THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT

PHYSICS B (ADVANCING PHYSICS) G494

Rise and Fall of the Clockwork Universe

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator
- Ruler (cm/mm)

Thursday 28 January 2010
Afternoon

Duration: 1 hour 15 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **60**.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means, for example, you should
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

Section A

1 Here is a list of units.

JK^{-1} **Jkg^{-1}** **Nkg^{-1}** **Ns**

(a) Which one is a correct unit for gravitational potential?

.... **[1]**

(b) Which one is a correct unit for momentum?

.... **[1]**

2 Sodium-24 is a radioisotope which decays with a half-life of 15 hours.

(a) Calculate a value for the decay constant λ of sodium-24.

$1\ h = 3.6 \times 10^3\ s$

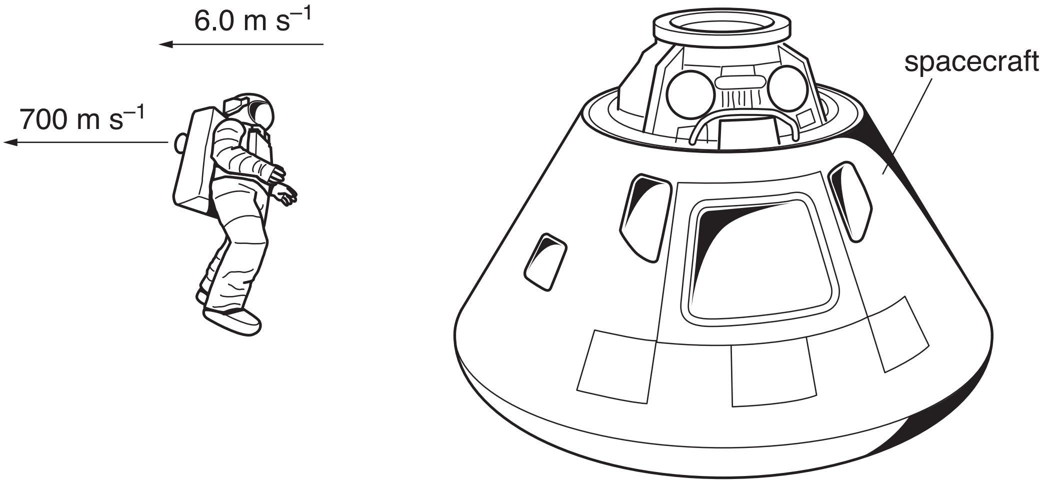
λ = ... s^{-1} **[1]**

(b) The decay of sodium-24 can be modelled as a random phenomenon.

What is the significance of the decay constant in this model?

[2]

3 Astronauts use small rockets to change their velocity in space.
Each rocket emits bursts of gas at high speed.



An astronaut with a mass of 120 kg is moving away from her spacecraft with a relative velocity of 6.0 m s^{-1}. Her small rocket is fired for 5.0 s, emitting a jet of gas directed away from the spacecraft. The rocket emits a mass of 0.15 kg of gas each second. The average velocity of the jet of gas is 700 m s^{-1} relative to the astronaut.

(a) Show that firing the rocket for 5.0 s changes the momentum of the astronaut by about 500 kg m s^{-1}.

[1]

(b) What is her velocity relative to the spacecraft after the rocket has been turned off?

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

4 The relativistic time dilation factor γ is given by $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$.

(a) Show that the value of γ for a particle moving in a beam at a relative speed of $2.0 \times 10^8\,\mathrm{m\,s^{-1}}$ is about 1.3.

$c = 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$

[1]

(b) The particle is unstable and decays with a half-life $T_{½}$ of 8.2×10^{-7} s when it is at rest. Calculate the observed half-life of the particles moving in the beam.

$T_{½}$ = ... s **[1]**

5 The planet Uranus has mass 8.7×10^{25} kg.

(a) Calculate the gravitational potential energy of a satellite of mass 43 kg in a circular orbit of radius 5.1×10^7 m around Uranus.

$G = 6.7 \times 10^{-11}\,\mathrm{N\,kg^{-2}\,m^2}$

gravitational potential energy = ... J **[2]**

(b) Here are four statements **A**, **B**, **C** and **D** about the satellite in its circular orbit.

Which **one** of the statements is correct?

A Its orbital path is on an equipotential surface.

B Its total energy must be greater than zero for a stable orbit.

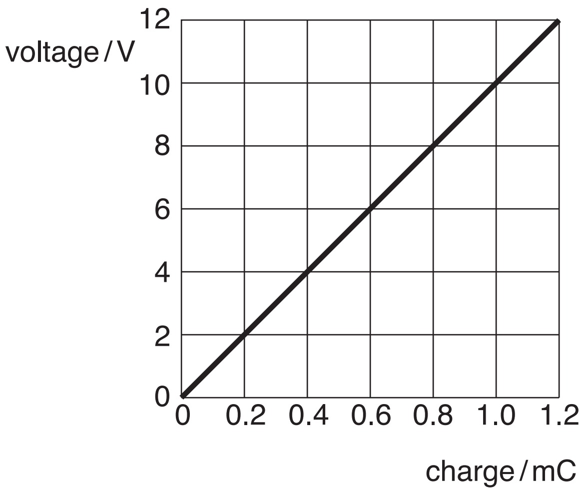
C The gravitational potential of the satellite is its centripetal force.

D The velocity of the satellite is in the direction of the planet's gravitational field.

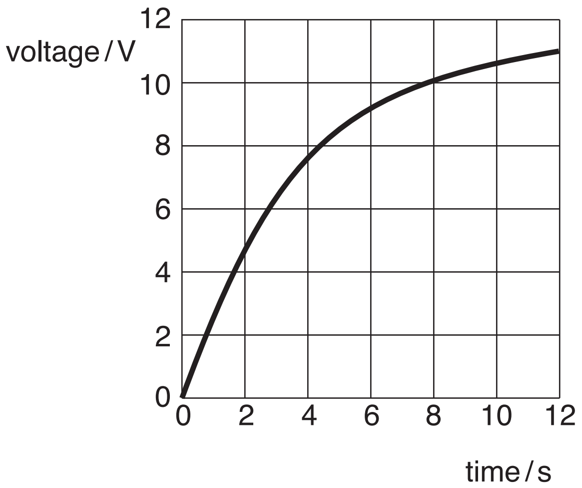
correct statement .... **[1]**

6 Here are three graphs **A**, **B** and **C** for a capacitor charging through a resistor from a 12V supply.

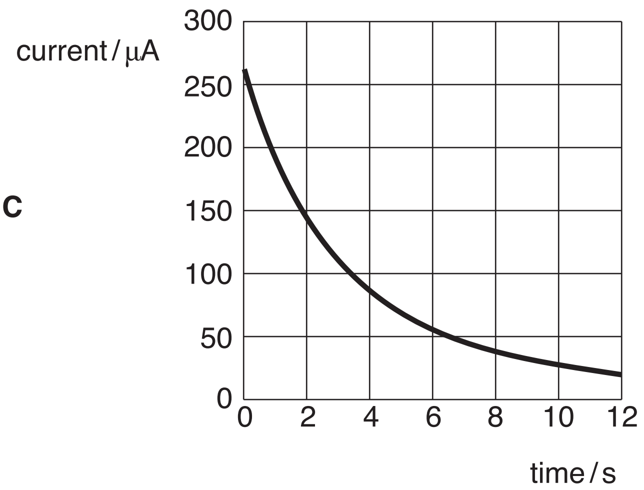
A



B



C



(a) For which graph does the area under the line represent the energy stored in the capacitor?

graph .... **[1]**

(b) Which **one** graph can be used to determine the charge transferred to the capacitor in the first 12 s of charging?

graph .... **[1]**

7 Fig. 7.1 shows a mass suspended from the end of a spring.

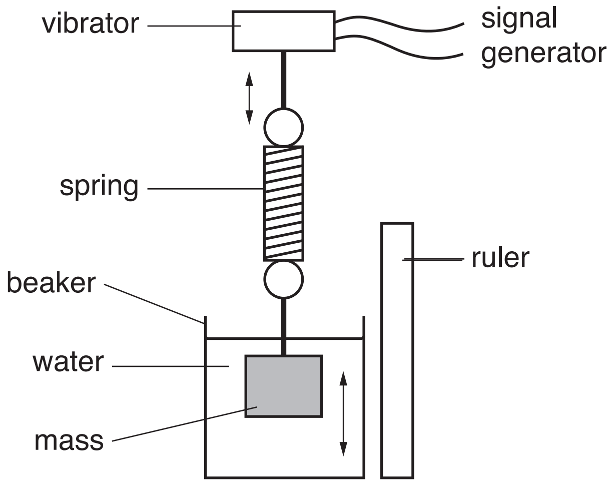


Fig. 7.1

The top of the spring is attached to a vibrator.
The mass is surrounded by water in a beaker.
The frequency of vibration is set by a signal generator.

Show on the axes of Fig. 7.2 how the amplitude of the vertical oscillation of the mass depends on the frequency of the signal generator.

natural frequency of mass and spring = 4 Hz
constant amplitude of vibrator oscillation = 5 mm
maximum amplitude of mass oscillation = 25 mm

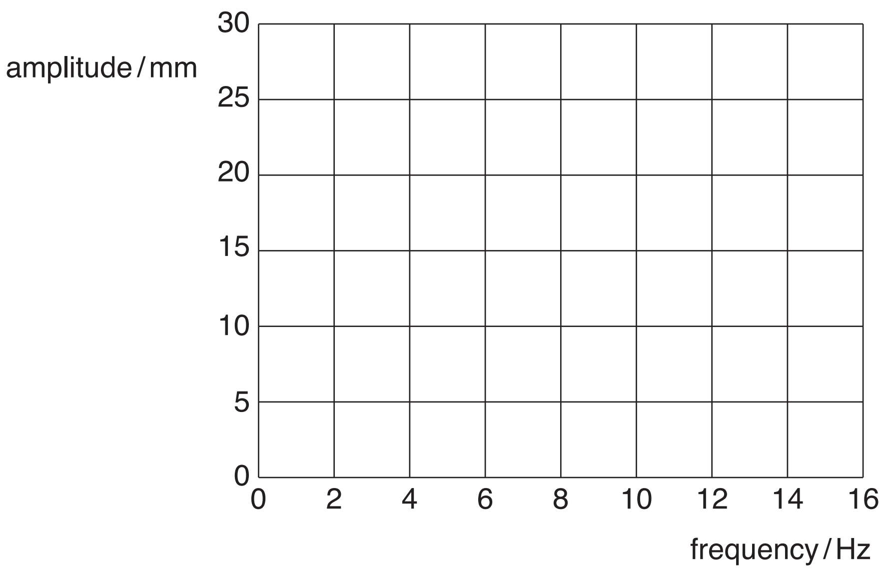


Fig. 7.2

[3]

8 The Universe is believed to be expanding, starting from an original ‘hot big bang’.

Put ticks in the boxes next to the **two** statements which provide support for this picture of the Universe.

Distant and close galaxies are very similar in shape and structure. ☐

Microwave radiation from the Universe can be detected in all directions. ☐

Massive stars explode as supernovae at a certain point in their lifecycle. ☐

Much of the mass of the Universe does not appear to emit electromagnetic radiation. ☐

The red-shift of lines in a galaxy’s spectrum is proportional to its distance from our galaxy. ☐

[2]

[Section A Total: 20]

Section B

9 This question is about heated gases doing work. Fig. 9.1 shows the sequence of changes to the gas trapped in the cylinder of a petrol engine. The graph shows the changes of pressure as the gas is compressed, ignited and allowed to expand again.

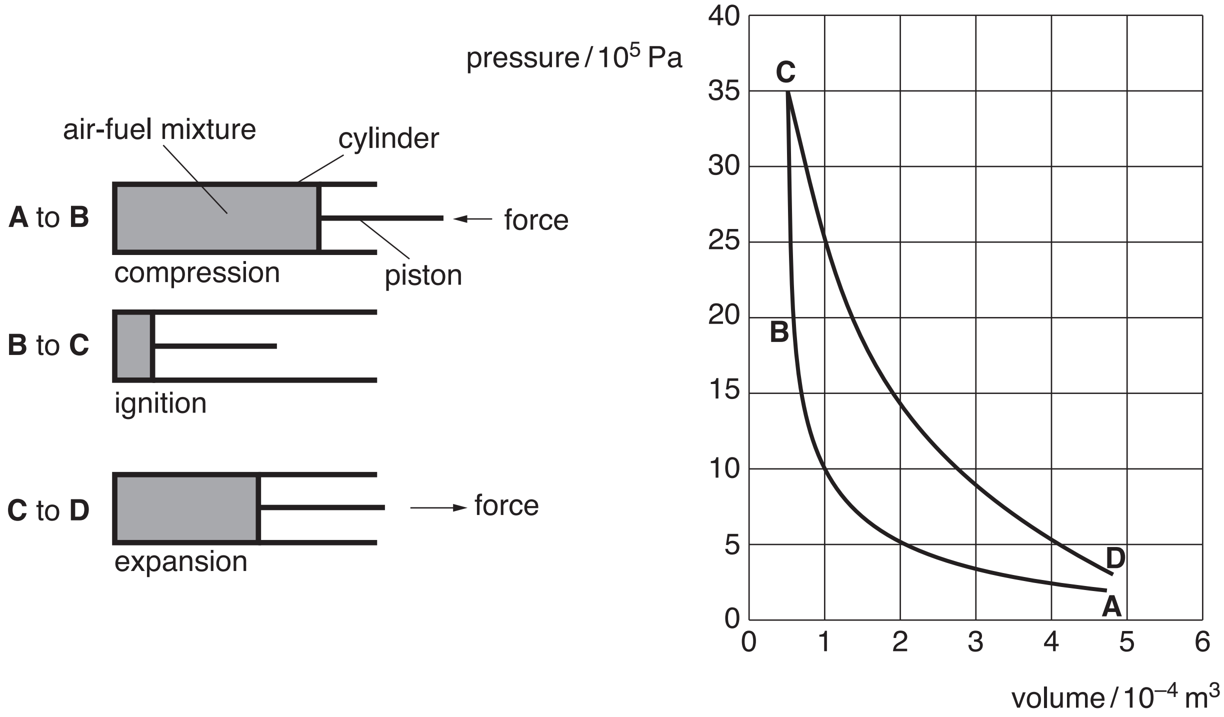


Fig. 9.1

(a) At point **A** the air-fuel mixture enters the cylinder at a pressure of 1.0×10^5 Pa and occupies a volume of $4.8 \times 10^{-4}\,m^3$, with a temperature of 27°C.

(i) Show that the air-fuel mixture at **A** contains about 1×10^{22} particles.
Treat the fuel-air mixture as an ideal gas.
$k = 1.4 \times 10^{-23}\,J\,K^{-1}$

[3]

(ii) It is then rapidly compressed to **B** by the piston to a volume of just $6.0 \times 10^{-5}\,m^3$. Using information from the graph, show that the temperature of the gas at **B** is about 500°C.

[2]

(b) At **B** in the sequence the fuel-air mixture is ignited, increasing the internal energy and pressure of the gas.

(i) Explain the increase in pressure in terms of changes in the motion of the particles in the gas.

Your answer should clearly link the change of pressure to the change in the motion of the particles.

[3]

(ii) Calculate the final temperature of the gas at **C**.

State any assumptions you need to make.

final temperature = ... K **[2]**

(c) From **C** to **D** the gas expands rapidly, applying a force on the piston, until the volume is $4.8 \times 10^{-4}\,m^3$ once more. Explain why the internal energy of the gas decreases, even though there is no time for energy to be conducted away from the gas.

[2]

[Total: 12]

10 This question is about using the motion of satellites to determine the mass of a planet.

Fig. 10.1 shows the path followed by the Moon as it orbits the Earth.

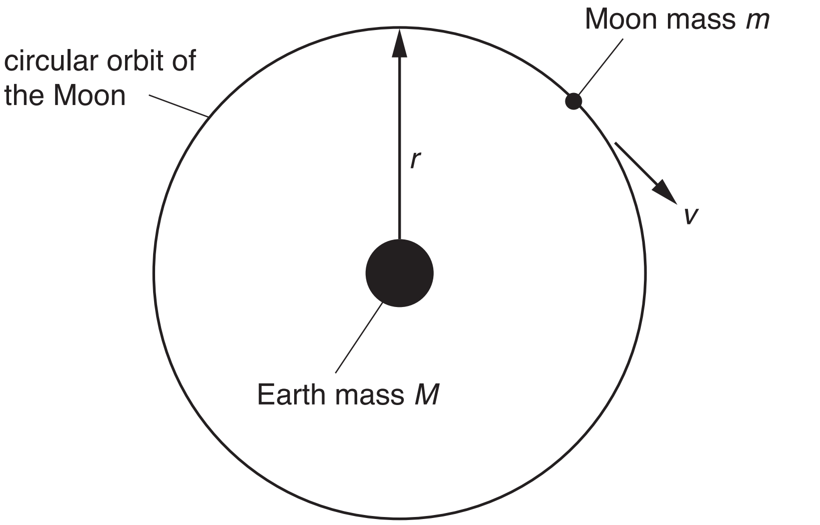


Fig. 10.1

(a) The average distance *r* from the centre of the Earth to the centre of the Moon is 3.8×10^8 m.

(i) Describe how electromagnetic waves can be used to measure the distance of the Moon from the surface of the Earth. State an assumption which has to be made about electromagnetic waves.

Your answer should have correct spelling, punctuation and grammar.

[3]

(ii) The Moon takes 27 days to make one complete orbit of the Earth. Show that the speed *v* of the Moon is about 1000 m s^{-1}.

[2]

(b) The Moon follows a circular orbit because it is accelerated by the gravitational field *g* of the Earth.

(i) Draw an arrow on Fig. 10.1 to show the direction of this acceleration. **[1]**

(ii) Explain why this acceleration does not change the speed of the Moon in its orbit around the Earth.

[1]

(iii) The gravitational force of the Earth upon the Moon is the centripetal force acting on the Moon. Use this idea to calculate the mass of the Earth *M* from the values of *v* and *r* given above.

$G = 6.7 \times 10^{-11}\ \text{N m}^2\,\text{kg}^{-2}$.

M = ... kg **[2]**

[Total: 9]

11 This question is about the simple harmonic motion of atoms in solid metals.
Solid copper can be modelled as follows:

- atoms are arranged in a simple cubic array, separated by an average distance d
- each atom behaves as a mass m held in place by a spring of force constant k.

One plane of these atoms in the solid is shown in Fig. 11.1.

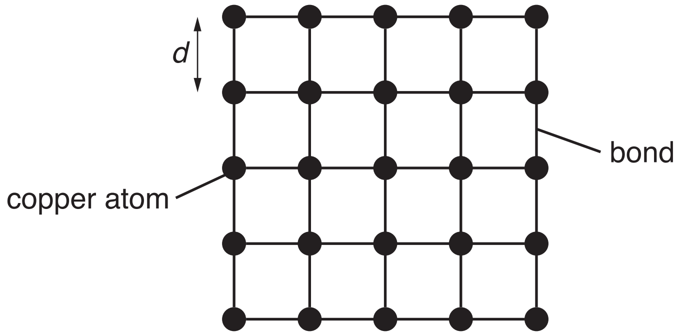


Fig. 11.1

(a) The separation of the atoms d can be calculated from the density of the solid ρ and the mass m of a single atom with the equation

$$\rho = \frac{m}{d^3}.$$

(i) Show how this equation follows from the model.

[1]

(ii) Show that d for copper atoms is about 2×10^{-10} m.
$m = 1.1 \times 10^{-25}$ kg
$\rho = 8.9 \times 10^3$ kg m^{-3}

[2]

(b) It can be shown that, in this model, the Young modulus E of the metal can be calculated from the force constant k and the atom spacing d by the equation

$$E = \frac{k}{d}.$$

(i) Show that k is about 30 N m^{-1}.
$E = 1.3 \times 10^{11}$ Pa

[1]

(ii) Show that E and $\frac{k}{d}$ have the same units.

[1]

(c) Fig. 11.2 shows how the displacement of a single atom varies with time.

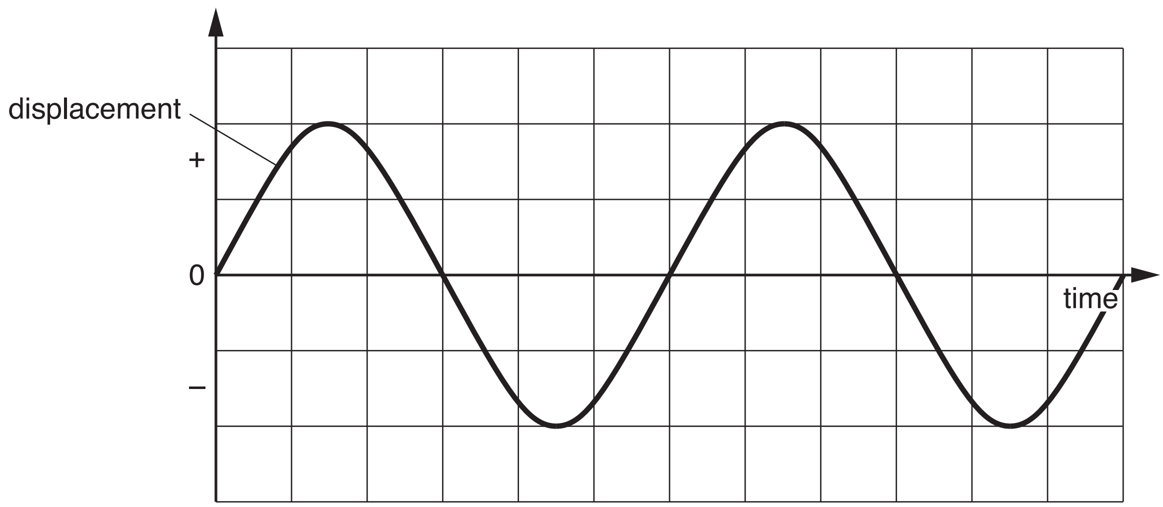


Fig. 11.2

(i) On Fig. 11.2, show how the velocity of the atom varies with time.
Label this curve **velocity**. **[1]**

(ii) On Fig. 11.2, show how the kinetic energy of the atom varies with time.
Label this curve **kinetic energy**. **[1]**

(d) It has been suggested that solid metals melt when the amplitude of oscillation of their atoms is about 15% of their separation. By using kT as an approximation to the average thermal energy per atom, estimate the melting point of copper.

Boltzmann constant, $k = 1.4 \times 10^{-23}\ \text{J K}^{-1}$

melting point = ... K **[3]**

[Total: 10]

12 Fig. 12.1 shows apparatus for measuring the current of electrons emitted from the surface of a metal in a vacuum.

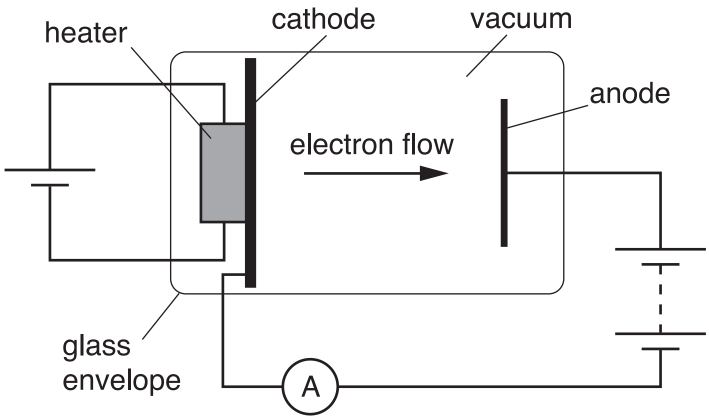


Fig. 12.1

(a) A metal cathode is heated to a temperature T. Its temperature can be found by measuring the energy of the photons emitted by it. Photons are emitted with a range of energies. A typical energy E_T of a photon is given by

$$E_T = 1.6kT$$

where T is the kelvin temperature of the emitting surface.

(i) Calculate the typical wavelength of these photons when the cathode has a temperature of 600 K.

$k = 1.4 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$
$h = 6.6 \times 10^{-34}\,\mathrm{J\,s}$

wavelength = ... m **[3]**

(ii) In what region of the electromagnetic spectrum do these photons lie?
Put a ring around the correct answer.

X-rays **ultraviolet** **visible** **infrared** **microwaves**

[1]

The p.d. across the battery is large enough to ensure that any electrons which leave the surface of the cathode are collected by the positive anode. The electrons then flow through the ammeter on their way back to the cathode.

(b) Suggest why the equation below, which includes the Boltzmann factor, gives an approximate value for the current I in the ammeter.

$$I = Ce^{-\varepsilon/kT}$$

where ε is the energy needed to remove an electron from the cathode, T is the temperature of the cathode, and C is a constant.

[2]

(c) The graph of Fig. 12.2 shows how the logarithm of the current I varies with T for a cathode made from zinc.

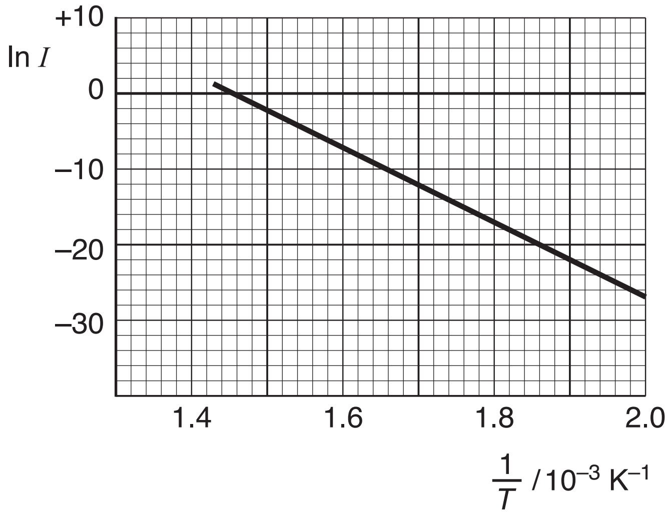


Fig. 12.2

(i) Show that if $I = Ce^{-\varepsilon/kT}$ then the gradient of the straight line of Fig. 12.2 is given by $-\dfrac{\varepsilon}{k}$.

[1]

(ii) Use the graph of Fig. 12.2 to determine the value of ε.
$k = 1.4 \times 10^{-23}$ J K^{-1}

ε = ... J **[2]**

[Total: 9]

[Section B Total: 40]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE