Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

AS
PHYSICS

Paper 1

Wednesday 17 May 2023 Morning Time allowed: 1 hour 30 minutes

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 70.
- 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	
TOTAL	

Answer **all** questions in the spaces provided.

Do not write outside the box

0 1 A strong interaction between a negative kaon (K^-) and a proton (p) produces an omega-minus (Ω^-) particle, a neutral kaon (K^0) and an unidentified particle **Y**.

The interaction is:

$$K^- + p \rightarrow \Omega^- + K^0 + \mathbf{Y}$$

Table 1 contains information on the particles in this interaction.

Table 1

	$\mathbf{K^-}$	**p**	$\mathbf{\Omega^-}$	$\mathbf{K^0}$	**Y**
Rest energy / MeV	493.8	938.3	1672	497.8	493.8
Baryon number		+1	+1		0
Charge	$-1e$	$+1e$	$-1e$	0	
Strangeness	−1	0	−3	+1	

0 1 . 1 Complete **Table 1**.

[2 marks]

0 1 . 2 Calculate, in J, the rest energy of the Ω^-.

[2 marks]

rest energy = _____ J

Do not write outside the box

0 1 . 3 Suggest how energy is conserved in this interaction.
Refer to the rest energies of the particles in **Table 1**.

[2 marks]

The quark structure of the Ω^- particle is sss.

The Ω^- is unstable. It decays into a proton through a series of decays:

$$\Omega^- \rightarrow \Xi^0 + \pi^-$$

followed by

$$\Xi^0 \rightarrow \Lambda^0 + \pi^0$$

followed by

$$\Lambda^0 \rightarrow p + \pi^-$$

The Ξ^0 and Λ^0 are both hadrons.

0 1 . 4 Deduce the quark structure of the Λ^0 particle.

[4 marks]

quark structure of Λ^0 = _____

Question 1 continues on the next page

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The products of the decay series include π^0 and π^- particles. These particles are unstable and decay.

0 1 . 5 The π^0 decays into gamma photons. Each gamma photon has a wavelength of 1.25×10^{-14} m.

Calculate the energy of one of these photons.

[2 marks]

energy of photon = _____ J

0 1 . 6 The negative pion π^- decays.

Which row shows the particles that could be created in this decay?
Tick (✓) **one** box.

[1 mark]

$\mu^- + \nu_\mu$ ☐

$e^- + \overline{\nu}_e$ ☐

$e^- + \nu_e$ ☐

$e^- + e^+ + e^-$ ☐

13

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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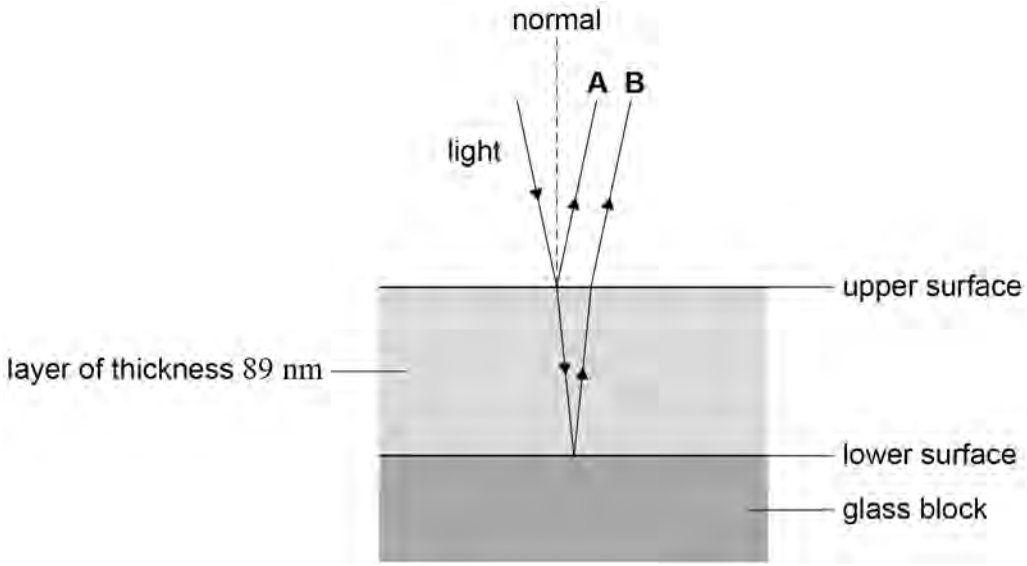
0 2 A glass block is coated with a layer of transparent material.
Figure 1 shows the incident ray and the reflected rays when monochromatic light is shone onto the upper surface of the transparent layer.

Figure 1



A is light reflecting from the upper surface of the layer.
B is light that leaves the layer after reflection from the lower surface.

When light reflects at the upper and lower surfaces, there is a change of phase.
In this case, the change of phase is the same at each surface and so can be ignored.

When the monochromatic light is incident **normally** on the upper surface of the layer, **A** and **B** meet and interfere.
Assume that the light is incident **normally** on the upper surface throughout this question.

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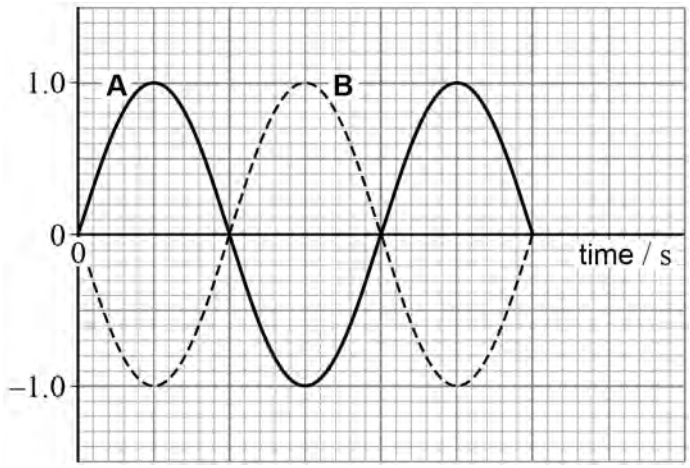
0 2 . 1 **Figure 2** shows how **A** and **B** vary with time at the upper surface.

Figure 2



In the layer, the light has a wavelength of 356 nm.
The thickness of the layer is 89 nm.

Explain why destructive interference occurs at the upper surface for this thickness.

[3 marks]

Question 2 continues on the next page

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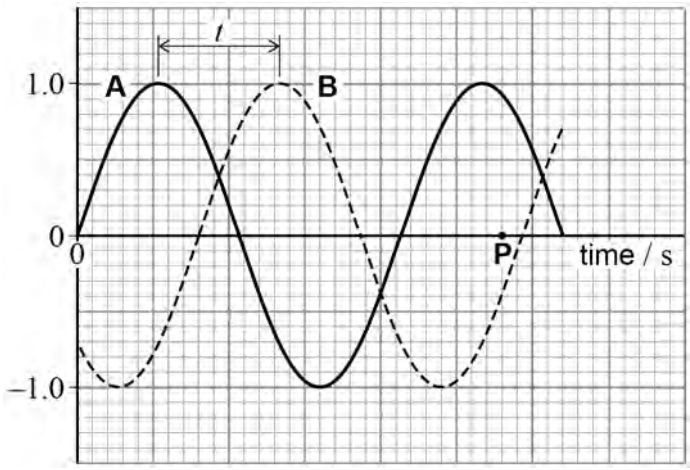
The frequency of the monochromatic light incident on the layer is changed.

Figure 3 shows how **A** and **B** vary with time at the upper surface for this light.

Figure 3



0 2 . 2 Calculate the resultant of the waves at time **P** in **Figure 3**.

[2 marks]

resultant = _____

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The frequency of the light in **Figure 3** is 4.72×10^{14} Hz.

0 2 . 3 The phase difference between **A** and **B** shown in **Figure 3** is 137°.

Show that the time interval labelled *t* in **Figure 3** is approximately 8×10^{-16} s.

[3 marks]

0 2 . 4 89 nm is the minimum thickness that will produce a phase difference of 137° between **A** and **B**.

Calculate the refractive index of the material of the layer.

[4 marks]

refractive index = _____

12

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0 3 A student sits near a lake on a sunny day.

Some sunlight is reflected from the surface of the lake. Sunlight is also reflected from objects submerged beneath the surface of the lake. The light reflected from the surface makes it difficult to see the submerged objects.

Sunlight that reflects from the surface of the lake is horizontally polarised. Sunlight that reflects from the submerged objects is unpolarised.

The student puts on a pair of Polaroid sunglasses. The amount of light he sees reflected from the surface is significantly reduced.

Explain why the student can now see the submerged objects more clearly.

In your answer you should:

- describe the nature of an unpolarised wave
- explain what is meant by polarisation
- explain the relative effect of the Polaroid sunglasses on the light reflected from the surface and the light reflected from the submerged objects.

[6 marks]

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6

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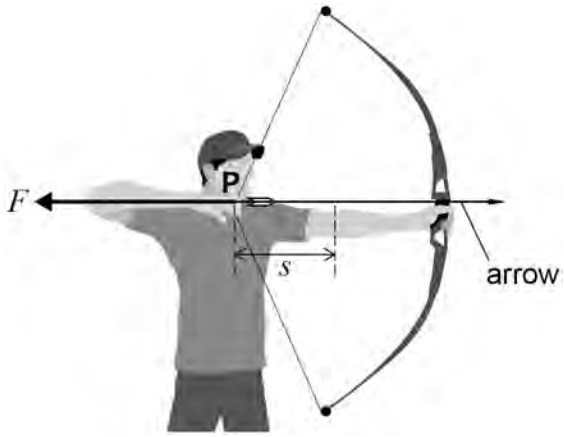
0 4 **Figure 4** shows an archer using a bow in a competition.

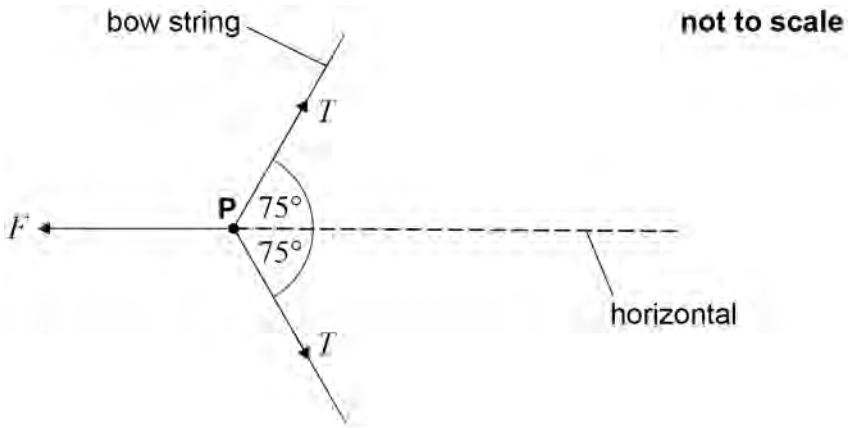
Figure 4



The archer exerts a force F to pull point **P** on the string back through a distance s.

0 4 . 1 **Figure 5** is a simplified diagram of the bow string showing the forces acting on **P**. The tension in the string is T and the string makes an angle of $75°$ to the horizontal.

Figure 5



In **Figure 5**, F is 160 N and **P** is in equilibrium.

Calculate T.

[2 marks]

$T =$ _____ N

Question 4 continues on the next page

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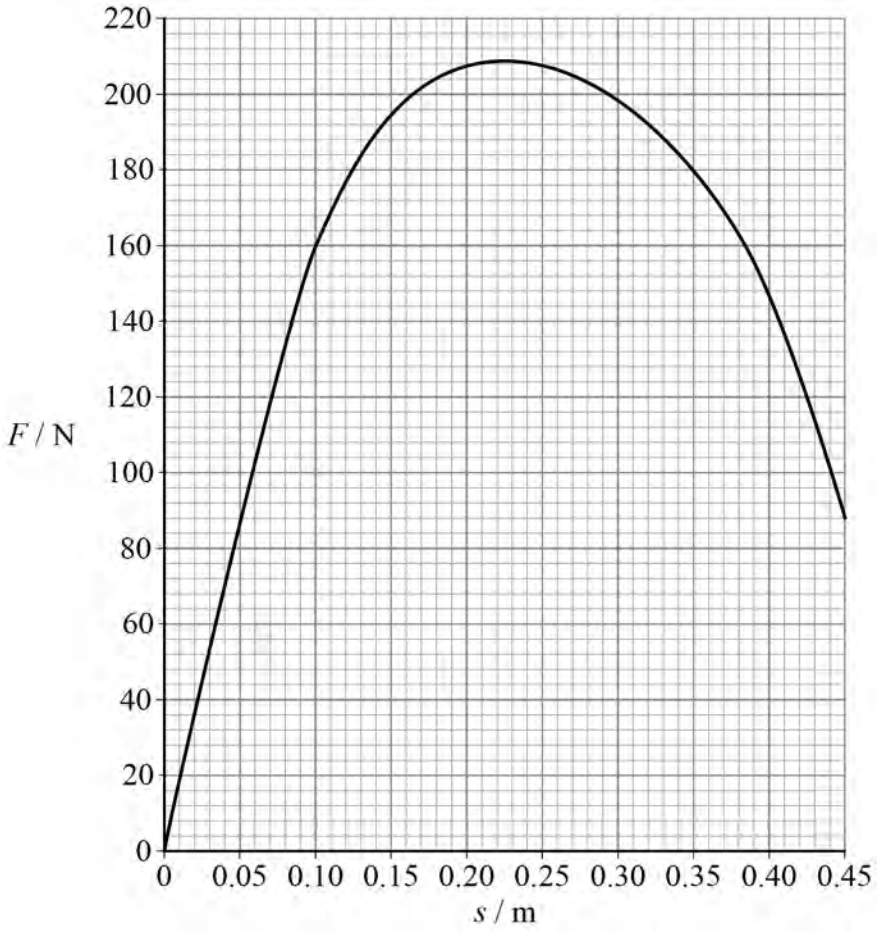
The bow is designed so that F varies with s as shown in **Figure 6**.

Figure 6



0 4 . 2 An arrow of mass 21 g is placed in the bow.

The archer pulls **P** back by a distance s of 0.22 m and then releases the arrow in a horizontal direction.

Assume that there are no resistive forces acting on the arrow as it is released.

Determine the initial horizontal acceleration of the arrow.

[2 marks]

initial horizontal acceleration = _____ m s^{-2}

Do not write outside the box

The arrow is replaced with a different arrow of mass m.
The archer pulls **P** back by a distance s_r so that the energy stored in the bow is 64 J and F is 160 N.

0 4 . 3 Deduce s_r.

[2 marks]

$s_r =$ _____ m

0 4 . 4 The bow has an efficiency of 0.82

The arrow leaves the bow in a horizontal direction with a velocity of 190 km h^{-1}.

Calculate m.

[3 marks]

$m =$ _____ kg

9

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0 5 **Figure 7** shows a robotic helicopter that is used on Mars. The helicopter is powered by a battery. Before each flight, the battery is charged by a solar panel.

Figure 7

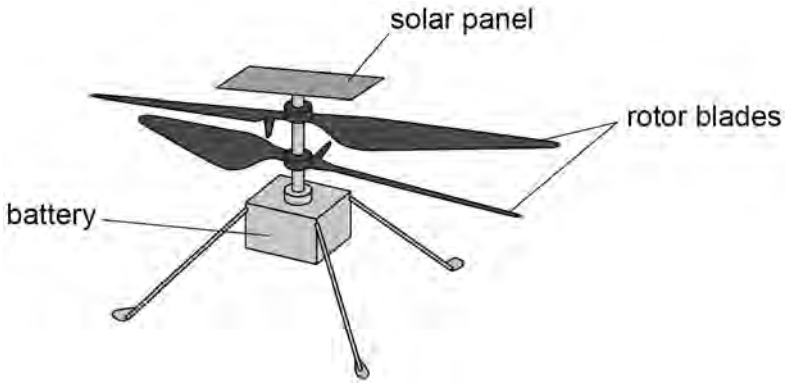
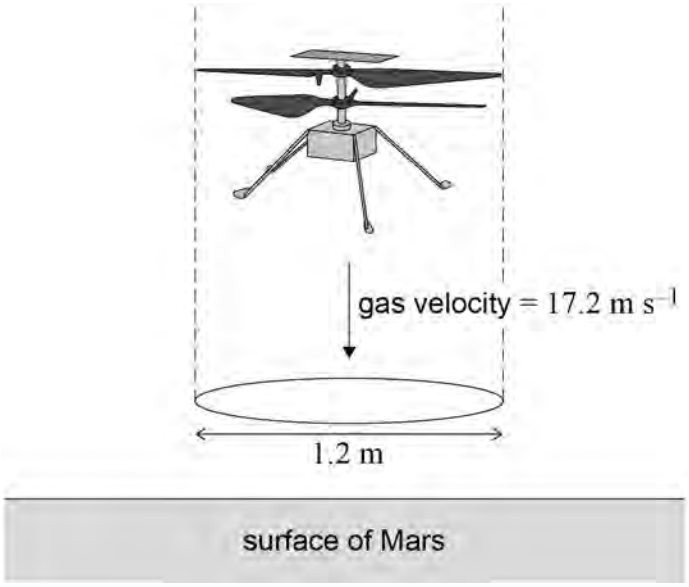


Figure 8 shows the helicopter hovering at a constant height above the surface of Mars. The rotor blades move a column of atmospheric gas vertically downwards at a velocity of $17.2\ \text{m s}^{-1}$. The diameter of this column is $1.2\ \text{m}$.

Figure 8



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0 5 . 1 The gas moved by the rotor blades has a density of $0.020\ \text{kg m}^{-3}$.

Show that the helicopter moves approximately $0.4\ \text{kg}$ of gas every second.

[3 marks]

The movement of the gas creates an upward force on the helicopter. This upward force enables the helicopter to hover at a constant height.

The gravitational field strength on Mars is $3.72\ \text{N kg}^{-1}$.

0 5 . 2 Calculate the mass of the helicopter.

[3 marks]

mass = _____ kg

Question 5 continues on the next page

Turn over ►

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0 5 . 3 The battery stores $0.035\ \text{kW h}$ of energy before a flight.
The flight lasts for $39\ \text{s}$.
The battery has a power output of $340\ \text{W}$ during the flight.

Determine the percentage of the initial energy stored in the battery that is transferred during the flight.

[2 marks]

percentage = _____ %

0 5 . 4 The helicopter has a maximum flight time of a few minutes due to the limited amount of energy stored in the battery. The battery accounts for about 15% of the helicopter's mass.

A student suggests that adding another identical battery that doubles the energy available to the helicopter would double its flight time.

Deduce without calculation whether the student's suggestion is correct.

[3 marks]

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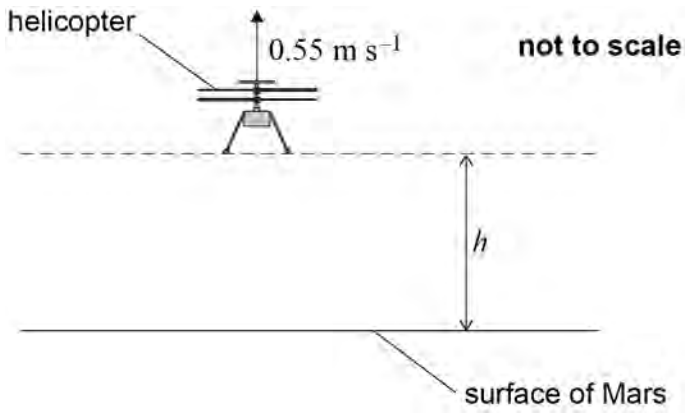
Figure 9 shows a simplified side view of the helicopter moving vertically upwards with a speed of $0.55\ \text{m s}^{-1}$.
At the instant shown, the helicopter is at a height h and the blades stop rotating.

Figure 9



The gravitational field strength on Mars is $3.72\ \text{N kg}^{-1}$.

The weight of the helicopter is the only force acting on it when the blades stop rotating. Drag forces on the helicopter are negligible as it rises to a maximum height and then falls back to the surface.

0 5 . 5 Calculate the time taken for the helicopter to reach its maximum height from the instant the blades stop rotating.

[2 marks]

time = _____ s

0 5 . 6 When the helicopter makes contact with the surface it has a velocity of $2.2\ \text{m s}^{-1}$.

Calculate h.

[2 marks]

h = _____ m

Question 5 continues on the next page

Turn over ►

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0 5 . 7 A student suggests that the acceleration of the helicopter is constant from the instant the blades stop rotating until the helicopter makes contact with the surface.

Discuss this suggestion with reference to an appropriate Newton's law of motion.

[2 marks]

17

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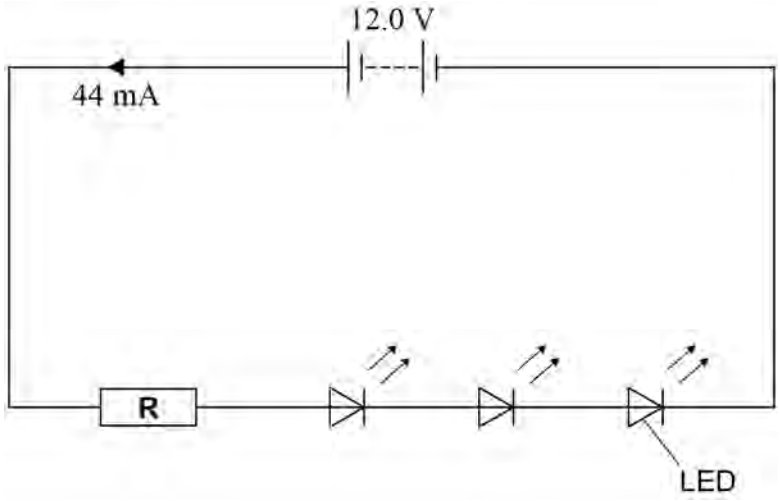
0 6 . 1 State what is meant by the emf (electromotive force) of a battery.

[1 mark]

Figure 10 shows the circuit diagram for a battery-powered torch.
The circuit contains three identical light emitting diodes (LEDs) and a resistor **R**.
The current in the circuit is 44 mA.

Figure 10



0 6 . 2 Calculate the number of electrons that pass a point in the circuit in 37 minutes.

[2 marks]

number of electrons = _____

Question 6 continues on the next page

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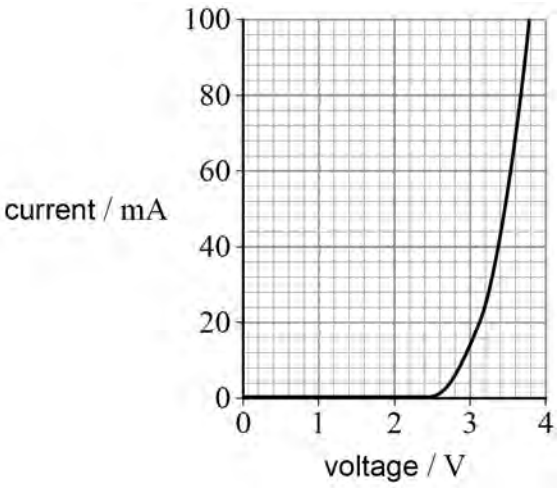
Figure 11 is the current–voltage characteristic for an LED used in the torch.

Figure 11



0 6 . 3 Determine the power output of one LED when the torch is on.

[3 marks]

power output = _____ W

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The battery has an emf of $12.0\ \text{V}$ and an internal resistance of $1.5\ \Omega$.

0 6 . 4 Determine the resistance of **R** in **Figure 10**.

[4 marks]

resistance = _____ Ω

Question 6 continues on the next page

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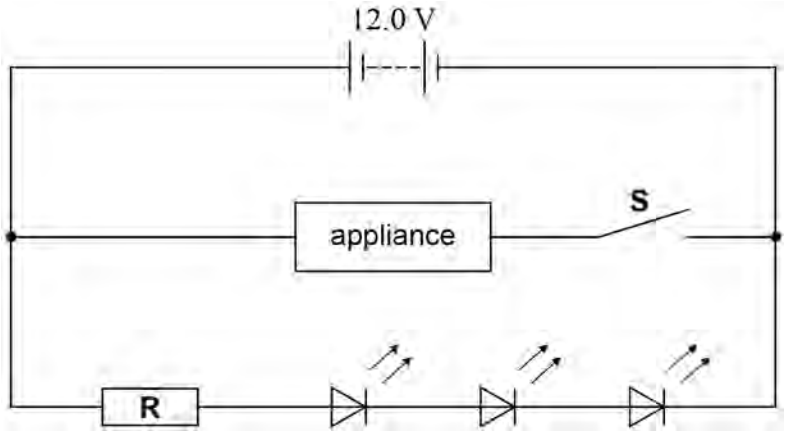
0 6 . 5 Another appliance is connected to the battery as shown in **Figure 12**.

The current in the battery is $3.5\ \text{A}$ when switch **S** is closed.

Figure 12



Each LED requires a voltage of at least $2.9\ \text{V}$ to light.

Deduce whether the LEDs will light when **S** is closed.

[3 marks]

13

END OF QUESTIONS

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