Cambridge International Examinations
Cambridge Pre-U Certificate

CANDIDATE NAME	

CENTRE NUMBER							CANDIDATE NUMBER					

7775658333

PHYSICS (PRINCIPAL) **9792/02**

Paper 2 Written Paper **May/June 2018**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section 1
Answer **all** questions.
You are advised to spend about 1 hour 30 minutes on this section.

Section 2
Answer the **one** question.
You are advised to spend about 30 minutes on this section.
The question is based on the material in the Insert.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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9	
Total	

This syllabus is approved for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document consists of **26** printed pages, **2** blank pages and **1** Insert.

DC (KN/FC) 149409/3

Data

gravitational field strength close to Earth's surface	$g = 9.81\,\mathrm{N\,kg^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \left(\frac{u+v}{2}\right)t$$

heating

$$\Delta E = mc\Delta\theta$$

change of state

$$\Delta E = mL$$

refraction

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$n = \frac{v_1}{v_2}$$

diffraction

single slit, minima $n\lambda = b\sin\theta$

grating, maxima $n\lambda = d\sin\theta$

double slit interference $\lambda = \frac{ax}{D}$

Rayleigh criterion $\theta \approx \frac{\lambda}{b}$

photon energy $E = hf$

de Broglie wavelength $\lambda = \frac{h}{p}$

simple harmonic motion $x = A\cos\omega t$

$v = -A\omega\sin\omega t$

$a = -A\omega^2\cos\omega t$

$F = -m\omega^2 x$

$E = \frac{1}{2}mA^2\omega^2$

energy stored in a capacitor $W = \frac{1}{2}QV$

capacitor discharge $Q = Q_0 e^{-\frac{t}{RC}}$

electric force $F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$

electrostatic potential energy $W = \frac{Q_1Q_2}{4\pi\varepsilon_0 r}$

gravitational force $F = -\frac{Gm_1m_2}{r^2}$

gravitational potential energy $E = -\frac{Gm_1m_2}{r}$

magnetic force $F = BIl\sin\theta$

$F = BQv\sin\theta$

electromagnetic induction $E = -\frac{\mathrm{d}(N\Phi)}{\mathrm{d}t}$

Hall effect $V = Bvd$

time dilation $t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$

length contraction $l' = l\sqrt{1-\frac{v^2}{c^2}}$

kinetic theory $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

work done on/by a gas $W = p\Delta V$

radioactive decay $\frac{\mathrm{d}N}{\mathrm{d}t} = -\lambda N$

$N = N_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

attenuation losses $I = I_0 e^{-\mu x}$

mass-energy equivalence $\Delta E = c^2\Delta m$

hydrogen energy levels $E_n = \frac{-13.6\,\text{eV}}{n^2}$

Heisenberg uncertainty principle $\Delta p\Delta x \geqslant \frac{h}{2\pi}$

Wien's displacement law $\lambda_{\max} \propto \frac{1}{T}$

Stefan's law $L = 4\pi\sigma r^2 T^4$

electromagnetic radiation from a moving source $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

Section 1

You are advised to spend about 1 hour 30 minutes on this section.

1 Fig. 1.1 shows a wooden block of mass m at rest on a ramp which is inclined at an angle θ to the horizontal.

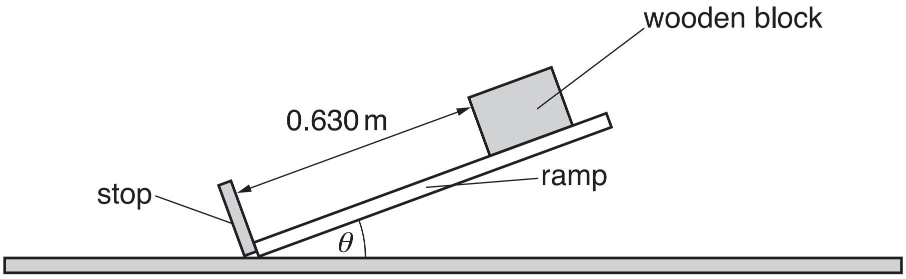

Fig. 1.1

The ramp is rotated very slowly so that the angle θ increases to 35.5° with the block stationary. The ramp stops moving and remains at 35.5° to the horizontal.

(a) **(i)** In the space below, draw a labelled vector triangle for the forces on the block.

[2]

(ii) With θ equal to 35.5°, the block is just on the point of sliding down the ramp but it remains stationary on the ramp.

Determine the coefficient of static friction μ_s between the block and the ramp.

μ_s = ... [1]

(b) The block is given a very gentle tap and it begins to move. It moves down the ramp with a constant acceleration of 0.150 m s^{-2}.

(i) Calculate the time taken for the block to travel 0.630 m down the ramp.

time = ... s [2]

(ii) Determine the coefficient of kinetic friction μ_k between the block and the ramp.

μ_k = ...[4]

(iii) The block collides with the stop at the bottom end of the ramp and comes to rest.

Discuss the energy transfers that take place from the moment the block starts to move until it comes to rest.

....

....

....

....[2]

[Total: 11]

2 A research engineer increases the tensile strain in a cylindrical sample of a metal. For each value of strain, he determines the stress in the sample. When the strain reaches 0.012 the sample breaks.

Fig. 2.1 is the stress-strain graph obtained using his values.

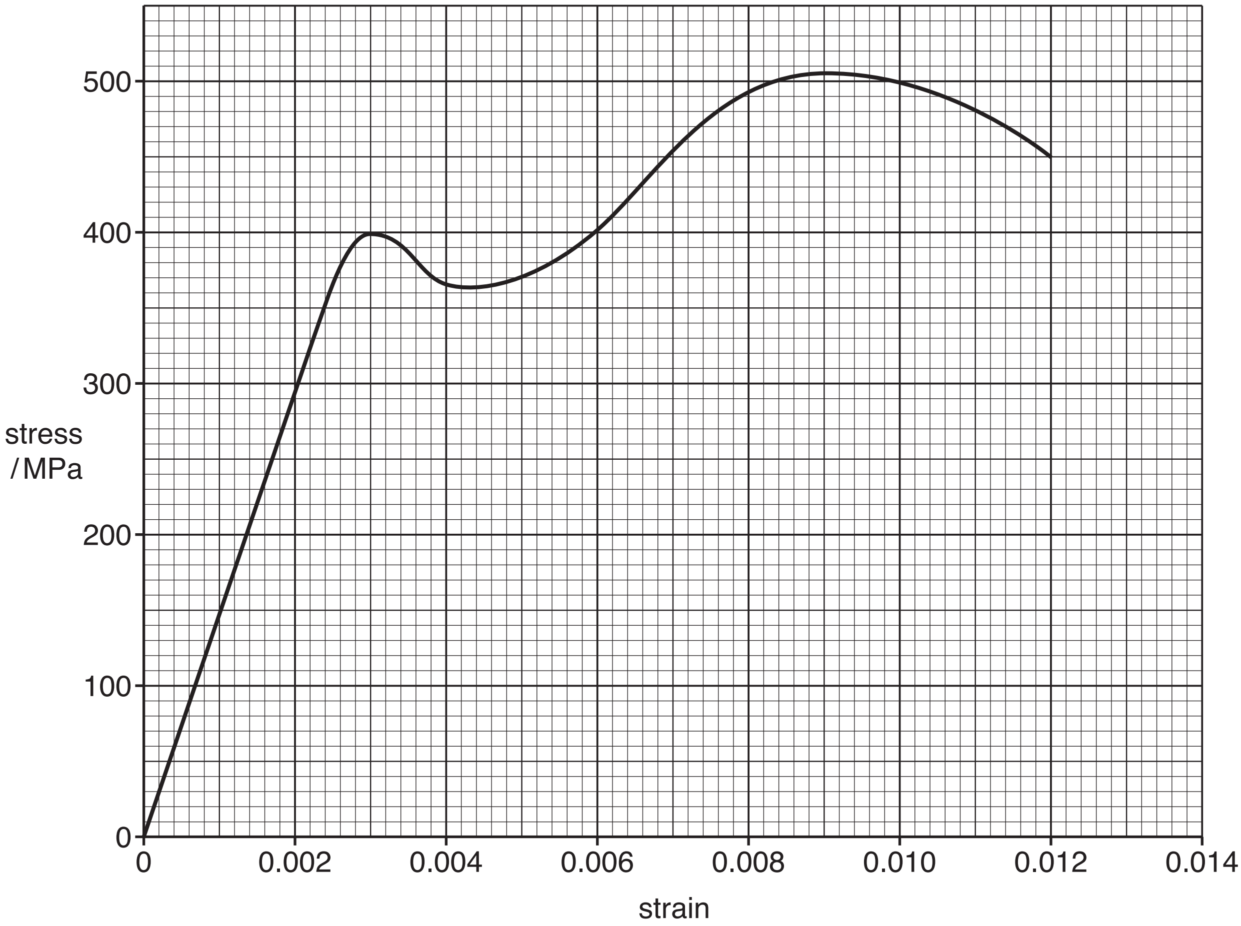

Fig. 2.1

(a) On Fig. 2.1, mark

(i) the limit of proportionality and label it P, [1]

(ii) the yield point and label it Y. [1]

(b) Use Fig. 2.1 to determine the Young modulus of the metal.

Young modulus = ... Pa [2]

(c) A wire made from the metal is stretched by hanging weights from one end.

Determine the minimum stress that must be applied to the wire in order to cause it to break.

breaking stress = ... MPa [1]

(d) The strain of the metal increases from 0.0030 to 0.0040.

(i) State what is happening to the metal.

....[1]

(ii) Explain what is happening to the metal, in terms of its microstructure.

....

....[1]

(e) As the sample is stretched, work is done on it.

Describe how the work done on the sample can be determined using the graph.

....

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....[2]

[Total: 9]

3 A river reaches the edge of a cliff and becomes a waterfall. Fig. 3.1 shows the water flowing over the cliff and into a pond at the bottom of the cliff.

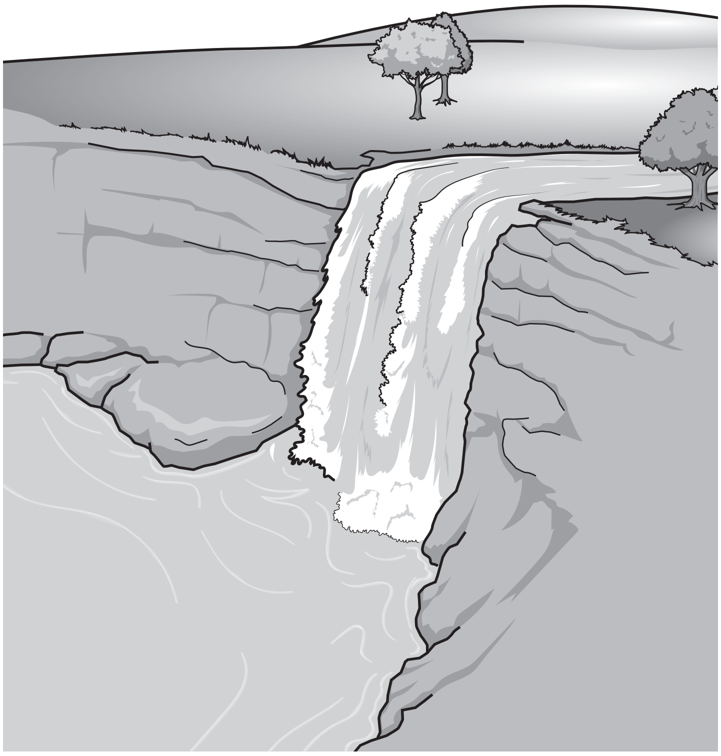

Fig. 3.1

The water drops through a distance of 82.3 m before it reaches the water surface in the pond where it is stationary.

(a) Calculate the change in gravitational potential between the top of the waterfall and the surface of the water in the pond.

change in gravitational potential = ...J kg^{-1} [2]

(b) Measurements show that the water in the pond is slightly warmer than that in the river.

(i) The specific heat capacity of water is 4180 J kg^{-1} K^{-1}.

Calculate a value for the temperature difference between the water in the river and the water in the pond.

temperature difference = ... K [2]

(ii) Suggest and explain **two** reasons why the actual temperature difference between the water in the river and the water in the pond may differ from the value calculated in **(b)(i)**.

State in each case whether the temperature difference is greater or less than the predicted value.

1. ....

....

....

....

2. ....

....

....

....
[2]

(c) On some days the rate at which water flows over the cliff is much smaller than on other days.

Explain why this does not affect the temperature difference between the river and the pond.

....

....

....[1]

[Total: 7]

4 **(a)** **(i)** Define *electromotive force (emf)* for a cell.

....

....

....[2]

(ii) Explain what is meant by *internal resistance* of a cell.

....

....[1]

(b) A cell has an emf of 1.52 V and an internal resistance of 0.450 Ω. Fig. 4.1 shows the cell connected to a variable resistor R.

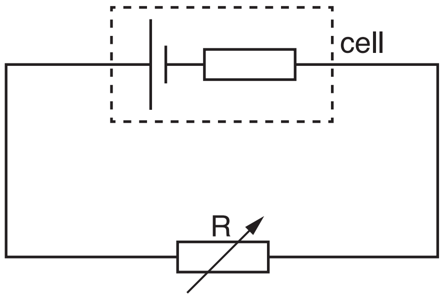

Fig. 4.1

The resistance of R is set to a value of 2.55 Ω.

Calculate

(i) the terminal potential difference across the cell,

terminal potential difference = ... V [2]

(ii) the power dissipated in R.

power = ... W [2]

(c) In different parts of a complicated electrical network, currents are determined using Kirchhoff's laws.

(i) **1.** Kirchhoff's first law is a consequence of a principle of physics.

State this principle.

....

....

....[1]

2. Kirchhoff's second law is also a consequence of a principle of physics.

State this principle.

....

....

....[1]

(ii) Three cells of emf 1.52 V and of internal resistance 0.450 Ω are connected in a circuit with a 13.0 Ω and an 18.5 Ω resistor. Fig. 4.2 is the circuit diagram.

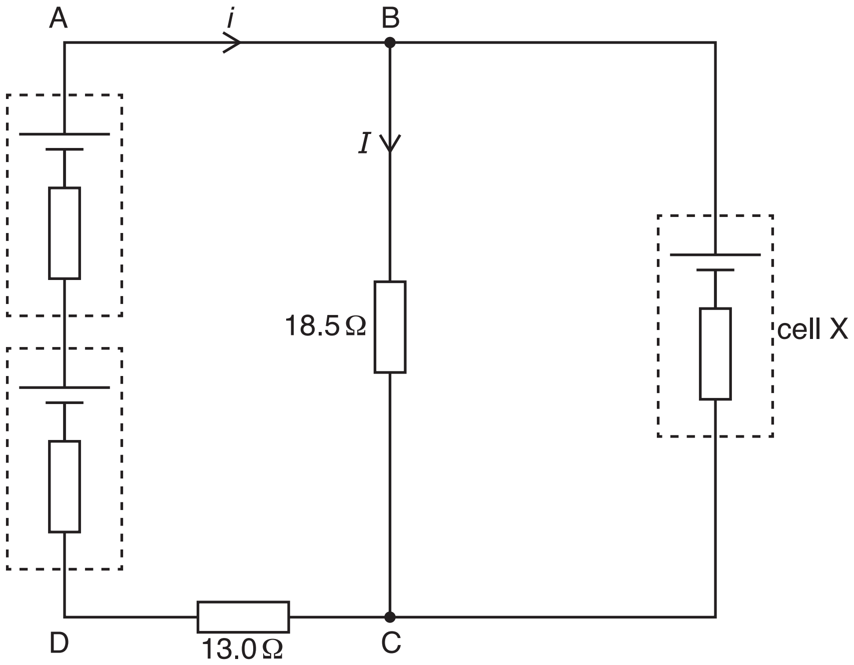

Fig. 4.2

The current i in one connecting wire and the current I in the 18.5 Ω resistor are shown on Fig. 4.2. One cell is labelled X.

1. Determine the equation that is obtained when Kirchhoff's second law is applied to the section of the circuit labelled ABCD in Fig. 4.2.

.... [2]

2. The current I is 0.0829 A.

Determine the size and direction of the current in the cell X.

current = ... A

direction of current ....
[2]

[Total: 13]

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5 The vertical wall of a swimming pool is made from a glass of refractive index 1.54.

The refractive index of water is 1.33.

(a) Determine

(i) the speed of light v_g in the glass wall,

v_g = ... m s^{-1}

(ii) the speed of light v_w in water.

v_w = ... m s^{-1} [2]

(b) Fig. 5.1 shows a ray of light in air striking the outer surface of the glass wall at point P at an angle of 25.0°.

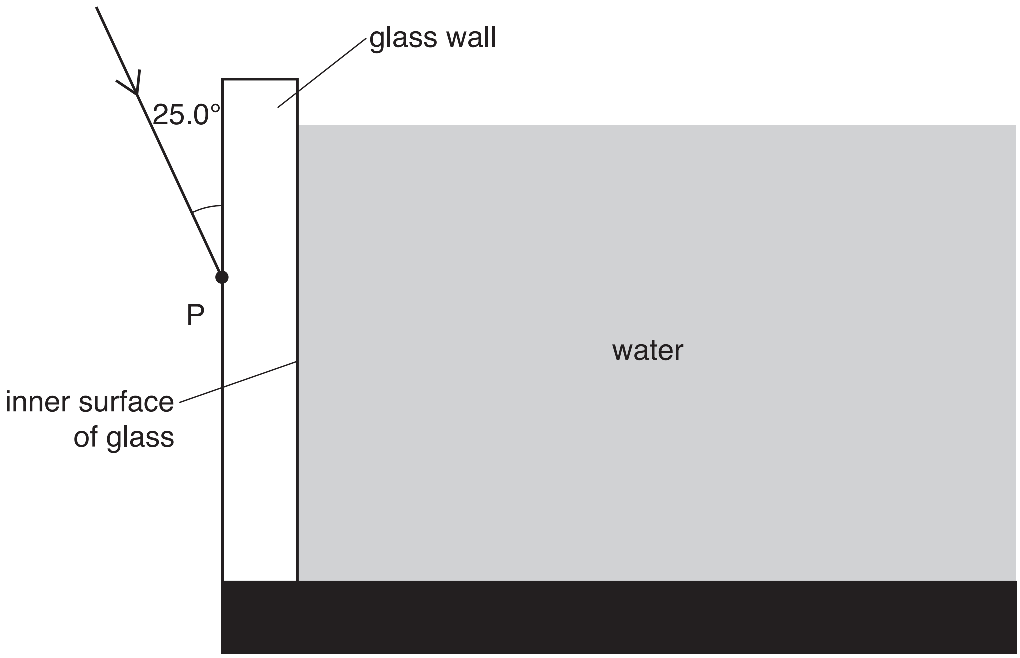

Fig. 5.1

The light travels through the glass. It then strikes the inner surface of the glass and passes into the water.

(i) Determine the angle of incidence at the inner surface of the glass.

angle of incidence = ... ° [2]

(ii) On Fig. 5.1, sketch the path of the light in the glass and in the water. [1]

(iii) **1.** Determine the critical angle for light travelling in the glass at the inner surface of the glass wall.

critical angle = ... ° [3]

2. The vertical wall of the swimming pool may be made of many different types of transparent glass and plastic. The refractive index *n* of the material used for the wall may have a value from within a very wide range.

Provided that it enters the glass at P, light striking the vertical inner surface of the glass can never undergo total internal reflection.

Discuss why this is so for all values of *n*.

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....[2]

[Total: 10]

6 A helium-neon (HeNe) laser produces light of wavelength 633 nm. The laser is placed behind a glass microscope slide that has been painted black. A single vertical slit of width 0.0800 mm has been produced by scratching through the paint with a razor blade.

Light from the laser passes through the slit and hits a white wall at a distance of 5.12 m from the slit. A patch of red light is formed on the screen. On both sides of this central patch there are smaller, less intense patches.

A light sensor connected to a data logger is moved across the screen and the distance moved by the light sensor and the intensity of the light is recorded. Fig. 6.1 is the intensity-distance graph generated.

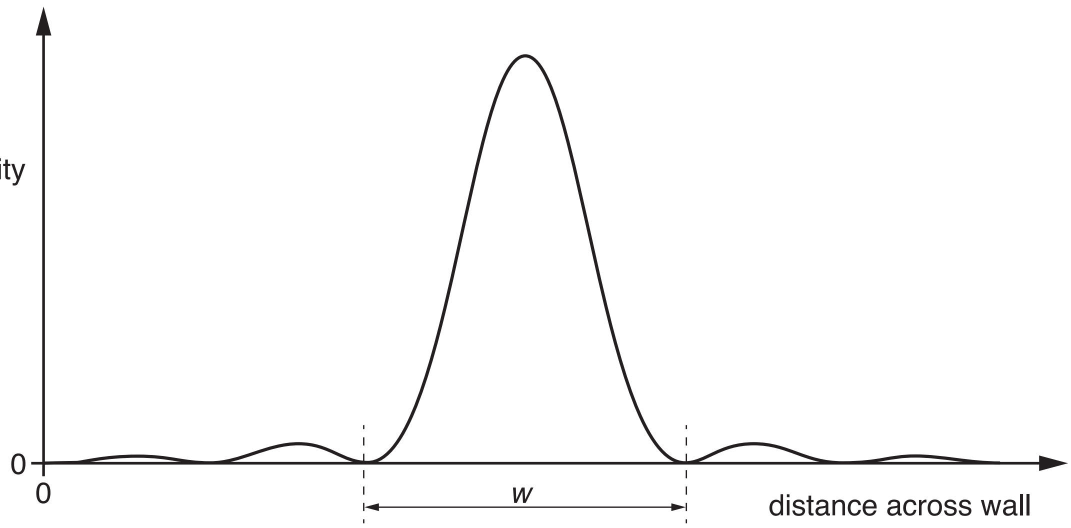

Fig. 6.1

The width *w* of the central patch is equal to the distance between the two minimum points on either side of the central patch where the intensity of red light is equal to zero.

(a) Determine *w*.

w = ... m [3]

(b) A second vertical slit of width 0.0800 mm is scratched across the slide. The second slit is parallel to the first and its centre is a horizontal distance of 0.240 mm away from the centre of the first slit.

The microscope slide now acts as a double slit. At the centre of the double-slit interference pattern on the wall, there are bright and dark fringes which are uniformly spaced.

(i) Some parts of the screen that were brightly lit when only the first slit was present are now dark, even though light is still passing through the first slit in the same way.

Explain what causes this to happen.

....

....

....[1]

(ii) Determine the separation *x* of the bright fringes.

x = ... m [2]

(iii) Most of the bright fringes are separated from adjacent bright fringes by a distance *x*. In a few places, away from the centre, however, there are separations of 2*x* and there is no light in the middle of the gap where a bright fringe might be expected.

Using the results from **(a)** and **(b)(ii)**, explain why there is no light at such places.

....

....

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....[2]

[Total: 8]

7 One type of electrical power source used in spacecraft contains a sample of the radioactive isotope nickel-63. Nickel-63 decays to an isotope of copper by β^- emission with a half-life of 100 years. An antineutrino $\left({}^{0}_{0}\overline{\nu}\right)$ is also emitted.

(a) Complete the equation for the decay of nickel-63.

$$^{63}_{28}\text{Ni} \longrightarrow {}^{.....}_{.....}\text{Cu} + {}^{.....}_{.....}\beta + {}^{0}_{0}\overline{\nu}$$

[2]

(b) The activity of the nickel-63 sample in a spacecraft is initially 2.56×10^7 Bq.

(i) Define the term *activity*.

....

....[1]

(ii) Fig. 7.1 is the activity-time graph for the sample.

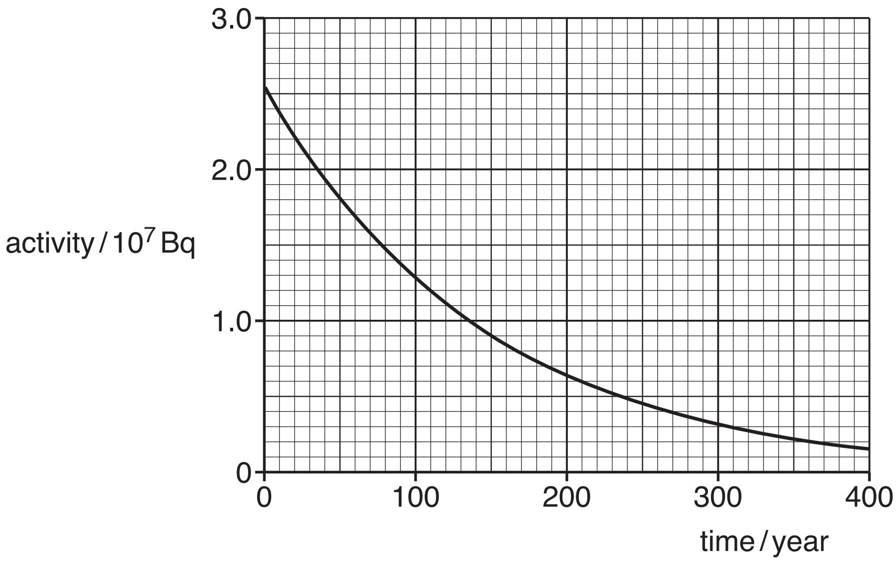

Fig. 7.1

Explain why the graph has this shape.

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....

....[3]

(c) In space, the temperature of the sample is extremely low.

State and explain how the activity of the sample is affected by its temperature.

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....[1]

[Total: 7]

8 A student investigates the photoelectric effect using a photoelectric cell which contains a small piece of a metal alloy in an evacuated glass tube. Fig. 8.1 shows the photoelectric cell.

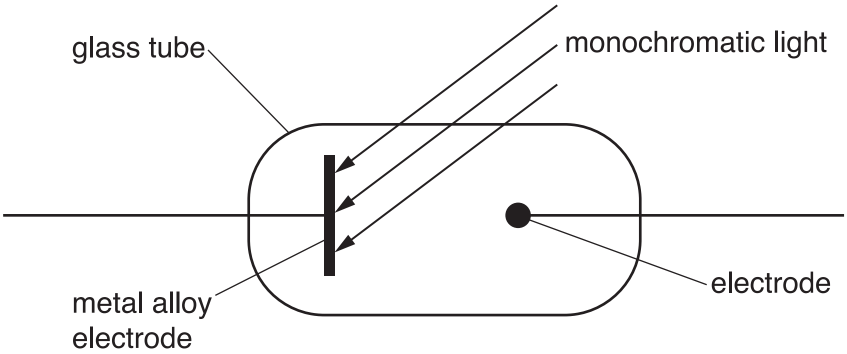

Fig. 8.1

The alloy is illuminated with monochromatic light from a light-emitting diode (LED) and the stopping potential is determined.

(a) State what is meant by *monochromatic*.

....[1]

(b) The experiment is repeated with several more LEDs each of which produces monochromatic electromagnetic radiation with a different wavelength. For each one, the corresponding stopping potential is recorded. Fig. 8.2 is the results table.

type of radiation	wavelength / nm	stopping potential / V	frequency / 10^{14} Hz
ultraviolet	370	no photoelectric emission observed	
violet	429	0.856	
light blue	463	0.635	
green-blue	505	0.412	
green	526	0.308	
orange	593	0.046	
red	631	no photoelectric emission observed	

Fig. 8.2

(i) Use the graph paper in Fig. 8.3 to plot a graph of stopping potential against frequency and explain what can be deduced.

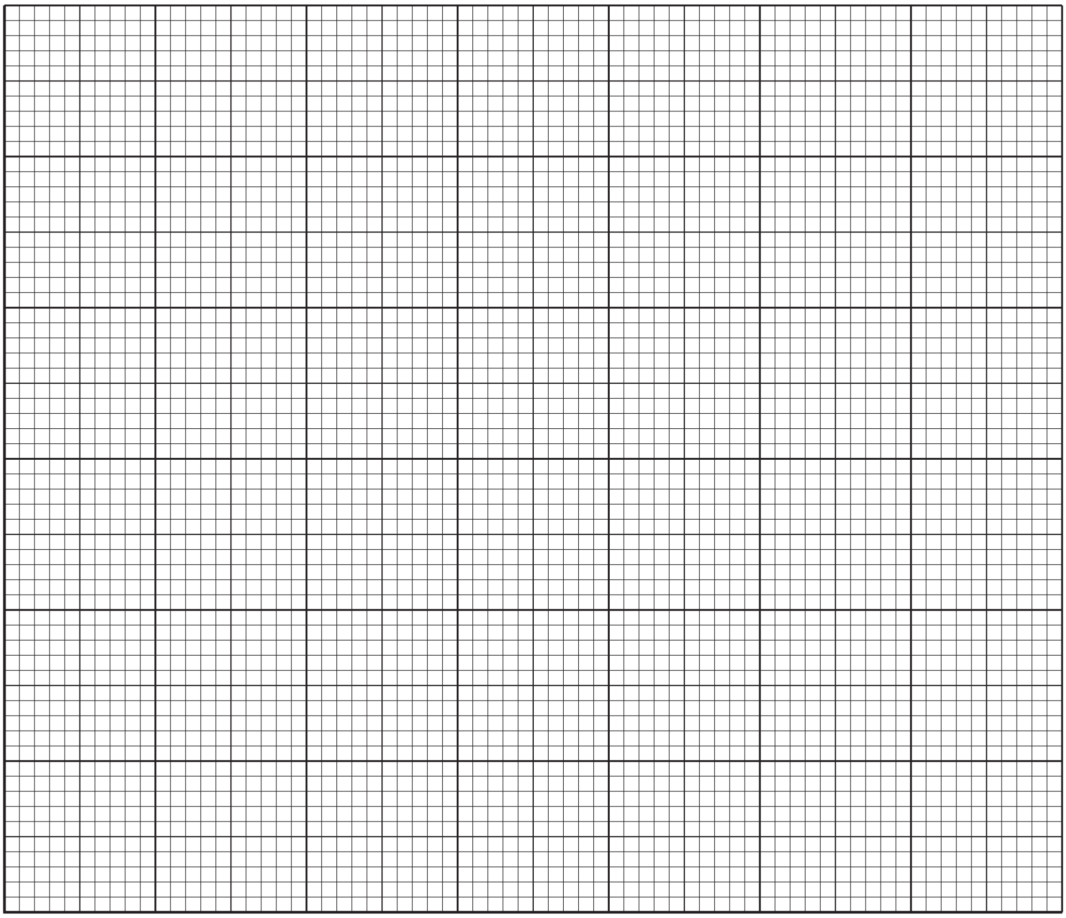

Fig. 8.3

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....[7]

(ii) No photoelectric emission is observed when the photocell is exposed to ultraviolet radiation or to red light.

1. State why no photoelectric emission occurs when the photocell is exposed to red light.

....

....[1]

2. Suggest why no photoelectric emission occurs when the photocell is exposed to ultraviolet radiation.

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....[1]

[Total: 10]

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Section 2

You are advised to spend about 30 minutes on this section.

The questions in this section refer to the pre-released material provided as an insert to the paper.

Your answers should, where possible, make use of any relevant physics.

9 Fig. 9.1 shows a simplified diagram of the construction of an X-ray machine.

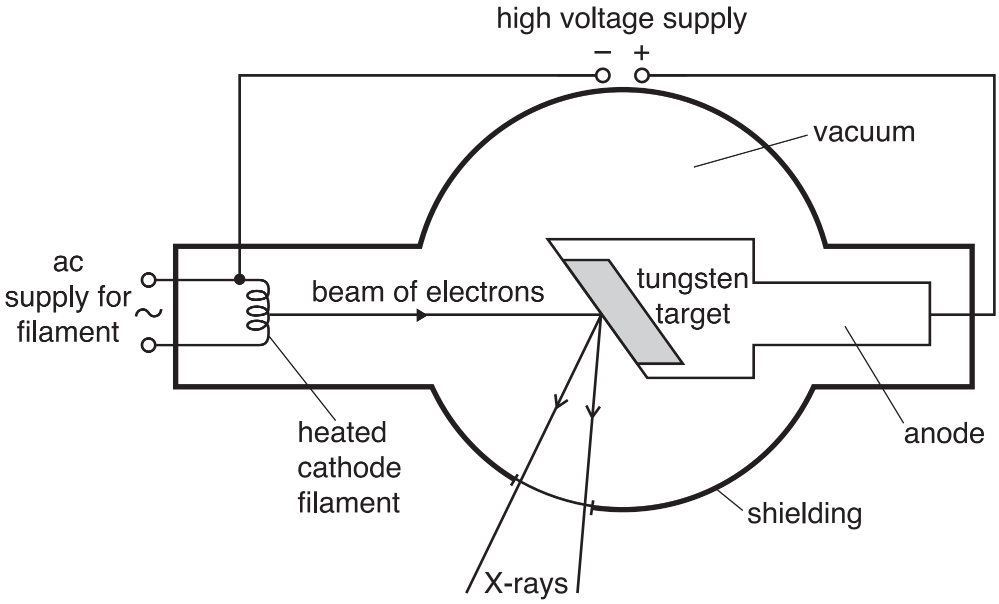

Fig. 9.1 (not to scale)

(a) In the production of X-rays electrons are emitted from a hot filament and accelerated in an electric field. The electron energy is often described in terms of electron-volts.

Explain what is meant by the term *electron-volt*.

....

....[2]

(b) Tungsten metal is an ideal material for the target, or anode, of an X-ray machine.

Electrons in the tungsten atom have energy levels in a similar way to the energy levels for a hydrogen atom.

(i) Fig. 9.2 shows the logarithm of the energy E of some of the energy levels of electrons in the tungsten atom. E is measured in electron-volts (eV).

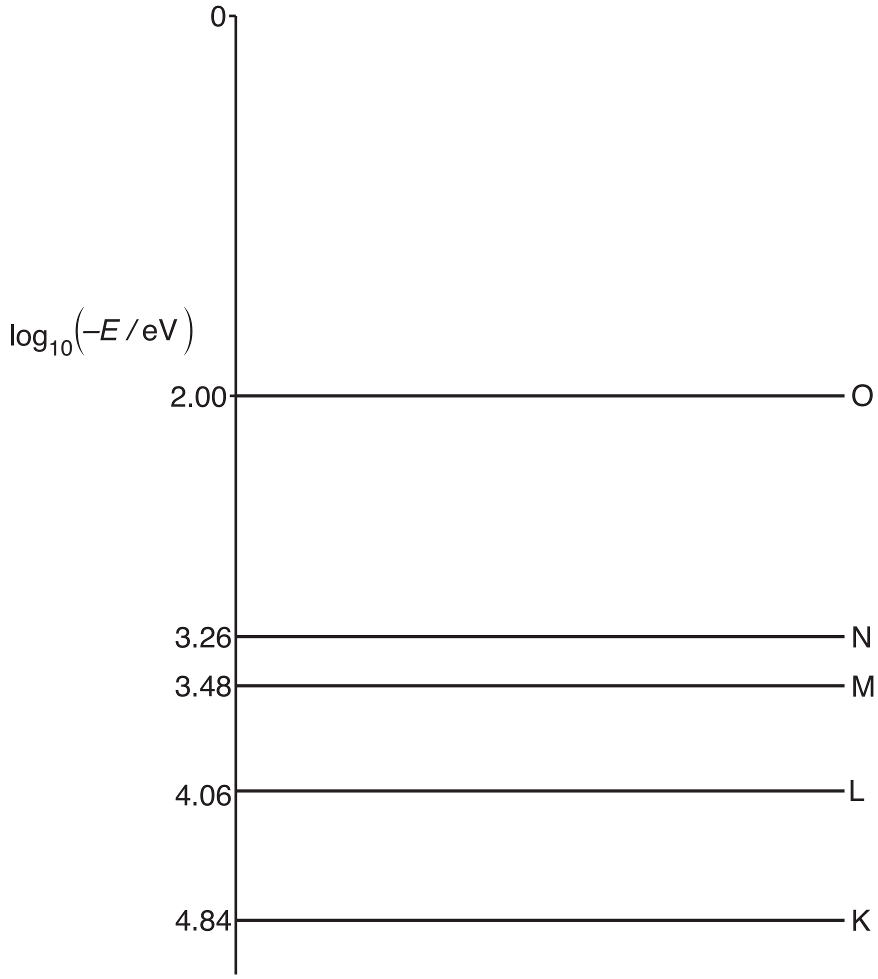

Fig. 9.2

Use information from Fig. 9.2 to determine the wavelength of the photon of radiation emitted from the tungsten atom when an electron falls from level L to level K.

wavelength = ... m [4]

(ii) Fig. 9.3 shows how the intensity of the X-rays produced at the target varies with X-ray wavelength.

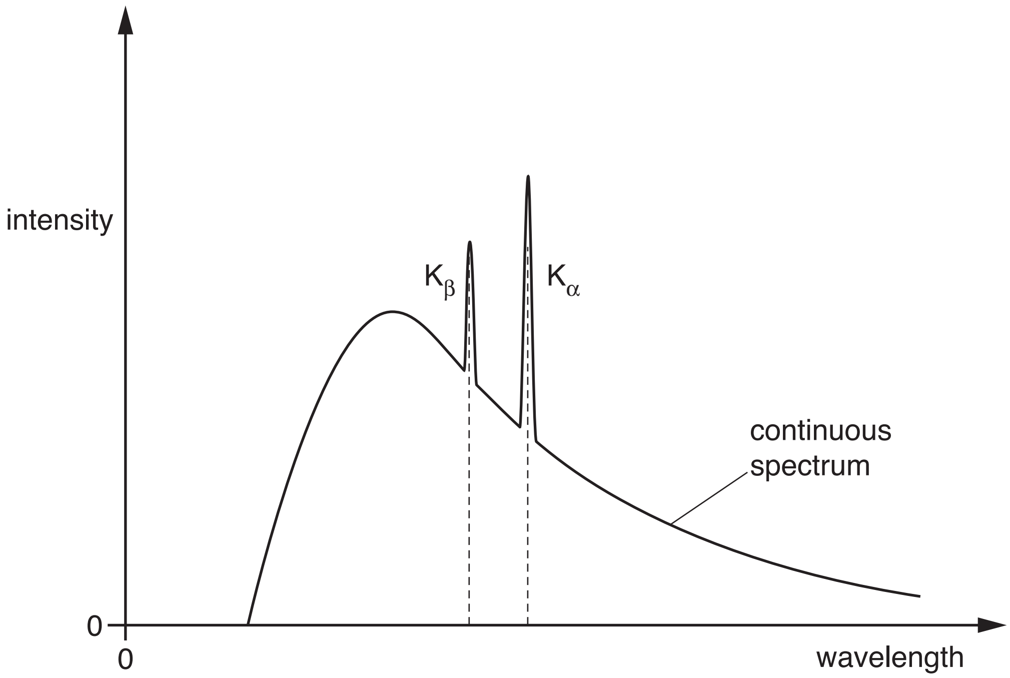

Fig. 9.3

The graph shows the continuous X-ray spectrum for tungsten and two of Tungsten's characteristic spectral lines, K_α and K_β.

1. Suggest how the characteristic spectral line K_β, shown in Fig. 9.3, is produced when an electron arrives at the target.

....

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....

....

....[2]

2. Explain why the K_β line has a shorter wavelength than the K_α line.

....

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....[2]

3. Draw, on Fig. 9.3 the spectrum that would be produced if the electrons in the X-ray machine were accelerated through a higher potential difference. [3]

(iii) An electron falling from the L to the K level gives rise to the K_α line.

The photon energy of electrons falling from level L to level K depends on the element used for the target. The table in Fig. 9.4 shows the photon energy and the proton number *Z* for three elements.

element	proton number *Z*	K_α photon energy / keV
chromium	24	5.40
copper	29	8.03
silver	47	22.10

Fig. 9.4

In 1914 Henry G.J. Moseley discovered that the wavelength λ of the K_α line is related to the proton number by the relationship:

$$\sqrt{\frac{1}{\lambda}} \propto Z$$

1. Describe, without making any calculations, how you would use the information in the table in order to show that Moseley's relationship is valid.

....

....

....[2]

2. Suggest and explain one feature of tungsten that makes it an ideal metal for the target of an X-ray machine.

....

....

....[2]

(c) A beam of X-rays is incident on a sample of human bone. The beam is attenuated as it passes through the bone. The total linear attenuation coefficient of the bone is $0.528\,\text{cm}^{-1}$.

(i) Calculate the depth of bone required to reduce the intensity of the beam to 40.0% of its initial value.

depth of bone = ... cm [2]

(ii) An identical beam of X-rays is also attenuated by 40% as it passes through 3.87 cm of human muscle.

Calculate the total linear attenuation coefficient of human muscle.

total linear attenuation coefficient = ... cm^{-1} [1]

(iii) Briefly explain how these different values of attenuation coefficient help in the interpretation of X-ray pictures taken of human bodies.

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....[2]

(d) The use of X-rays in CT scanning is a powerful non-invasive process used by modern archaeologists.

Give one specific example where CT scanning has enabled an archaeologist to identify characteristic features of a mummified body.

Identify their observations and outline how these have led to conclusions about the body.

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....[3]

[Total: 25]