H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

Paper 2 Structured Questions

9749/02

2 Sep 2025
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 8
2	/ 10
3	/ 6
4	/ 6
5	/ 10
6	/ 10
7	/ 10
8	/ 20
Total	/ 80

This document contains **24** printed pages and **0** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.	$v = v_0 \cos\omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A small pellet of mass 8.00×10^{-3} kg is projected at an angle θ above the horizontal, as shown in Fig.1.1. The speed of projection is u.

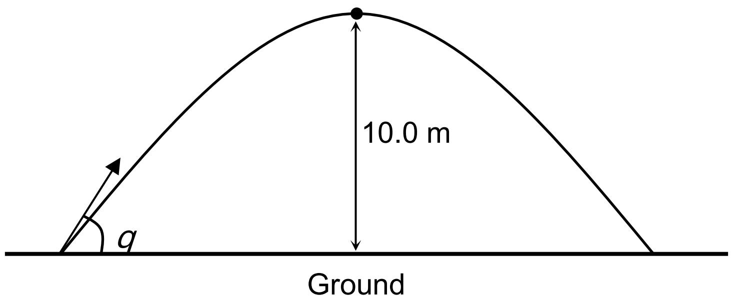

Fig. 1.1

The pellet reaches a maximum height of 10.0 m and travels at a speed of 5.00 m s^{-1} at maximum height.

(a) Air resistance is negligible.

(i) Using energy conservation, show that the initial speed of projection is 14.9 m s^{-1}.

[1]

(ii) Calculate the angle of projection θ.

θ = …………………. ° [2]

(iii) Determine the time taken by the pellet from launch to impact with the ground.

time = ………………… s [2]

(iv) Determine the average rate of change of momentum of the pellet from the instant of projection to the instant before it hits the ground.

rate of change of momentum = ……………… N [1]

(b) Fig. 1.2. shows part of the graph (up to the maximum height) of the variation with time of the vertical displacement of the pellet when air resistance is not negligible.

Complete the graph from the maximum height to the instant the pellet hits the ground. Numerical values are not required. [2]

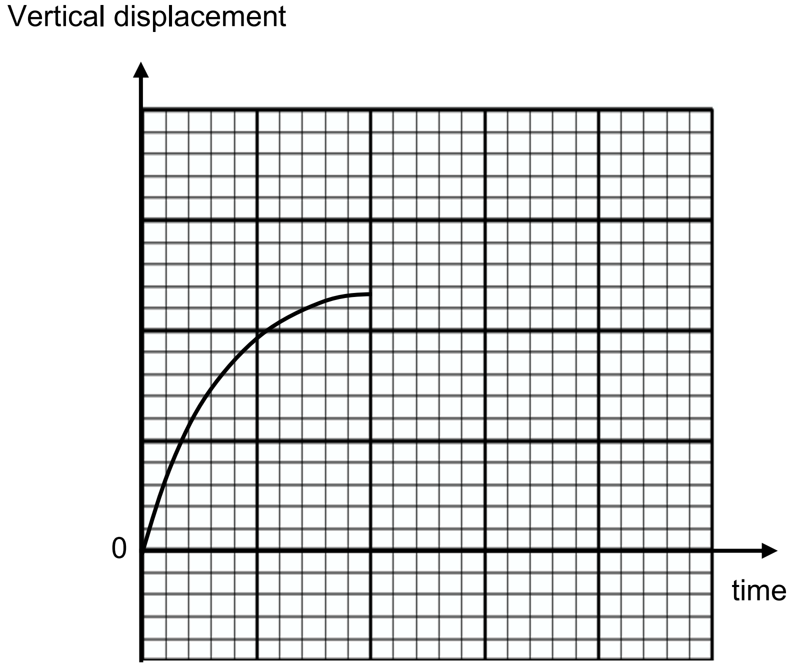

Fig. 1.2

[Total: 8]

2 **(a)** Momentum is conserved when two objects collide.

State the condition under which momentum is conserved.

……

……[1]

(b) Fig. 2.1 shows the variation with time of the momentum of two colliding trucks A and B.

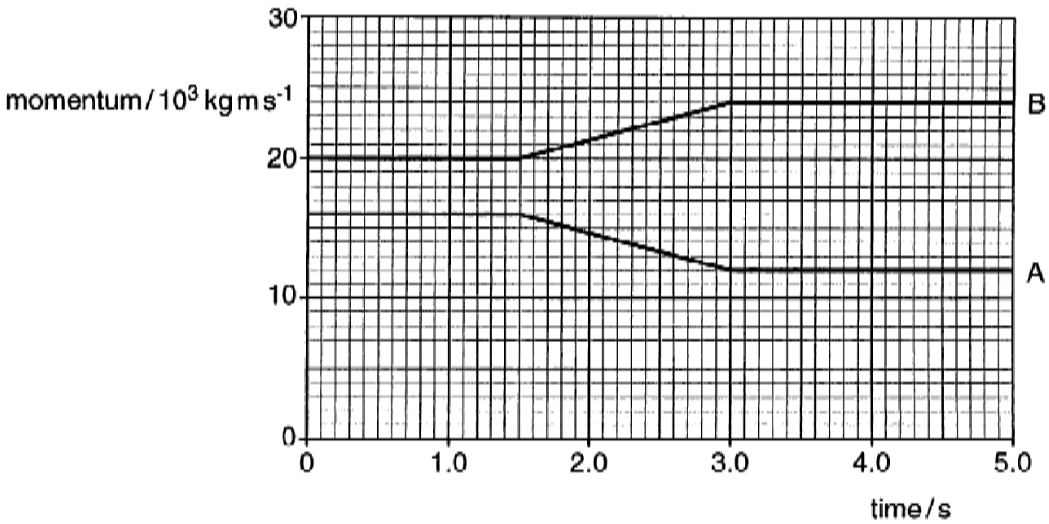

Fig. 2.1

The masses of trucks A and B are 2000 kg and 4000 kg respectively. The period of collision is between 1.5 s and 3.0 s.

(i) Calculate the force acting on truck B during the collision

force = ……………. N [2]

(ii) Explain using Newton's laws, the relationship between the gradients of both graphs during the collision.

……

……

……

……

…………………………………………………………………………………………..……………[2]

(iii) Using the concepts of impulse and momentum, explain why the total momentum of the two trucks is conserved during collision.

…………………………………………………………………………………………..………………

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…………………………………………………………………………………………..……………[2]

(iv) Calculate the change in the total kinetic energy of the trucks before and after the collision. State the type of collision.

change in kinetic energy = ………………………… J [2]

type of collision: ………………………………….……[1]

[Total: 10]

3 Fig. 3.1 shows a wheel that is being pulled over a kerb of height 0.080 m by a horizontal force F. The weight of the wheel is 700 N and the wheel has a radius of 0.60 m.

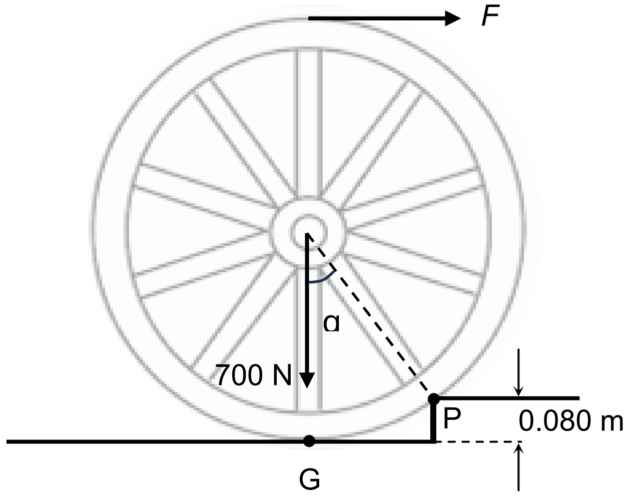


Fig. 3.1 (Not to scale)

At the instant shown, the wheel just loses contact with the ground at G.

(a) Show that θ is 30°.

[1]

(b) On Fig. 3.1, draw an arrow to represent the contact force exerted on the wheel at P. [1]

(c) Show that the minimum value of F is 190 N.

[1]

(d) Hence, determine the magnitude of the contact force at P.

magnitude = ……………….. N [3]

[Total: 6]

4 Binary star systems, consisting of two stars orbiting around each other, are very common.

Fig. 4.1 shows two stars of mass *M* and 2*M* in circular orbits about point C.

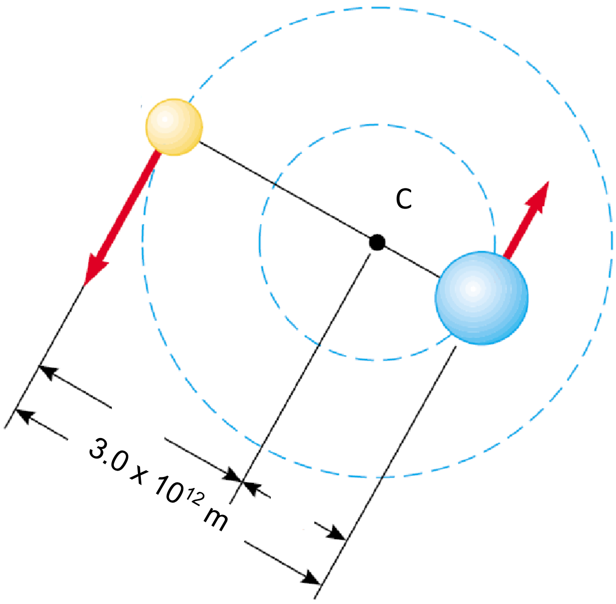


Fig. 4.1

The centre-to-centre separation between the two stars is 3.0×10^{12} m. Both stars have the same orbital period, and they are always located on opposite sides of C.

(a) Explain how the gravitational force acting on one star is equal to the gravitational force acting on the other star.

………

………[1]

(b) The orbital radius of M is r_1 and the orbital radius of 2M is r_2. By considering the magnitude of the centripetal forces acting on the two stars, show that

$$\frac{r_1}{r_2} = 2$$

[Turn over

[1]

(c) Hence, or otherwise, determine the value of r_1.

r_1 = ……………………… m [2]

(d) M is 2.0×10^{30} kg.

Determine the orbital period T of the stars.

T = ………………….. s [2]

[Total: 6]

5 **(a)** State **two** features of a stationary wave that distinguish it from a progressive wave.

1. ……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2. ……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

(b) A microwave emitter is placed in front of a large metal sheet in a vacuum as shown in Fig. 5.1.

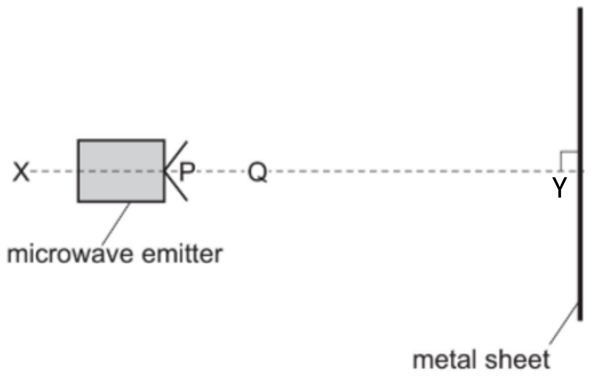


Fig. 5.1 (not to scale)

The line XY is perpendicular to the metal sheet. Distance between P and Q is 1.5 m.

(i) When the emitter is at position P, a stationary wave is formed between the emitter and the sheet.

Explain how the stationary wave is formed between P and Y.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………[2]

(ii) A microwave receiver is placed between P and Y. At point P the receiver detects a maximum amplitude of the stationary wave.

The receiver is moved slowly from point P to point Q along the line PY. The receiver detects another 50 maximum amplitudes including the maximum amplitude at Q.

Determine the wavelength of the microwaves.

wavelength = …………………. m [2]

(iii) Explain whether the number of maximum amplitudes detected between P and Q remains the same, decreases or increases for the following independent changes.

1. The frequency of the microwave is increased from **(b)(ii)** while the intensity remains the same.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2. The intensity of the microwaves is increased while the frequency of the microwaves remains the same as **(b)(ii)**.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……
.

[4]

[Total: 10]

6 **(a)** Define *magnetic flux density*.

……
……………….

……
.

……[2
]

(b) A long, straight wire carries a current into the page, as shown in Fig. 6.1.

Fig. 6.1

On Fig. 6.1, draw field lines to represent the magnetic field around the wire due to the current. [2]

(c) Two long straight, current carrying wires, X and Y are carrying current. They are parallel and separated by a distance of 0.12 m. The current in wire X is 2.0 A and the current in wire Y is 3.0 A as shown in Fig. 6.2.

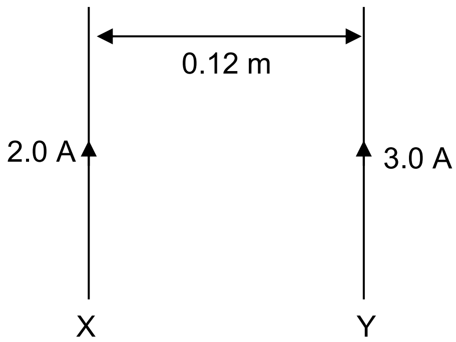


Fig. 6.2

(i) Explain why the two wires exert a magnetic force on each other.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………….

……………………………………………………………………………………………………
.

…………………………………………………………………………………………………..…[2]

(ii) On Fig. 6.2, draw an arrow to show the direction of the magnetic force exerted on wire X. Label your arrow F. [1]

(iii) Calculate the magnetic force per unit length on wire X.

force per unit length = ………………………….. N m^{-1} [2]

(iv) Wire X forms a circular loop centred at wire Y. Wire X carries a current in a clockwise direction and wire Y carries a current into the page, as shown in Fig. 6.3. Current in wire X and wire Y remain the same.

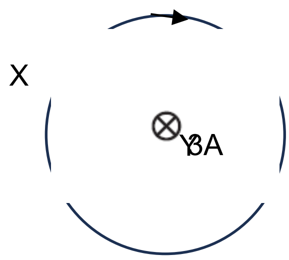


Fig. 6.3

The magnitudes of the currents in wire X and wire Y remain the same.

Explain why no force acts on wire Y.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………….[1
]

[Total: 10]

7 Fig. 7.1 shows the variation with light intensity of the resistance of an LDR.

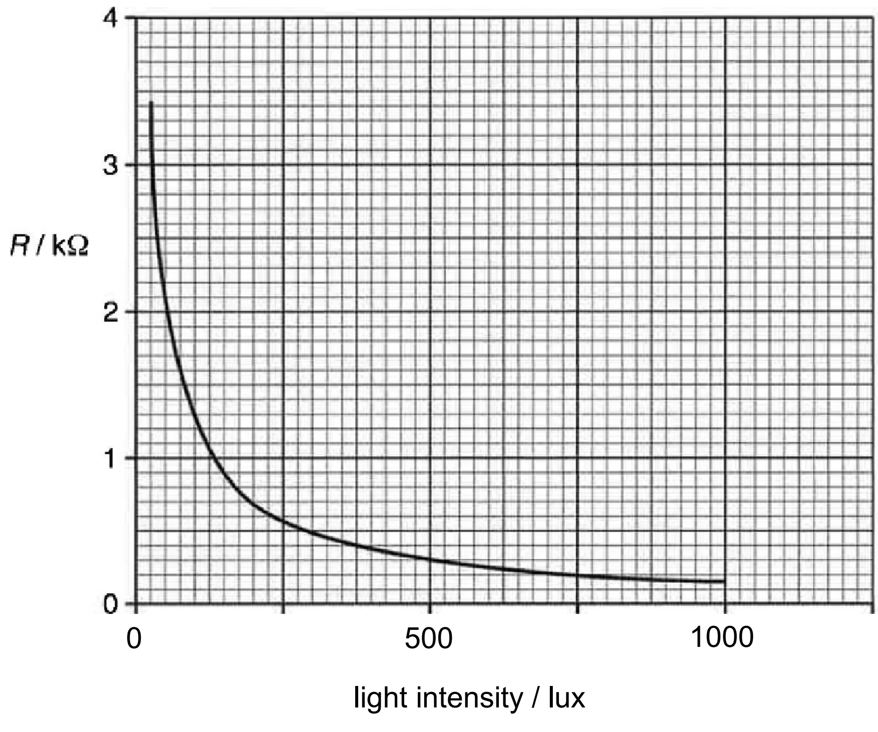


Fig. 7.1

(a) State the resistance of the LDR when the light intensity is 500 lux.

resistance = ………….. Ω [1]

(b) The LDR is to be used as a light sensor in a potential divider circuit shown in Fig. 7.2.

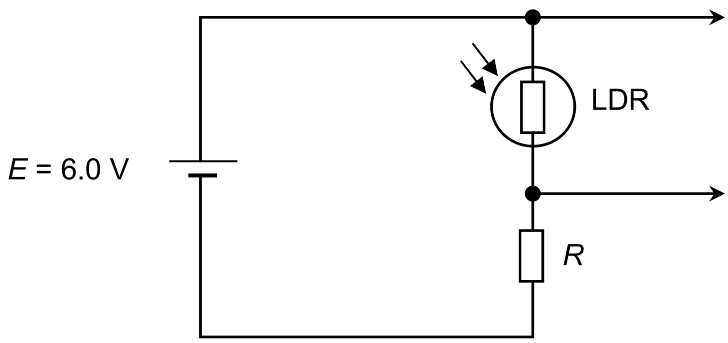


Fig. 7.2

It is required that the potential difference across the LDR be 2.4 V at a light intensity of 500 lux.

(i) Calculate the value of the fixed resistor *R* to achieve this.

R = ………………. Ω [2]

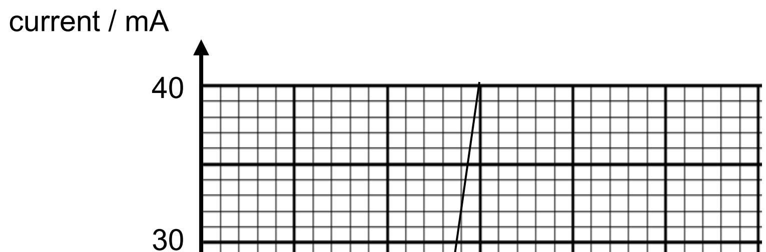
(ii) Explain how the potential difference across the LDR changes if the light intensity incident on the LDR falls below 500 lux.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………..

……………………………………………………………………………………………….[2]

(c) Fig. 7.3 shows the I-V characteristics of an LED. The LED starts to conduct when the potential difference across it is 2.0 V**.**



Calculate the resistance at 3.0 V.

Resistance =…………………………… Ω [1]

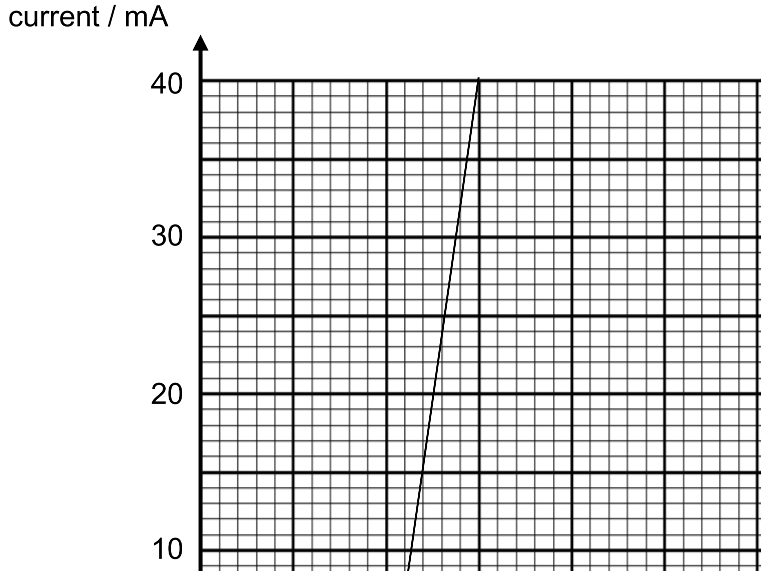
(d) The LDR in Fig. 7.2 is now replaced with component X. Component X consists of the same LDR in parallel with the LED in **(c)**.

The light intensity incident on the LDR remains constant at 500 lux. The resistance of the LDR follows Ohm's law when the intensity of light incident on it is constant.

On Fig. 7.4, draw the I-V characteristics of

(i) the LDR. Label your line as L. [1]

(ii) component X. Label your line as X. [1]



(iii) Hence, determine the current from the 6.0 V battery.

current = ………………. A [2]

[Total: 10]

8 Read the passage and answer the questions that follow.

X-Rays

A modern X-ray tube is illustrated in Fig. 8.1. A heated cathode produces electrons, known as cathode ray, and these are accelerated by the potential difference between the cathode and anode. X-ray tubes used by dentists typically use potential differences of 60 kV. As the electrons hit the anode, X-rays are produced. Tungsten metal is an ideal material for the target, or anode, of an X-ray machine. In practice, only about 1 % of the energy of the electron beam produces X-rays. The rest is wasted as heat.

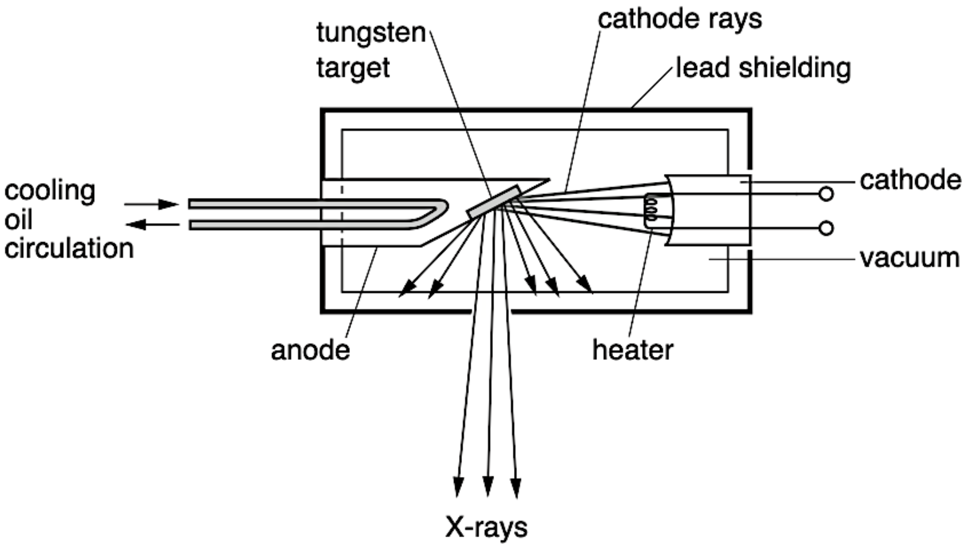


Fig. 8.1

The X-ray spectrum is both a continuous and a superimposed line spectrum, as shown in Fig. 8.2. Fig. 8.2a shows the X-ray spectrum and Fig. 8.2b shows how X-ray intensity varies with the wavelength. The wavelengths of the X-ray spectra are determined by the element from which the target is made.

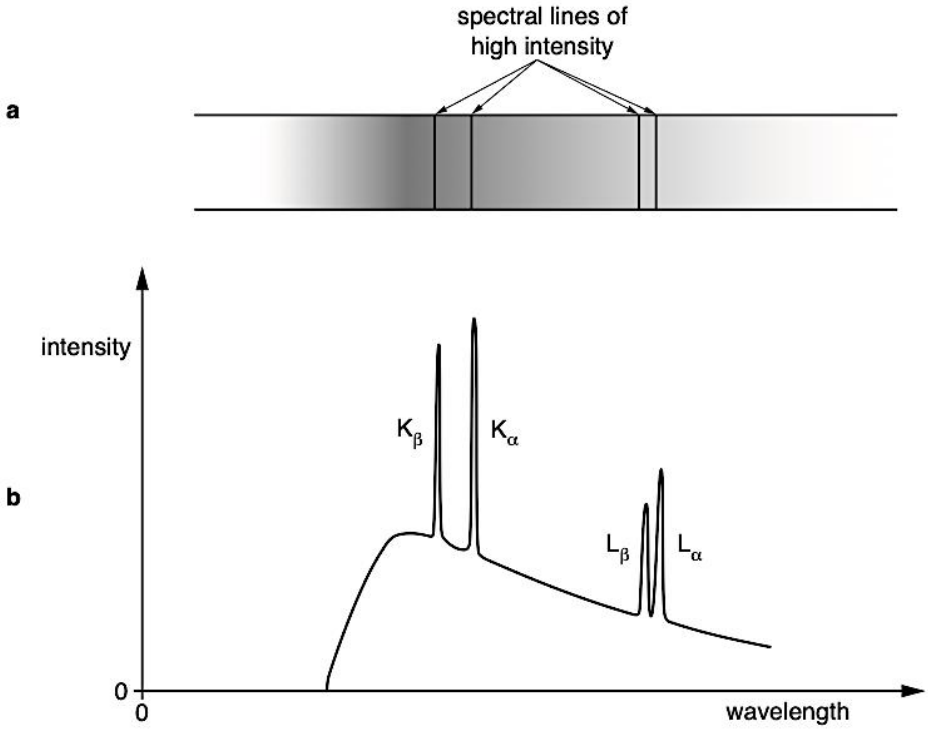


Fig. 8.2

Electrons in the tungsten atom have energy levels in a similar way to the energy levels for a hydrogen atom. Fig. 8.3 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).

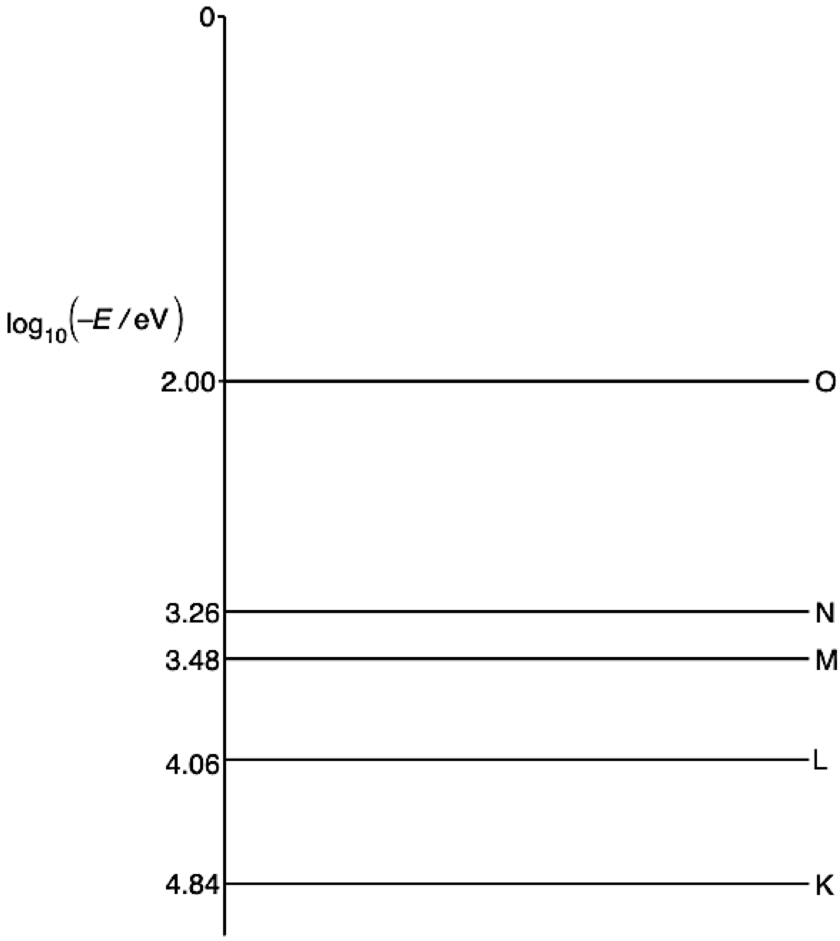


Fig. 8.3

Attenuation of X-ray

When X-ray passes through a medium, it is absorbed by the medium.

The intensity I of a beam of X-ray is related to the distance x it travels through a medium by the relationship:

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

where I_0 is the incident intensity and μ is the **total linear attenuation coefficient**, a constant which depends on the medium and the photon energy of the X-rays.

The decrease variation with distance of the intensity is shown in Fig. 8.4.

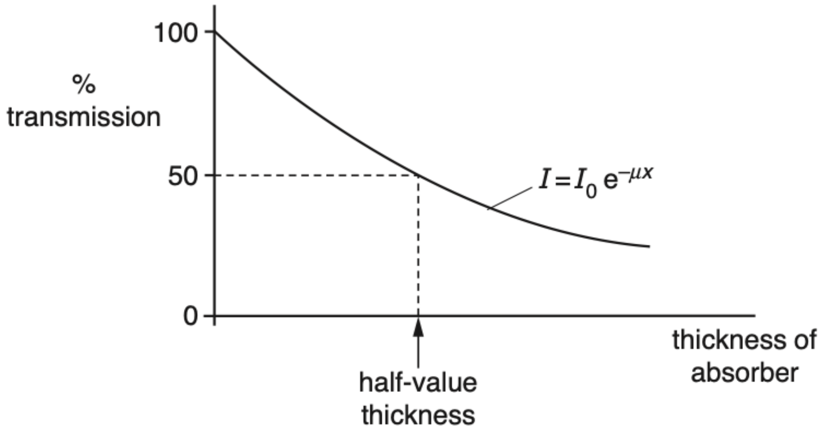


Fig. 8.4

The penetrating power, or quality, of a radiation can conveniently be described in terms of the thickness of material needed to reduce the intensity to half the original value. This is called the **half-value thickness (HVT)**, $x_{\frac{1}{2}}$.

(a) In the production of X-rays, electrons are emitted from the cathode 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) **(i)** When an electron strikes the target anode, it can emit energy in creating a single photon.

Determine the minimum wavelength for the X-ray spectrum used by dentist.

minimum wavelength = …………………………......... m [3]

(ii) Suggest how the continuous spectrum of X-rays in Fig. 8.2 are produced.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

………………………………………………………………………………………………… [1]

(c) 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. 8.5 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
tungsten	74	

Fig. 8.5

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

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

which is known as the Moseley's law.

(i) Determine the K_α photon energy for the tungsten atom.

energy = ……………………...... keV [2]

(ii) Determine quantitatively, without drawing a graph, whether Moseley's law is valid.

[3]

(iii) Explain why the K_β line has a shorter wavelength than the K_α line.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [1]

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

……

……

………………………………………………………………………………………………… [2]

(e) A beam of X-rays is incident on a hand and the X-ray photograph is taken, as shown in Fig. 8.6.

Fig. 8.6

(i) The beam is attenuated as it passes through the bone. The total linear attenuation coefficient of the bone is 0.528 cm^{-1}.

1. Show that the penetrating power of the X-ray in human bone is 1.31 cm

[1]

2. 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]

[Turn over

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

……..

……..

………………………………………………………………………………………………………. [2]

[Total: 20]