H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

Paper 2 Structured Questions

9749/02

27 August 2024
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	/ 9
3	/ 4
4	/ 6
5	/ 11
6	/ 10
7	/ 10
8	/ 22
Total (80)	

[Turn over

This document contains **28** printed pages and **3** 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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

/er

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

1 An object is launched at a speed of 30 m s^{-1} with an angle of 60° from the ground as shown in Fig. 1.1.

Ignore air resistance.

60°
30 m s^{-1}

Fig 1.1

(a) Show that the time taken for the object to reach its maximum height is 2.6 s.

[1]

(b) Sketch the variation with time t of the vertical component of the velocity v_y on Fig. 1.2, from the time it leaves the ground to the time it returns to the ground. [2]

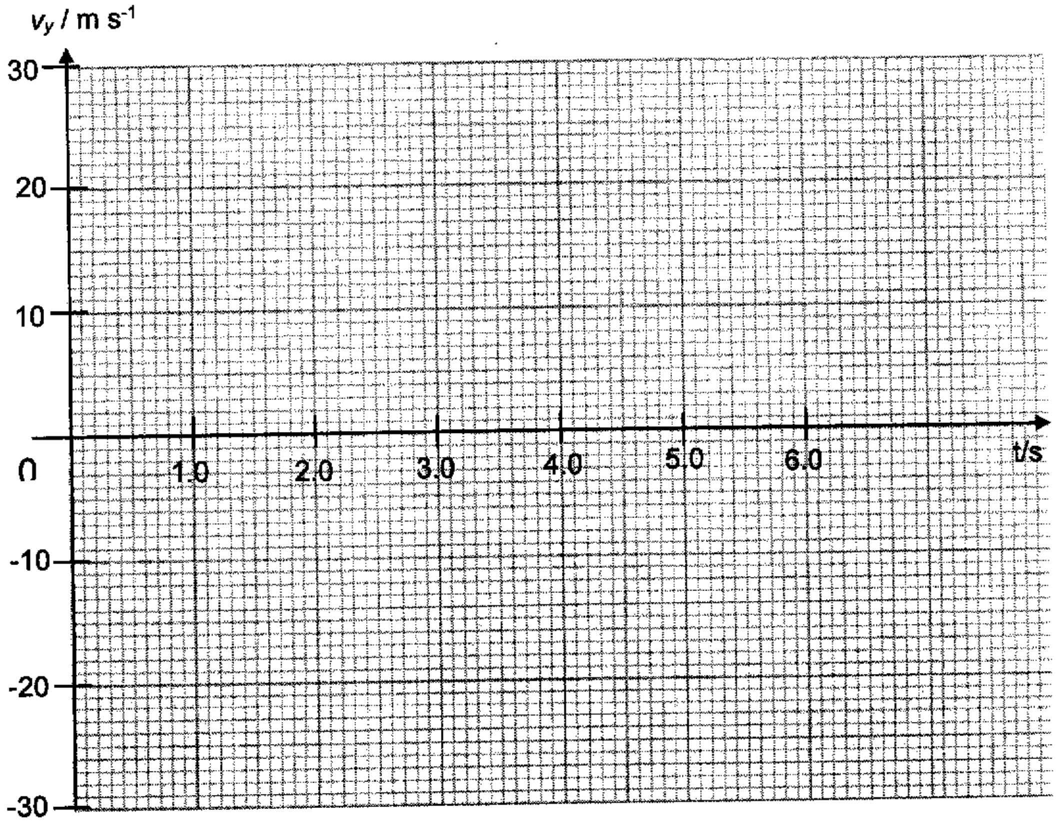


Fig. 1.2

(c) Sketch on Fig. 1.3,

(i) the variation of the horizontal component of the velocity v_x with time of the object for the duration of time in flight.
Label this line **A**. [1]

(ii) the variation of the horizontal component of the velocity v_x with time of the object for the duration of time in flight if air resistance is not negligible.
Label this line **B**. [2]

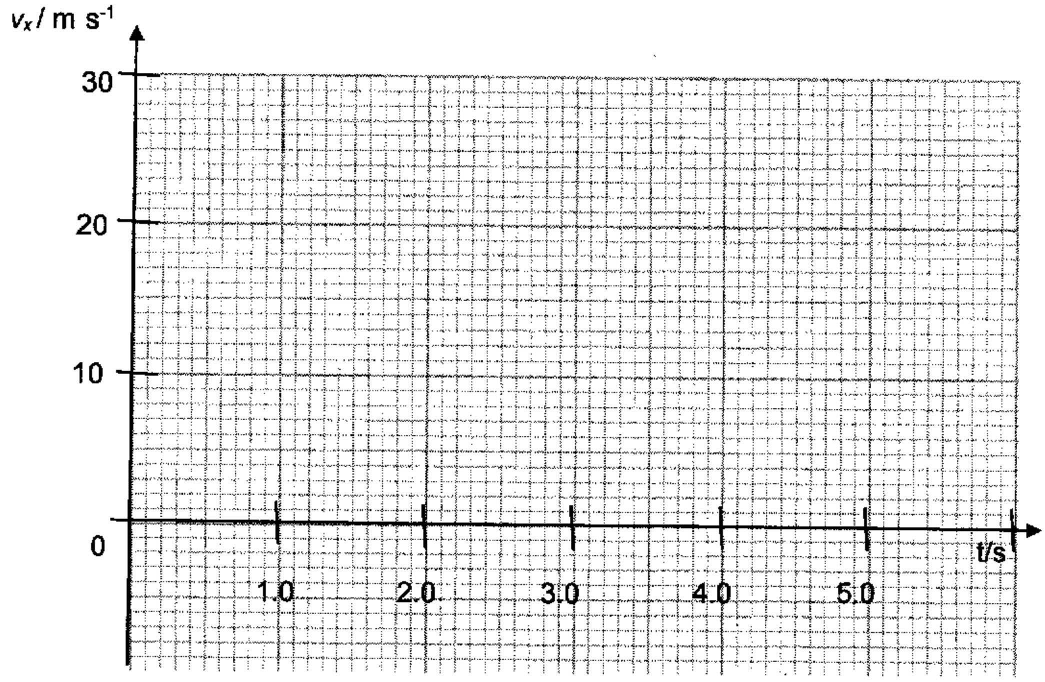


Fig. 1.3

(d) A second object is launched at the same instant with the same speed but at an angle of 30° above the ground. Air resistance is negligible.

Determine the vertical displacement between the two objects at 2.6 s.

vertical displacement = ... m [2]

[Total: 8 marks]

2 **(a)** State the relation between force and momentum.

.... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 2.1

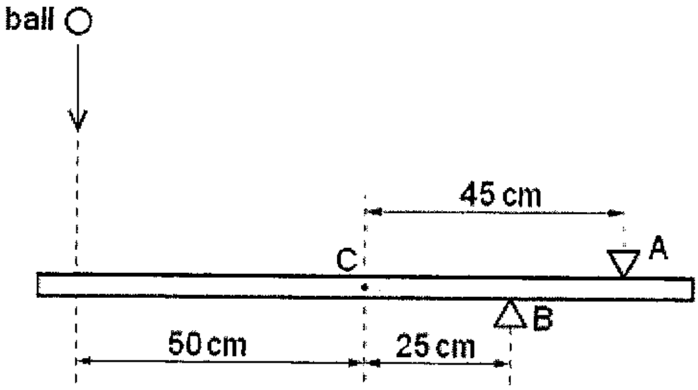


Fig. 2.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 2.1.

The variation with time *t* of the velocity *v* of the ball before, during and after hitting the bar is shown in Fig. 2.2.

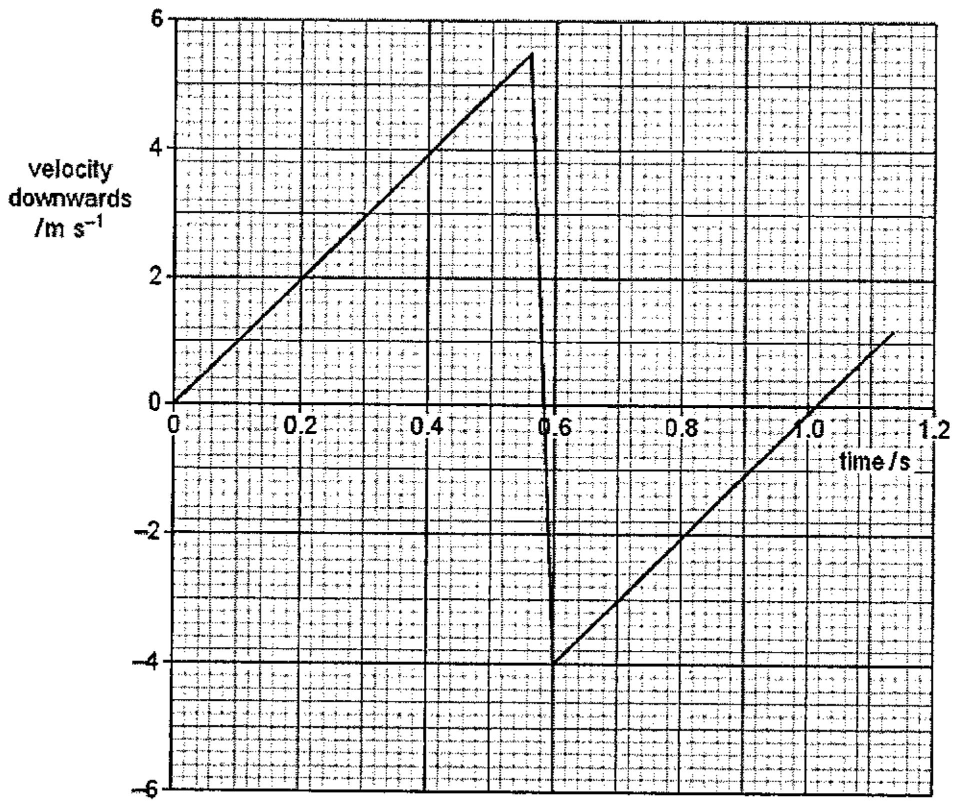


Fig. 2.2

For the time that the ball is in contact with the bar, use Fig. 2.2 to

(i) determine the resultant force acting on the ball,

resultant force = ... N [2]

(ii) show that the force exerted by the ball on the bar is 35 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 2.1. and (b)(ii) to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B,

force = ... N [2]

[Total: 9 marks]

3 **(a)** Fig 3.1 below shows a closed symmetrical jar with dimensions as shown. It contains a liquid of mass 3.0 kg and density 900 kg m^{-3}. The liquid exerts a pressure on the base of the jar.

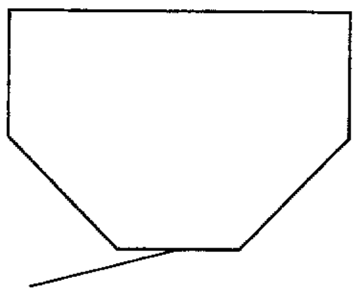


Fig. 3.1
3.0 cm
3.0 cm
Area of base 9.0 cm^2

Determine the pressure exerted by the liquid at the base of the jar.

pressure = ... Pa [2]

(b) Fig 3.2 below shows an object that is not in equilibrium partially submerged in water.

water

Object not in equilibrium

Fig 3.2

The density of the object is uniform and is less than the density of water.

By drawing the weight of the object *W* and the upthrust *U* acting on the object on Fig. 3.2, describe briefly what will happen to the object and suggest its approximate position after it comes to equilibrium.

....

....

.... [2]

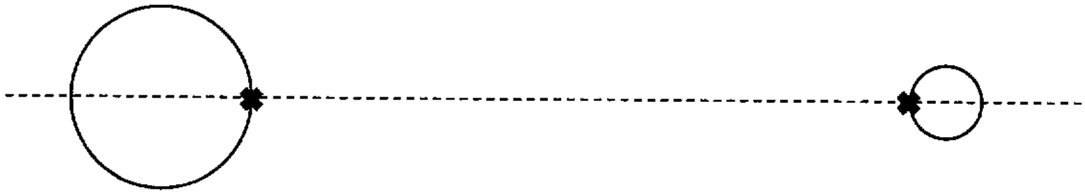
[Total: 4 marks]

4 **(a)** Define gravitational field strength.

....

.... [1]

(b) Fig 4.1 shows point A and point B on the surface of the Earth and the Moon respectively, along the line joining their centres.



Earth
Moon
A
B

Fig 4.1 (not to scale)

(i) There exist a point X on the line joining the centres of Earth and Moon where the resultant gravitational field strength is zero. Estimate and label this point X on Fig 4.1. [1]

(ii) The mass of Earth is 5.97×10^{24} kg, the mass of Moon is 7.34×10^{22} kg, the radius of Earth is 6.37×10^{3} km, and the radius of Moon is 1.74×10^{3} km. The centre-to-centre distance between Earth and Moon is 3.84×10^{5} km.

Determine the magnitude of gravitational field strength at A and B respectively.

gravitational field strength at A = ... N kg^{-1}

gravitational field strength at B = ... N kg^{-1}
[3]

(iii) Without further calculations, sketch the variation with distance d of gravitational field strength g, experienced along the line joining the centre of Earth and Moon between points A and B in Fig. 4.2. [1]

g / N kg^{-1}
d / m
A
B

Fig. 4.2

[Total: 6 marks]

5 Fig. 5.1 shows a horizontal string of length 1.000 m, stretched between a vibrator at A and a pulley at B. The vibrator produces a small oscillation at A and energy is transferred as a wave along the string. P is a point 0.300 m from B. You may consider B to be a fixed point.

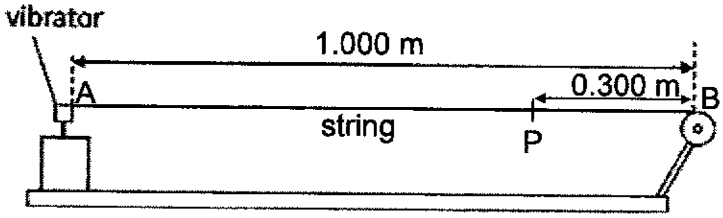


Fig. 5.1

(a) The wave from A, travelling along the string, reaches P along two paths:

Path 1: A to P (the incident wave)
Path 2: A to B to P (the reflected wave)

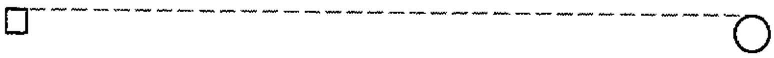
(i) Show that the path difference between the two waves meeting at P is 0.600 m.

[1]

(ii) The wavelength is 1.000 m. When the wave is reflected at B, an additional phase difference of π rad is added to the reflected wave. Determine the phase difference between the two waves when they superpose at P.

phase difference = ... rad [2]

(iii) A stationary wave is formed along AB in Fig 5.1. Sketch the stationary waveform along AB below. [2]



A
B

(iv) Point Q is 0.300 m to the right of A. Using your answer in **(a)(iii)**, state the phase relation between the motion of the particles at P and Q.

....
[1]

[Turn over

(b) Fig. 5.2 shows a modified set up where the string at B is now attached to slotted masses to vary the tension in the string. The pulley at B is frictionless.

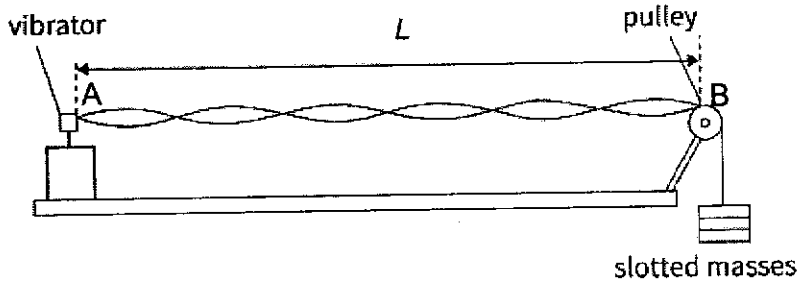


Fig. 5.2

The speed *v* of the wave travelling along the string is related to the weight *mg* of the slotted masses and the mass per unit length / of the string according to the equation:

$$v = \sqrt{\frac{mg}{\square}}$$

The amplitude of oscillation of the vibrator is small and hence point A is approximately a node.

L is 1.000 m.

(i) Show that for stationary waves to form along the string in Fig. 5.2, the frequency *f* of oscillation of the vibrator must satisfy the following relation:

$$f = \frac{n}{2}\sqrt{\frac{mg}{\square}}$$

where *n* is an integer.

[2]

(ii) The mass per unit length μ of the string is 7.0×10^{-3} kg m^{-1} and the frequency of oscillation of the vibrator is f = 25 Hz. Calculate the mass *m* of the slotted masses needed to produce the stationary wave shown in Fig 5.2.

m = ... kg [1]

(iii) The mid-point of the string in Fig 5.2 is now fixed so that it will always be a node. The total mass hanging from the pulley at B remained unchanged. The frequency of oscillation of the vibrator is slowly increased from 25 Hz. Determine the next higher frequency that a stationary wave will form along the string.

frequency = ... Hz [2]

[Total: 11 marks]

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6 **(a)** Fig. 6.1 shows a circuit with a network of resistors.

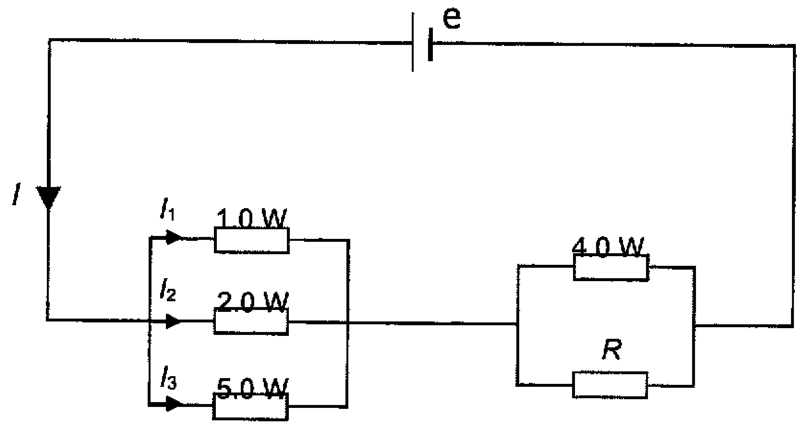

Fig. 6.1

The current from the cell is I.

(i) Determine the ratio of the currents $I_1 : I_2 : I_3$.

$I_1 : I_2 : I_3$ = ... [2]

(ii) 1.0×10^{-3} mol of electrons flowed through the 4.0 ∧ resistor in a time interval of 320 s. During this time interval,

1. Show that the total charge that flowed through the 4.0 ∧ resistor is 96 C.

[1]

2. Show that the electrical energy dissipated in the 4.0 ∧ resistor is approximately 115 J.

[2]

[Turn over

3. The current through the 4.0 ∧ resistor is three times the current through resistor *R*. Determine *R*.

R = ... ∧ [2]

(b) Fig. 6.2 shows a circuit in which a non-ohmic device X is connected in series with a 20 ∧ resistor. The cell has e.m.f. 6.0 V and negligible internal resistance. Fig 6.3 shows the *I*-*V* characteristics of X and the 20 ∧ resistor.

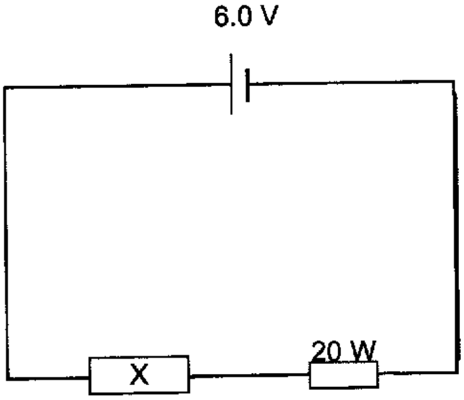

Fig. 6.2

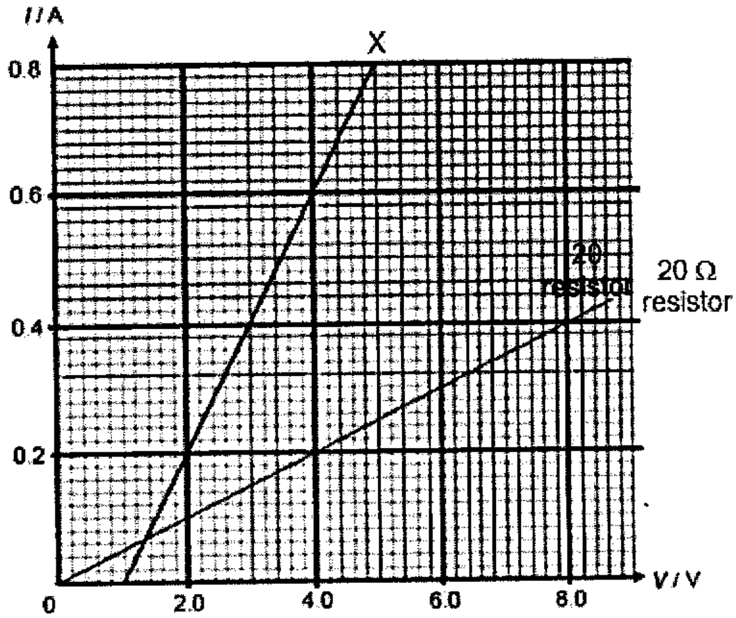

Fig. 6.3 **Fig. 6.3**

(i) Determine the current in the circuit.

current = ... A [1]

(ii) Device X consists of an ideal diode, a cell with negligible internal resistance and an ohmic resistor, connected in series as shown in Fig. 6.4. Suggest the values of the e.m.f of the cell and resistance of the ohmic resistor that will give the I-V characteristics shown in Fig. 6.3.

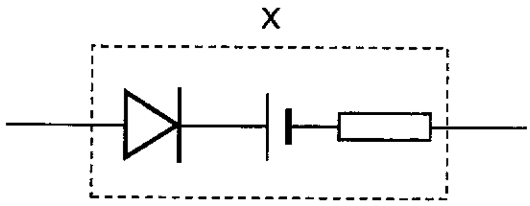

Fig. 6.4

emf of cell = ... V

resistance of resistor = ... Ω

[2]

[Total: 10 marks]

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7 **(a)** State the number of protons, neutrons of a single nuclide whose symbol is

612C

number of neutrons = ...

number of protons = ...

[1]

(b) Define the terms

(i) decay constant,

....

.... [1]

(ii) half-life.

....

.... [2]

(c) Explain why the random nature of radioactive decay makes it difficult to measure the values of the terms in **(b)** to a high degree of accuracy.

....

....

....

.... [2]

(d) Radiocarbon dating, or carbon-14 dating, is a scientific method that can estimate the age of organic materials. Measurements are made of the activity of a specimen of carbon from pieces of wood found in a fireplace at an archaeological site.

The specimen is found to contain one Carbon-14 atom per 8.6×10^{10} Carbon-12 atoms. In a similar wood specimen from a modern fireplace, the concentration of Carbon-14 atoms is greater at one Carbon-14 atom per 3.3×10^{10} Carbon-12 atoms.

(i) The difference between the concentrations of Carbon-14 to Carbon-12 atoms in the old pieces of wood and modern wood is because Carbon-14 is radioactive and some atoms have decayed over the years.

Show that the ratio of undecayed Carbon-14 atoms N to original amount of Carbon-14 atoms N_0 of the old specimen is 0.384. State any assumption(s) made.

Assumption(s): ....

....

[2]

(ii) Hence, determine the age of the wood from the ancient fire. The half-life of Carbon-14 is 5700 years.

age of wood = ... years [2]

[Total: 10 marks]

8 Read the passage below and answer the questions that follow.

Light emitting diodes, commonly called LEDs, are real unsung heroes in the electronics world. They are found in all kinds of devices such as transmitting information from remote controls, digital display on your appliances and form images on television screen.

In LEDs, electrons in the higher energy conduction band fall into empty orbitals of lower energy to release energy in the form of photons. For a standard silicon diode, the photon's is in the infra-red portion of the electromagnetic spectrum and is invisible to the human eye. Depending on the materials used in LEDs, they can be built to shine in infra-red, ultraviolet, and all the colours of the visible spectrum in between. Fig. 8.1 shows different types of LEDs producing distinct wavelengths of colour made of exotic semiconductor compounds mixed together at different ratios such as Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN).

typical LED characteristics			
semiconductor material	wavelength / nm	perceived colour	forward operating voltage V_F at 20 mA / V
GaAs	850 to 940	Infra-red	1.1
GaAsP	630 to 660	Red	1.8
GaAsP	605 to 620	Amber	2.0
GaAsP:N	585 to 595	Yellow	2.2
SiC	430 to 505	Blue	3.4

Fig. 8.1

When operating in a circuit there is a minimum voltage that must be connected across an LED to make it emit light known as the forward operating voltage V_F. V_F is related to the average wavelength (λ) of emitted light by the following equation:

$$V_F = k\,(\lambda)^n$$

where k and n are constants.

An LED is damaged when the p.d. across it is too high. A protective resistor is connected in series with the LED to prevent this. The normal operating current through an LED is 20 mA.

Bare, uncoated semiconductors has a very high refractive index relative to air, which prevents the passage of photons at sharp angles relative to the air-contacting surface of the semiconductor. Uncoated LED semiconductor chip will emit light only perpendicular to the semiconductor's surface, and a few degrees to the side, in a cone shape illustrated in Fig. 8.2. The angle of the cone is determined by the maximum angle of incidence known as the *critical angle*. When this angle is exceeded, photons no longer penetrate the semiconductor, but are instead, reflected internally inside the semiconductor crystal as if it were a mirror.

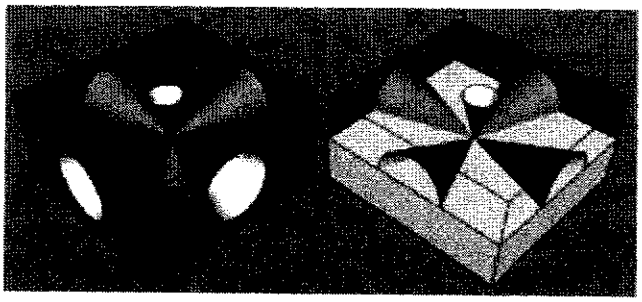

Fig. 8.2

LEDs are specially constructed to release a large number of photons outwards. Additionally, they are housed in a plastic bulb that concentrates the light in a particular direction. As shown in Fig. 8.3, most of the light from the diode bounces off the sides of the bulb, travelling on through the rounded end.

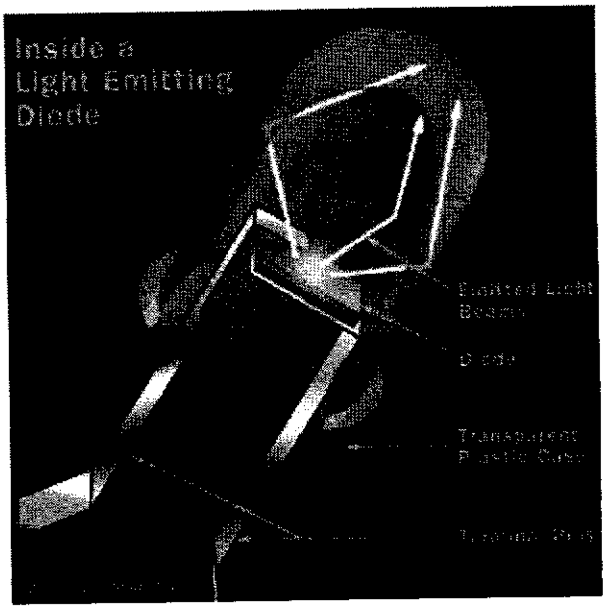

Fig. 8.3

LEDs have several advantages over conventional incandescent lamps. They don't have a filament that will burn out and their small plastic bulb makes them a lot more durable, so LEDs can have lifetimes of 50 000 hours or more. They also fit easily into modern electronic circuits. The main advantage is their efficiency. In conventional incandescent bulbs, the light-production process involves generating a lot of heat so a huge portion of the electrical energy isn't going toward producing visible light. LEDs generate very little heat, relatively speaking, so a much higher percentage of the electrical power goes directly to generating light.

The luminous flux of a device is the total amount of light produced per second and the SI unit of luminous flux is the lumen (symbol: lm). The efficacy of the device is the ratio of its luminous flux to the electrical power supplied and this is measured in lumens per watt (lm W^{-1}). The luminous efficacy of a device is a measurement related to its efficiency. The key advantages of LED-based lighting sources is high luminous efficacy.

Until quite recently, LEDs were too expensive to use for most lighting applications because they're built around advanced semiconductor material. However, the price of semiconductor devices has plummeted since the year 2000, making LEDs a more cost-effective lighting option for a wide range of situations. While they may be more expensive than incandescent lights up front, their lower cost in the long run can make them a better buy.

(a) The photons from a standard silicon diode are invisible to the human eye.

Suggest how other LEDs are able to emit light in the visible light spectrum.

....

....

....

.... [2]

(b) Use information in Fig. 8.1.

(i) Determine the lowest energy of the photons emitted by a nitrogen doped Gallium Arsenide Phosphide (GaAsP:N) LED,

energy = ... eV [3]

(ii) The minimum voltage that must be connected across an LED to make it emit light is called the forward operating voltage V_F.

Explain

1. why no light is emitted by an LED when the voltage supplied is less than V_F,

....

.... [1]

2. why the value of V_F for an LED that emits blue light is greater than that for a LED that emits red light.

....

.... [1]

[Turn over

(c) Data relating average wavelength $\langle\lambda\rangle$ of the light photons emitted by an LED and the forward operating voltage V_F of the five semiconductor materials in Fig. 8.1 are listed in Fig. 8.4.

semiconductor material	$\langle\lambda\rangle$ / nm	V_F / V	lg ($\langle\lambda\rangle$ / nm)	lg (V_F / V)
GaAs	895	1.1	2.952	0.041
GaAsP	645	1.8	2.810	0.255
GaAsP	613	2.0	2.787	0.301
GaAsP:N	590	2.2	2.771	0.342
SiC	468	3.4	2.670	0.531

Fig. 8.4

The variation of lg (V_F / V) with lg ($\langle\lambda\rangle$ / nm) is shown in Fig. 8.5.

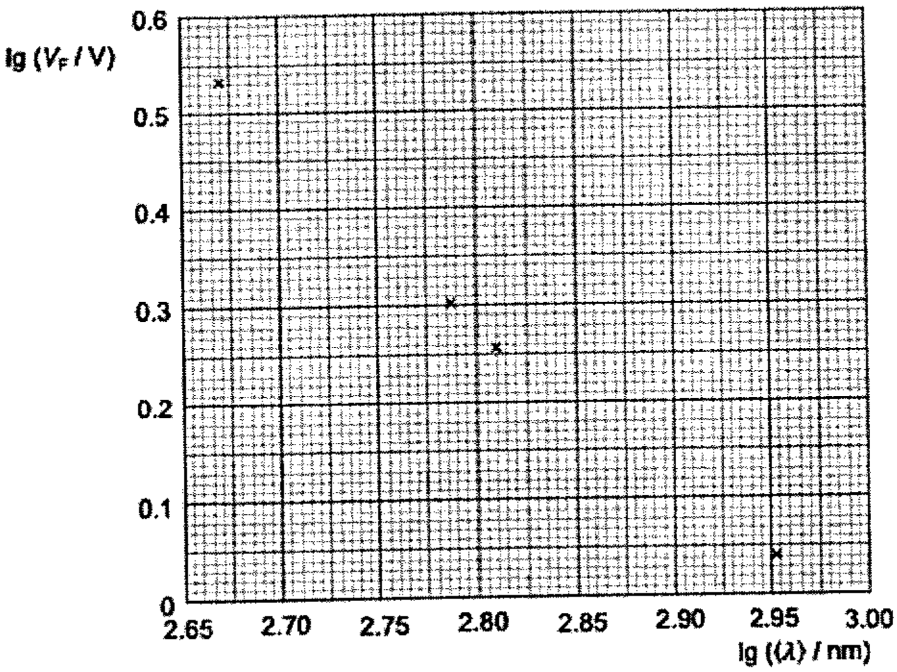

Fig. 8.5

(i) Plot the point for GaAsP:N on Fig. 8.5. [1]

(ii) Complete Fig. 8.5 by drawing the line of best fit. [1]

(iii) Determine the value of n from your line.

n = ... [2]

(d) An unknown LED emits photons of average wavelength 520 nm.

(i) Determine V_F across this LED.

V_F = ... V [2]

(ii) The LED is connected to a power supply of e.m.f. 4.5 V with negligible internal resistance and operates under normal conditions.

Calculate the resistance of the series resistor required for safe operation of the LED.

resistance = ... Ω [2]

(e) The light produced by an uncoated LED is produced in the silicon layer. The refractive index of silicon is 4.24 and air is 1.00.

(i) Show that the speed of light in silicon is 7.08×10^{7} m s^{-1}.

[1]

(ii) Determine the critical angle for light passing from silicon into air.

critical angle = ... ° [2]

(iii) Explain why encapsulating a semiconductor chip in a suitable material increases the efficiency of the LED.

....

....

....

.... [2]

(f) A incandescent lamp produces an illumination of 840 lumens for a 60 W power consumption. An LED lamp produces an illumination of 900 lumens for a 9 W power consumption.

Determine the ratio

$$\frac{efficiency\ of\ LED}{efficiency\ of\ incandescent\ lamp}.$$

ratio = ... [2]

[Total: 22]

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NJC Preliminary Examination 2024
H2 Physics Paper 2

Solutions and Marks Scheme

1 **(a)** Use $v_y = u_y + a_y t$
At max height, $v_y = 0$
0 = 30 sin 60° – (9.81) t M1

t = 2.6 s A0

(b) initial velocity = 26 m s^{-1}, final velocity = –26 m s^{-1} B1

straight line intersects x-axis at 2.6 s and ends at 5.2 s (or 5.3 s) B1

(c) **(i)** horizontal line at u_x = 15 m s^{-1} from t = 0 to 5.2 s (or 5.3 s) B1

(ii) downward sloping curve from 15 m s^{-1} and its gradient decreases numerically B1

ending before t = 5.20 s B1

(d) Calculate displacements of first and second object to be 34.4 m and 5.84 m respectively using 2.6 s (or 34.5 m and 5.31 m using 2.65 s) C1

Displacement between objects = 29 m A1

2 **(a)** Force is the <u>rate of change of momentum</u> B1

(b) **(i)** Resultant force = change of momentum / time taken = [0.140 x (5.5 – (– 4.0))]/0.04 M1

= 33 N A1

(ii) resultant force on ball = Δp/Δt = 33.25 N

Taking forces on the ball, (N is force on ball by bar)

33.25 = N – W M1

N = 33.25 + 0.14*9.81 = 34.62 N

By N3L, force on bar by ball is 35 N. A0

(c) **(i)** Taking pivot about support B,
clockwise moments = F_A x (45 – 25) C1

anti clockwise moments = (0.450 x 9.81) (25) + 35 (25 + 50) C1

Clockwise moments = anti clockwise moments
F_A = 136.768 N = 140 N (to 2 sf) A1

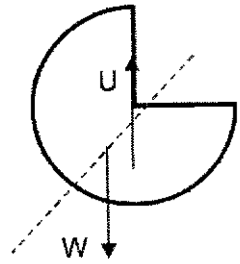
(ii) net force = 0
Upward force = downward force
F_B = 35 + 140 + 0.450 x 9.81 M1

= 180 N (to 2 sf) A1

3 **(a)** Pressure = ρgh = 900 x 9.81 x 6.0/100 M1

= 530 Pa A1

(b) weight and upthrust drawn in correct places (weight starts along the central blue dotted line and upthrust from centre of submerged part, ignore lengths) B1



the object turn anticlockwise (rotating ACW and CW with decreasing angle) until the weight and upthrust are on the same line of action (dotted line is vertical) B1

4 **(a)** The gravitational field strength at a point in a gravitational field is defined as the **gravitational force exerted per unit mass** acting on a small mass placed at that point. B1

(b) **(i)** point X is on the line and closer to Moon B1

(ii) Gravitational field strength at A = $\frac{G(5.97\times10^{24})}{(6.37\times10^{6})^2} - \frac{G(7.34\times10^{22})}{(3.84\times10^{8}-6.37\times10^{6})^2}$ = 9.81 m s^{-2}

Gravitational field strength at B = $\frac{G(7.34\times10^{22})}{(1.74\times10^{6})^2} - \frac{G(5.97\times10^{24})}{(3.84\times10^{8}-1.74\times10^{6})^2}$ = 1.61 m s^{-2}

Marks awarded as follow for both calculations:
- correct equations that include contributions by both Earth and Moon M1
- correct substitutions (e.g. unit conversion, etc) M1
- correct final values A1

(iii) Shape of graph, one positive one negative, cut x-axis closer to B. B1

5	**(a)**	**(i)**	Length of path 1 = 1.000 - 0.300 = 0.700 m Length of path 2 = 1.000 + 0.300 = 1.300 m Path difference = 1.300 – 0.700 = 0.600 m	B1
		(ii)	Phase difference = $\left(\frac{0.600}{1.000} \times 2\pi\right) \pm \pi$	M1
			$= 2.2\pi$ or 6.91 rad or 0.2π or 0.628 rad.	A1
		(iii)	Two segments / loops	M1
			One solid line + one dotted line	A1
		(iv)	Antiphase or π rad / 3.14 rad / 180° out of phase	A1
	(b)	**(i)**	For stationary waves to form, $L = 1.0 = n\left(\frac{\lambda}{2}\right)$ or $\lambda = \frac{2L}{n}$	M1
			From $v = f\lambda$	M1
			$f = \frac{v}{\lambda} = \left(\frac{n}{2L}\right)\sqrt{\frac{mg}{\mu}} = \left(\frac{n}{2}\right)\sqrt{\frac{mg}{\mu}}$ since $L = 1.000$	A0
		(ii)	$m = \frac{4f^2}{n^2}\left(\frac{\mu}{g}\right) = \frac{4(25)^2}{6^2}\left(\frac{7.0\times10^{-3}}{9.81}\right) = 0.050$ kg	A1
		(iii)	Next higher frequency has 8 segments	C1
			Frequency = 33 Hz	A1
6	**(a)**	**(i)**	From $V = IR$, $I = \frac{V}{R}$ hence $I \propto \frac{1}{R}$	C1
			Ratio = 1 : 0.5 : 0.2 or 10 : 5 : 2	A1
		(ii)	**1.** Q = Ne = $1.0 \times 10^{-3} \times 6.02 \times 10^{23} \times 1.6 \times 10^{-19} = 96.32 \approx 96$ C (shown)	A1
			2. Current through the resistor: $I = \frac{Q}{t} = \frac{96}{320} = 0.30$ A	M1
			Energy dissipated = $I^2Rt = (0.30)^2(4.0)(320)$ $= 115.2 \approx 115$ J	M1
			OR	
			p.d. V = IR = 0.30 x 4.0 = 1.2 V	(M1)
			Energy = QV = 96 x 1.2 or Energy = $\frac{V^2}{R}t = \frac{1.2^2}{4.0} \times 320$	(M1)
			3. Let the current through R be I. Current through 4-ohm resistor = 3I Since resistors are in parallel: I x R = 3I x 4	M1
			R = 12 Ω	A1
	(b)	**(i)**	0.2 A	A1
		(ii)	1.0 V	A1

5 ohms A1

7 **(a)** 6, 6 A1

(b) **(i)** Decay constant is the probability of decay per unit time of a nucleus. B1

(ii) Half-life is the time taken for half the (number of radioactive nuclei/count rate/activity) present in any given sample of a given isotope to decay at any given time. B2

(c) Radioactive decay is a random process, in other words we don't know which nuclei will decay next; we only know the probability of decay.

After one half-life, it is not guaranteed that exactly half of the original atoms remain, but that this is just the most likely, and the average outcome.

Marks awarded as follow:
- meaning of random M1
- a reasonable discussion of what that means. A1

(d) **(i)** Original ratio = $\frac{C_{14,initial}}{C_{12,initial}} = \frac{1}{3.3\times10^{10}}$

Over the years, the ratio became $\frac{C_{14,final}}{C_{12,initial}} = \frac{1}{8.6\times10^{10}}$

$\frac{N}{N_o} = \frac{C_{14,final}}{C_{14,initial}} = \frac{C_{14,final}}{C_{12,initial}} \times \frac{C_{12,initial}}{C_{14,initial}} = \frac{1}{8.6\times10^{10}} \times \frac{3.3\times10^{10}}{1}$ C1

$= 0.384$ A0

Assumption: Ratio of C-12 to C-14 for a fresh sample of wood is constant/ C-12 remains the same B1

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

$\lambda = \frac{ln2}{5700} = 1.2160 \times 10^{-4}$ y^{-1}

$0.384 = e^{-1.2160 \times 10^{-4}(t)}$ M1

$t = 2.49 \times 10^{11} s$ = 7870 years A1

8 **(a)** <u>larger energy gap</u> between conduction band and lower orbitals than standard silicon — M1

resulting in a larger energy / higher frequency photons — A1

(b) **(i)** wavelength = 595 nm — C1

energy = $(6.63 \times 10^{-34})(3.00 \times 10^{8}) / (595 \times 10^{-9})$ (= 3.343×10^{-19} J) — M1

energy = $3.343 \times 10^{-19} / 1.60 \times 10^{-19}$ = 2.09 eV or 2.1 eV — A1

(ii) **1.** insufficient energy for electron to promote / excite to appropriate energy level — B1

2. energy of the photons greater / wider gap between the conduction band and the lower orbitals than red LED
so higher energy per unit charge is required — B1

(c) **(i)** point correctly plotted — B1

(ii) even distribution of points on either side of the line along the full length — B1

(iii) correct method to compute gradient i.e. $\Delta y / \Delta x$ and coordinates are read accurate to half the smallest square — M1

gradient calculated correctly (most line will give a gradient of about −1.7 to −1.8) — A1

(d) **(i)** *either* obtain lg V_F from graph and $V_F = 10^{\text{value}}$ (e.g. lg (520) = 2.716, lg V_F = 0.435)
or calculate k from y-intercept and substitute 520 nm into $V_F = k(\lambda)^n$ — M1

$V_F \approx 2.7$ V (final answer depends on the line of best fit and rounding in the intermediate calculations) — A1

(ii) p.d. across resistor = 4.5 − V_F from **(d)(i)**
resistance = p.d. / 20 mA — M1

resistance ≈ 90 Ω — A1

(e) **(i)** $v = c / n = 3.00 \times 10^{8} / 4.24$ — M1

$v = 7.08 \times 10^{7}$ m s^{-1} — A0

(ii) $n_1 \sin\sin\theta_1 = n_2 \sin\sin\theta_2 \Rightarrow 4.24 \sin\sin\theta = (1.00) \sin\sin 90°$ — C1
$\theta = 13.6°$ — A1

(iii) coating increase critical angle so more photons emerge / allows photons with larger angles to the normal of the surface of diode (that are otherwise trap in diode) to emerge — M1

these photons (with those emerging perpendicularly) are then reflected by plastic bulb and concentrated in forward direction — A1

so, more photons released for given energy input

(f) ratio = (900 / 9) / (840 / 60) — M1

= 7.1 — A1