizontal distance of 38 m from the posts.

Deduce whether the ball can pass over the crossbar.

[1 mark]

Calculate range

$R = V_h t$

$= 20 \cos 40° \times 2.37$

$= 36.3 m.$

Since $R = 36.3 m$, the ball does not reach the posts which are at a distance of 38 m from where the ball is
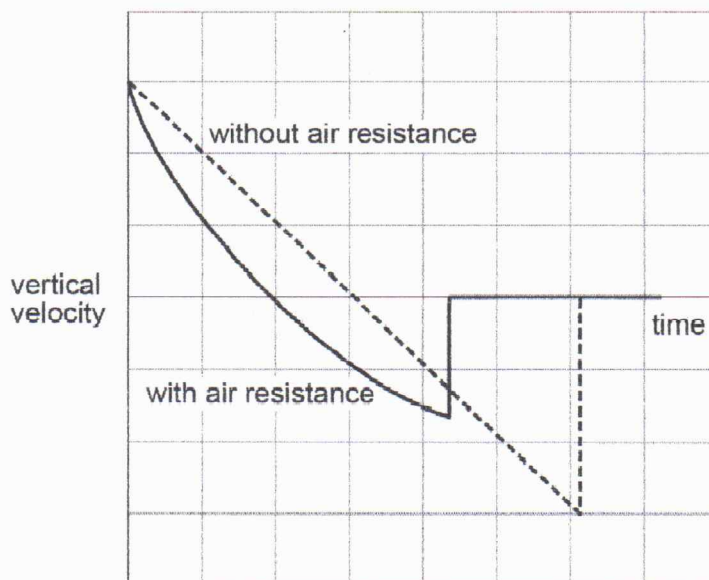
kicked from.

Question 5 continues on the next page

Turn over ▶

0 5 . 5 **Figure 10** shows the variations with time of the vertical velocity of a ball with and
without air resistance.

Figure 10

Discuss the features of the motion of the ball shown by the two graphs.

In your answer you should refer to

- the gradients of the graphs
- the area between each line and the time axis.

[5 marks]

— In v-t graph, gradient is equal to
acceleration.
— Area under graph is verticle distance
travelled by the ball.
— Without air resistance, gradient (acc)
is constant and displacement is zero
since area going up is equal to area down.
— With air resistance, gradient is steeper
since air resistance is in same direction with
weight, so a is greater than g.
— Max height without air resistance is greater
than max height with air resistance.

– This is because area under graph
without air resistance is greater than
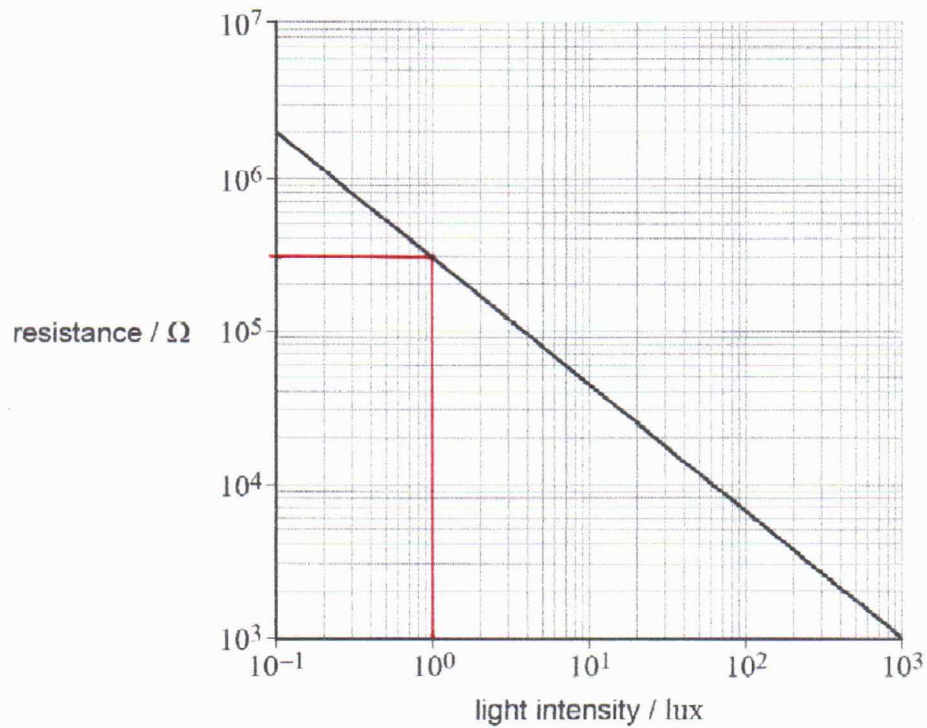area with air resistance.
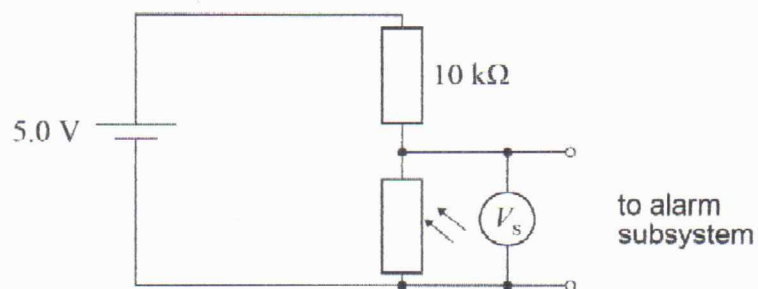
14

Turn over for the next question

0 6 **Figure 11** shows how the resistance of an LDR varies with light intensity.

Figure 11

The LDR is used as part of an alarm system in a dim room. **Figure 12** shows one proposal for a sensor circuit for this system.

Figure 12

The power supply to the sensor has an emf of 5.0 V and a negligible internal resistance. A negligible current is drawn from the sensor circuit by the alarm subsystem.

A light beam illuminates the LDR. When the light beam is broken the LDR is not illuminated by the light beam. This causes the alarm to sound.

Table 3 shows how the light intensity at the LDR changes.

Table 3

	Light intensity / lux
LDR illuminated by light beam	4.0
LDR **not** illuminated by light beam	1.0

$10^0 = 1.0$

0 6 . 1 Show that the current in the sensor circuit when the LDR is **not** illuminated by the light beam is approximately $16\ \mu A$.

[2 marks]

$1 \times 10^6 - 1.0 \times 10^5$

$= 900{,}000 \times \frac{1}{3}$

$= 300000\ \Omega$

$\simeq 300\ k\Omega$

$I = \frac{V}{R}$

$= \frac{5}{300000}$

$= 0.000016666\ A.$

$\simeq 1.6 \times 10^{-5}$

$= 16 \times 10^{-6} \approx 16\mu A.$

0 6 . 2 The alarm sounds when the potential difference V_S across the LDR changes by more than 25% of the power supply emf.

Discuss whether the circuit shown in **Figure 12** is suitable.
Support your answer with a calculation.

[3 marks]

without light

$V = 16 \times 10^{-6} \times 300 \times 10^3$

$= 4.84\ V$

with light

$V = \frac{5 \times 93 \times 10^3}{(93-10) \times 10^3}$

$= 4.51\ V$

$4.84 - 4.51$

$= 0.33\ V$

$25\% \text{ of } 5 = \frac{5 \times 25}{100} = 1.25\ V$

—so $1.25\ V$ is greater than $0.33\ V$ so the circuit is not suitable for alarm

END OF SECTION A

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Section B

Each of Questions **07** to **31** 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 7 Which is approximately equal to 3 kW h?

[1 mark]

Handwritten working:
$E = P \times t$

$3 \times 10^3 \times 3600 s$
$= 10,800,000 J$
$= 1.08 \times 10^7 J$
$\simeq 1.0 \times 10^7 J$

A 3×10^3 J ○

B 1×10^4 J ○

C 2×10^5 J ○

D 1×10^7 J ● ✓

---

0 8 Which is the shortest distance?

[1 mark]

A 10^{-19} Gm ○ ← $1 \times 10^{-19} \times 10^9 = 10^{-10}$ m.

B 10^{-14} km ● ← $10^{-14} \times 10^3 = 10^{-11}$ m ← smallest

C 10^{-4} μm ○ ← $10^{-4} \times 10^{-6} = 10^{-10}$ m

D 10^7 fm ○ ← $10^7 \times 10^{-12} = 10^{-5}$ m ← largest
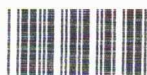
0 9 The gravitational force is one of the four fundamental forces.
The ticks in the table match particles with the other fundamental forces.

In which row is the particle matched to the only other fundamental forces it experiences?

[1 mark]

	Particle	Electromagnetic force	Weak nuclear force	Strong nuclear force	
A	μ^+	✓	✓		⬤ ✓
B	$\bar{p}$	✓		✓	◯
C	π^0	✓	✓	✓	◯
D	v_c		✓	✓	◯

1 0 The proton number of uranium is 92 and the proton number of radon is 88

Which series of decays turns a uranium nucleus into a radon nucleus?

[1 mark]

A $\alpha + \beta^- + \beta^- + \alpha + \alpha$ ⬤ ✓

B $\beta^- + \beta^- + \alpha + \beta^- + \alpha$ ◯

C $\alpha + \alpha + \alpha + \alpha + \beta^-$ ◯

D $\beta^- + \beta^- + \beta^- + \beta^- + \alpha$ ◯

$$_{92}U \longrightarrow _{90}X + _2^4\alpha$$

$$_{90}X \longrightarrow _{91}Y + _{-1}^0\beta$$

$$_{91}Y \longrightarrow _{92}Z + _{-1}^0\beta$$

$$_{92}Z \longrightarrow _{90}K + _2^4\alpha$$

$$_{90}K \longrightarrow _{88}R_a + _2^4\alpha \checkmark$$
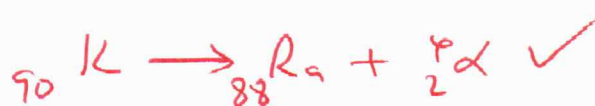
Turn over ▶

1 1 The diagram represents a particle interaction.

F d

β^+

G *neutrino*

E u
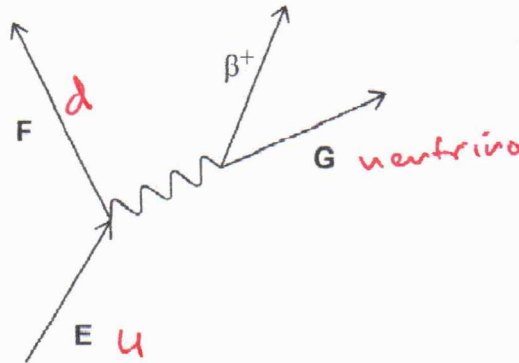
Which row identifies particles E, F and G?

[1 mark]

	E	F	G	
A	up quark	down quark	neutrino	✔
B	down quark	up quark	neutrino	
C	up quark	down quark	antineutrino	
D	down quark	up quark	antineutrino	

1 2 The quark combination of a particle is s$\bar{u}$.

Which is true for this particle?

[1 mark]

A It has a baryon number of 1

B It has a charge of -1.6×10^{-19} C. ✔

C It is a pion.

D It has a strangeness of $-\dfrac{1}{3}$

*pion = u$\bar{d}$
so s$\bar{u}$ is not a
pion though it's a
meson.*

	s	$\bar{u}$
charge	$-\frac{1}{3}$	$-\frac{2}{3}$
Baryon No	$\frac{1}{3}$	$\frac{1}{3}$
strangeness	-1	0

$-\frac{1}{3} + -\frac{2}{3} = \frac{-3}{3} = -1 \times 1.6 \times 10^{-19}$
$= -1.6 \times 10^{-19}$ C

$\frac{1}{3} + \frac{1}{3} = \frac{2}{3}$

$-1 + 0 = -1$

1 3 · Monochromatic light with a photon energy of 4.1×10^{-19} J is incident on a metal surface. The maximum speed of the photoelectrons released is 4.2×10^5 m s^{-1}.

What is the work function of the metal?

[1 mark]

$E_K = \frac{1}{2} \times 9.11 \times 10^{-31} \times (4.2 \times 10^5)^2$

$E = \phi + E_K$. $= 8.04 \times 10^{-20}$ J.

A 2.5×10^{-19} J ☐ $\phi = hf - \frac{1}{2}mv^2$

B 3.3×10^{-19} J ☒ ✓ $= 4.1 \times 10^{-19} - 8.04 \times 10^{-20}$

C 4.1×10^{-19} J ☐ $= 3.296 \times 10^{-19}$ J

D 4.9×10^{-19} J ☐ $\simeq 3.3 \times 10^{-19}$ J.

1 4 What is the role of the mercury vapour in a fluorescent tube?

[1 mark]

A It absorbs photons of UV light and emits visible light. ☐

B It absorbs photons of visible light and emits UV light. ☐

C It emits photons of visible light following ionisation or excitation. ☐

D It emits photons of UV light following ionisation or excitation. ☒ ✓

The photons are absorbed by electrons in the fluorescent coating which when

Turn over for the next question

they get excited and de-excite they emitt photons with frequency in the visible region.

1 5 The diagram shows the three lowest energy levels for an atom.
The energy levels have been drawn to scale.

level 2 ——————————————

level 1 ——————————————

ground state ——————————————

Transitions of electrons between these energy levels produce photons of the following frequencies:

4.56×10^{14} Hz
2.46×10^{15} Hz
2.92×10^{15} Hz.

What is the difference in energy between the ground state and energy level 1?

[1 mark]

A 0.3×10^{-18} J ▢

B 1.3×10^{-18} J ▢

C 1.6×10^{-18} J ▣ ✓

D 1.9×10^{-18} J ▢

- energy level 2 to ground has the highest frequency

- energy level 2 to energy level 1 has smallest frequency.

- Energy difference

$$hf = (6.63 \times 10^{-34})(2.92 \times 10^{15} - 4.56 \times 10^{14})$$

$$= 1.6336 \times 10^{-18} \text{ J}$$

$$\simeq 1.6 \times 10^{-18} \text{ J}$$

1 6 A muon and an electron are travelling at the same speed.

[handwritten: $E_k = \frac{1}{2}mv^2$]
[handwritten: $p = mv$]

Which row gives the particle with the greater kinetic energy and the particle with the longer de Broglie wavelength?

[handwritten: $\lambda = \frac{h}{p}$]

[1 mark]

[handwritten: muon has more mass than e⁻, so has greater K.E.]

	Greater kinetic energy	Longer de Broglie wavelength	
A	muon	muon	⬭
B	muon	electron	⬬ ✓
C	electron	muon	⬭
D	electron	electron	⬭

[handwritten: – Electron momentum is less than muon's, so has a longer λ.]

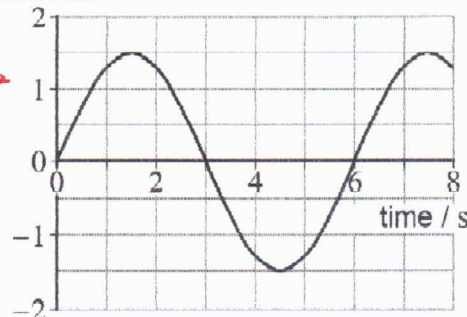**1 7** The diagrams show the displacement–distance graph for a wave and the displacement–time graph for a point in the wave.

displacement / m

[graph: displacement/m vertical axis from -2 to 2, horizontal axis distance/m marked 0, 20, 40, 60, showing a cosine-like wave. Handwritten: 1·5 m ↑ Amplitude, $\lambda = 40\,m$]

displacement / m

[graph: displacement/m vertical axis from -2 to 2, horizontal axis time/s marked 0, 2, 4, 6, 8, showing a sine-like wave]
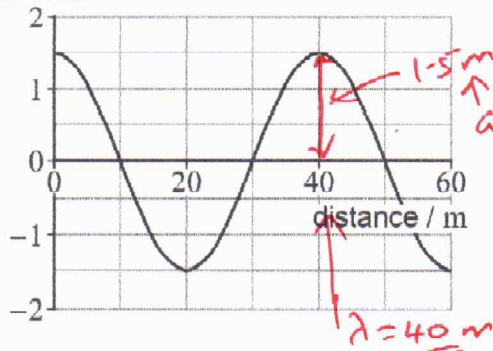
Which is correct for this wave?

[1 mark]

[handwritten: $T = 6\,s$]
[handwritten: $f = \frac{1}{T}$]
[handwritten: $= \frac{1}{6}$]
[handwritten: $= 0.17\,Hz$]

A The amplitude is 3.0 m. *[handwritten: ✗]* ⬭

B The wavelength is 6 m. *[handwritten: ✗]* ⬭

C The speed is 8.3 m s⁻¹. ⬭

D The frequency is 0.17 Hz. *[handwritten: ✓]* ⬬

[handwritten: $s = \frac{d}{t}$]
[handwritten: $= \frac{40m}{6s}$]
[handwritten: $= 6.67\,m\,s^{-1}$]

[handwritten: ∴ 8.3 m s⁻¹ is greater than 6.67 m s⁻¹.]

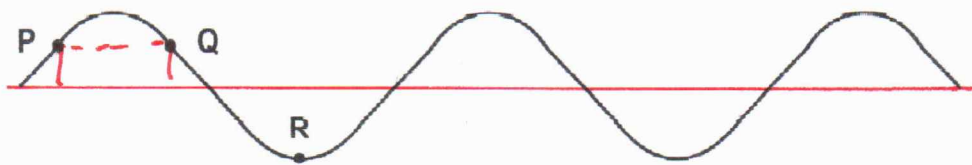**Turn over ▶**

1 8 The diagram shows a stationary wave on a string at one instant in time.
P, Q and R are three points on the string.

Which row is correct?

[1 mark]

A	P is in antiphase with R ✓	P has the same amplitude as Q	⬤ ✓
B	P is out of phase with R	P has the same amplitude as R	▢
C	P is in phase with Q	P has the same amplitude as R	▢
D	P is out of phase with Q	P has a smaller amplitude than R	▢

1 9 · A diffraction grating is illuminated normally.

The second-order maximum for light of wavelength 650 nm occurs at the same angle as the third-order maximum for light of wavelength λ.

What is λ?

[1 mark]

A 217 nm ▢

B 325 nm ▢

C 433 nm ⬤ ✓

D 975 nm ▢

$d \sin \theta = n\lambda$.

d is same

θ is same

∴ $d \sin \theta =$ constant

$k = n\lambda$.

$k = 2 \times 650$

$k = 3 \times \lambda$.

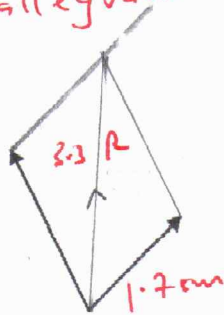$3\lambda = 2 \times 650$

$\lambda = \dfrac{2 \times 650}{3}$

$= 433 nm$

2 0 The diagram shows a vector diagram of two forces acting on an object.
The diagram is drawn to scale.
The magnitude of the smaller force is 5.0 N.

(handwritten) — Construct a parallegram to measure the length of resultant force R.
— Then use the scale to calculate R.

$R = 3.3$ cm.
$5N = 1.7$ cm

$R = \dfrac{3.3 \text{ cm} \times 5N}{1.7 \text{ cm}}$

$= 9.7$ N

What is the magnitude of the resultant force on the object?

[1 mark]

A 3.2 N   ⬭

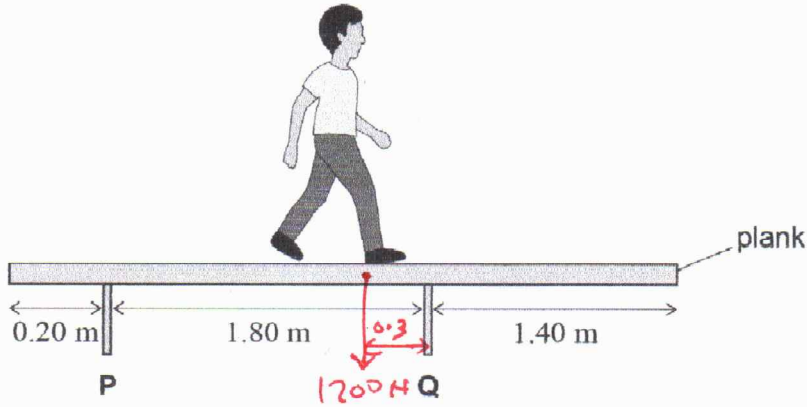B 7.5 N   ⬭

C 8.6 N   ⬭

D 9.6 N   ⬤ ✓

Turn over for the next question

2 1 A uniform plank weighs 1200 N and rests on two pillars **P** and **Q**.
P and **Q** are 1.80 m apart.
P is 0.20 m from one end of the plank. **Q** is 1.40 m from the other end of the plank.
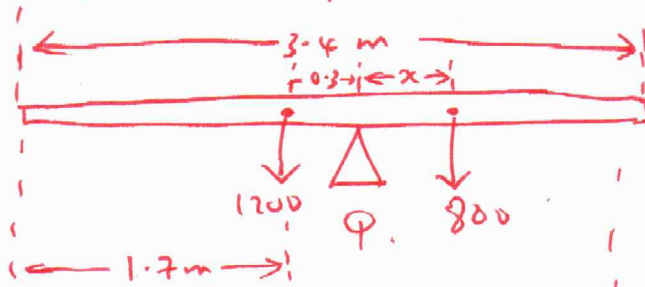A man weighs 800 N and walks along the plank away from pillar **P**.

plank

0.20 m   1.80 m   0·3   1.40 m

P   1200H **Q**

What is the horizontal distance between pillar **P** and the centre of mass of the man when the plank starts to tip?

[1 mark]

A 0.45 m

B 2.25 m   ✓

C 2.45 m

D 3.15 m

Take Q to be pivot

—— 3·4 m ——
0·3→ ←x→

↓   ↓
1200   Q.   800

←— 1·7m —→

$1200 N \times 0·3 = 800 \times x$

$x = \dfrac{1200 \times 0·3}{800}$

$= 0·45$

from
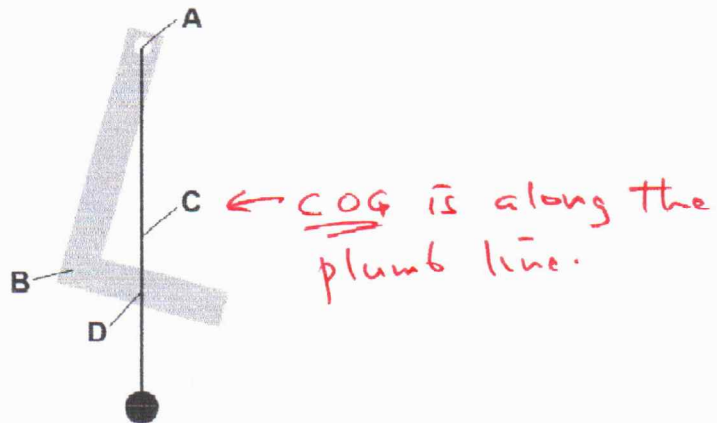
P to Q distance is

1·80 m

∴ 1·8 + 0·45

$= 2·25 m$

2 2 A uniform piece of card in the shape of the letter L is suspended freely from a horizontal pin.
A plumb line is also suspended from the pin.
The diagram shows the card in its equilibrium position.

C ← COG is along the plumb line.

What is the position of the centre of mass of the piece of card?
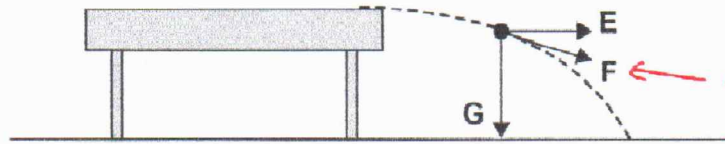
[1 mark]

A ⬭

B ⬭

C ⬬ ✓

D ⬭

Turn over for the next question

2 3 A coin is projected horizontally from the top of a desk.
The diagram shows the coin at one point in its path. The air resistance is negligible.

← direction of speed of coin.

The arrows **E**, **F** and **G** represent different directions.

Which row gives the direction of the acceleration and the direction of the momentum of the coin at this point?

↑ due to gravity   p = mv

[1 mark]

	Acceleration	Momentum	
A	F	F	⬭
B	F	E	⬭
C	G	F	⬮ ✓
D	G	E	⬭

2 4 A Formula 1 racing car uses up its fuel during the race, causing its lap times to decrease.

The lap times decrease because

$$s = \frac{d}{t}$$

$$t = \frac{d}{s}$$

[1 mark]

A the acceleration of the car increases.   ⬮ ✓

B the drag forces on the car decrease.   ⬭

C the maximum speed of the car increases.   ⬭

D the tyres become worn, reducing the friction with the road.   ⬭

– t will decrease if speed increases since distance of lap remains same.

– Speed increase is acceleration.

– So acceleration is increasing.

2 5 A golf ball has a mass of 46 g and is initially stationary.
The diagram shows the variation with time of the force acting on the golf ball as it is hit with a golf club.

force / kN

time / ms
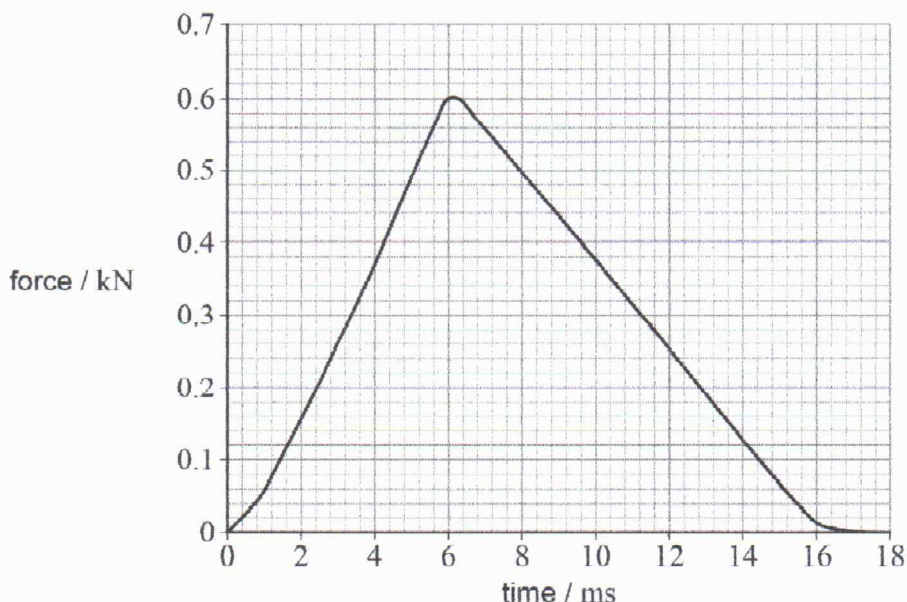
What is an estimate of the kinetic energy of the golf ball immediately after it is hit?

[1 mark]

A 5 J

B 50 J

C 250 J ✓

D 500 J

$F = ma$

$a = \dfrac{F}{m}$

$V = u + at$

$= u + \dfrac{F}{m} \times t$

but $u = 0$

$\therefore V = \dfrac{F}{m} \times t$

$V = \dfrac{0.6 \times 10^{3}}{0.046} \times 6 \times 10^{-3}$

$= 78 \, m s^{-1}$

$E_K = \tfrac{1}{2} m v^{2}$

$= 0.5 \times 0.046 \times 78^{2}$

$= 140 \, J$

$\approx 250 \, J$

Turn over for the next question

Turn over ▶

| 2 | 6 |

Two wires **X** and **Y** have the same extension for the same load.
X has a diameter d and is made of a metal of density ρ and Young modulus E.
Y has the same mass and length as **X** but its diameter is $2d$.

What are the density and the Young modulus of the metal from which **Y** is made?

[1 mark]

	Density	Young modulus	
A	$\dfrac{\rho}{2}$	$\dfrac{E}{4}$	◯
B	$\dfrac{\rho}{2}$	$4E$	◯
C	$\dfrac{\rho}{4}$	$\dfrac{E}{4}$	⬤ ✓
D	$\dfrac{\rho}{4}$	$4E$	◯

$x = \dfrac{FL}{AE}$

for X

$x = \dfrac{FL}{\pi \frac{d^2}{4} \times E}$

For Y

$x = \dfrac{FL}{\pi d^2 \times E_y}$

$\therefore \dfrac{FL}{\pi \frac{d^2}{4} \times E} = \dfrac{FL}{\pi d^2 \times E_y}$

$\dfrac{1}{E/4} = \dfrac{1}{E_y}$

$\therefore E_y = \dfrac{E}{4}$

$\rho = \dfrac{m}{V}$

$V = \pi \dfrac{d^2}{2} \times L$

For X

$\rho = \dfrac{m}{\pi \frac{d^2}{4} \times L}$

For Y

$\rho_y = \dfrac{m}{\pi d^2 \times L}$

since m is same
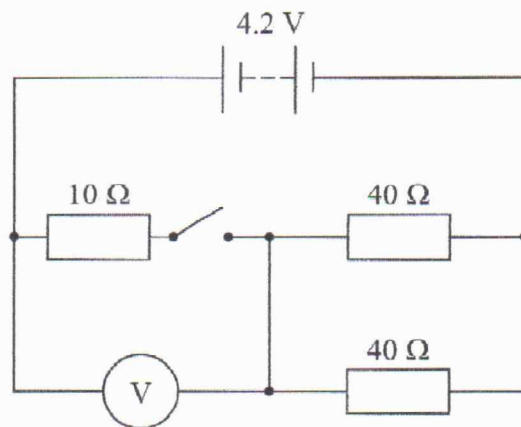
$m = \rho \times \pi \dfrac{d^2}{4} \times L$

$m = \rho_y \times \pi d^2 L$

$\rho_y \times \pi d^2 = \rho \times \pi \times \dfrac{d^2}{4} \times L$

$\rho_y = \dfrac{\rho}{4}$

2 7 The battery in this circuit has an emf of 4.2 V and negligible internal resistance.

4.2 V

10 Ω   40 Ω

40 Ω

V

$R_S = \dfrac{40 \times 40}{40 + 40}$

$= 20\,\Omega$

What are the readings on the voltmeter when the switch is open (off) and when the switch is closed (on)?

[1 mark]

	Open	Closed	
A	0 V	2.1 V	⬭
B	4.2 V	2.1 V	⬭
C	0 V	1.4 V	⬭
D	4.2 V	1.4 V	⬤ ✓

- When switch is open the voltmeter measures the battery voltage only.

Turn over for the next question
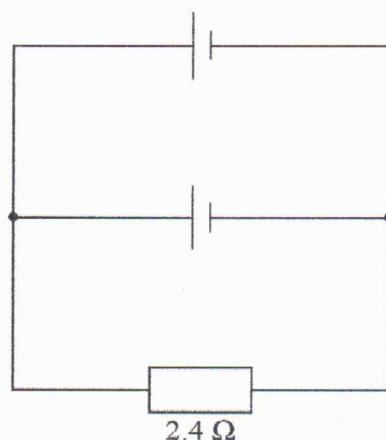
- When switch is closed, the circuit is a potential divider.

$V = \dfrac{4.2 \times 10}{20 + 10}$

$= 1.4 V$

2 8   Two identical batteries each of emf 1.5 V and internal resistance 1.6 Ω are connected in parallel. A 2.4 Ω resistor is connected in parallel with this combination.

2.4 Ω

What is the current in the 2.4 Ω resistor?

[1 mark]

A   0.38 A

B   0.47 A   ✓

C   0.75 A

D   0.94 A

Total internal resistance

$$\frac{1.6 \times 1.6}{1.6 + 1.6} = 0.8 \ \Omega$$

Total resistance in circuit

$$= 2.4 + 0.8$$

$$= 3.2 \ \Omega$$

Cell in parallel have e.m.f of one cell.

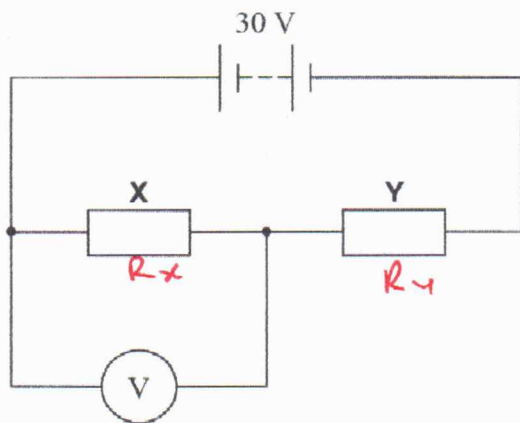$$\therefore I = \frac{V}{R}$$

$$= \frac{1.5 V}{3.2 \ \Omega}$$

$$= 0.468$$

$$\approx 0.47 A$$

2 9 Two resistors **X** and **Y** are connected in series with a power supply of emf 30 V and negligible internal resistance.
The resistors are made from wire of the same material. The wires have the same length.
X uses wire of diameter d and **Y** uses wire of diameter $2d$.

30 V

X

Y

R_x

R_y

V

What is the reading on the voltmeter?

[1 mark]

A 10 V

B 15 V

C 20 V

D 24 V ✓

$R = \dfrac{\rho L}{A}$

$A = \dfrac{\pi d^2}{4}$

$R_x = \dfrac{\rho L}{\frac{\pi d^2}{4}}$ $\qquad R_y = \dfrac{\rho L}{\pi d^2}$

$\rho L = R_x \pi \dfrac{d^2}{4}$ $\qquad \rho L = R_y \pi d^2$

but ρL is same

$\therefore R_x \dfrac{\pi d^2}{4} = R_y \pi d^2$

Turn over for the next question

$\dfrac{R_x}{4} = R_y$

$R_x = 4 R_y$

Let $R_y = 1\,\Omega$

$\Rightarrow R_x = 4\,\Omega$

$V = \dfrac{30 \times 4}{4 + 1}$

$= 24\,V$

Turn over ▶

3 0 A simple pendulum and a mass–spring system each have a time period T on the Earth.

They are taken to the surface of a planet where the acceleration due to gravity is $\dfrac{g}{4}$.

For pendulum

What are the time periods of the pendulum and the mass–spring system on this planet?

$T = 2\pi\sqrt{\dfrac{L}{g}}$ *when g decrease by 4, T will double (2T).* **[1 mark]**

	Simple pendulum	Mass–spring system	
A	$\dfrac{T}{2}$	T	○
B	$2T$	T	● ✓
C	$\dfrac{T}{2}$	$2T$	○
D	$2T$	$2T$	○

For mass–spring $T = 2\pi\sqrt{\dfrac{L}{k}}$, so T does not depend on g. so T does not change.

3 1 A particle of mass m is oscillating with simple harmonic motion.
The period of the oscillation is T and the amplitude is A.

What is the maximum kinetic energy of the particle?

[1 mark]

A $\dfrac{mA^2}{2T^2}$ ○

B $\dfrac{\pi^2 mA^2}{2T^2}$ ○

C $\dfrac{2mA^2}{T^2}$ ○

D $\dfrac{2\pi^2 mA^2}{T^2}$ ● ✓

$E_K = \dfrac{1}{2}m\omega^2 A^2$

but $\omega = \dfrac{2\pi}{T}$, $\omega^2 = \dfrac{4\pi^2}{T^2}$

$\therefore E_K = \dfrac{1}{2}m\dfrac{4\pi^2}{T^2}A^2$

$E_K = \dfrac{2m\pi^2 A^2}{T^2}$

25

END OF QUESTIONS