NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/03**

Paper 3 Structured Questions

26 Aug 2022
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.

Section A
Answers **all** questions.

Section B
Answer one question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B

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

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 12**
3	**/ 14**
4	**/ 10**
5	**/ 6**
6	**/ 8**
Section B	
7	**/ 20**
8	**/ 20**
Total (80)	

This document contains **24** printed pages and **4** 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	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 If an object is projected vertically upwards from the surface of a planet at a fast enough speed, it can escape the planet's gravitational field. This means that the object can arrive at infinity where it has zero kinetic energy. The speed that is just enough for this to happen is known as the escape speed.

(a) r is the distance from the centre of the planet.
On Fig 1.1, draw the variation with distance r of the kinetic energy E_K, gravitational potential energy E_P and the total energy E_T of this object from the surface of the planet.

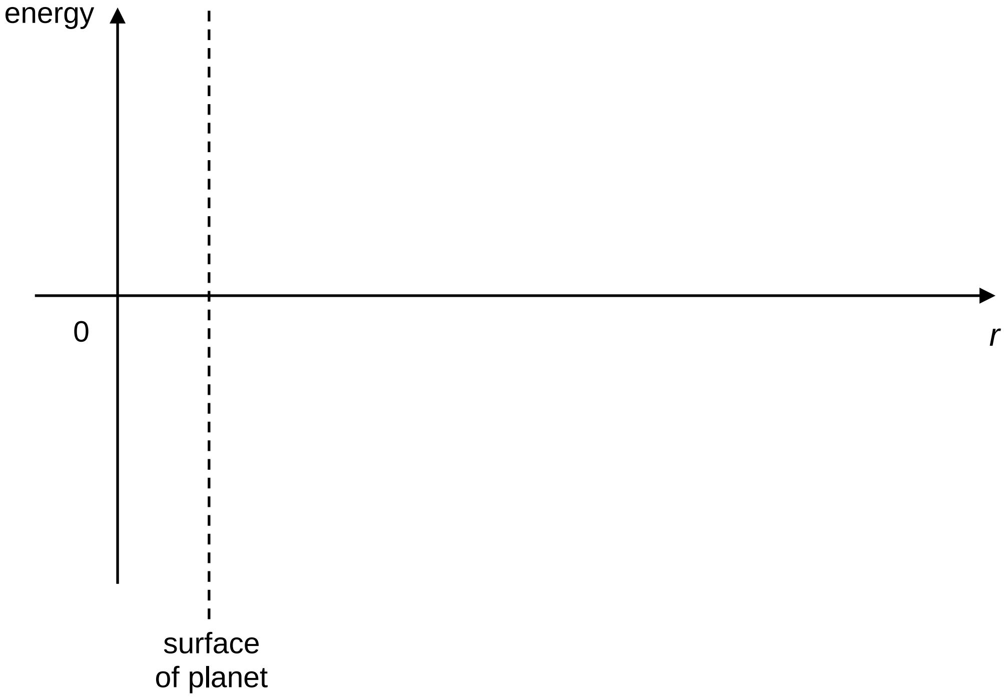

Fig. 1.1

[3]

(b) **(i)** By equating the kinetic energy of the object at the planet's surface to its total gain of potential energy in going to infinity, show that the escape speed v is given by

$$v^2 = \frac{2GM}{R}$$

where R is the radius of the planet and M is its mass.

[1]

(ii) Hence show that

$$v^2 = 2Rg$$

where g is the acceleration of free fall at the planet's surface.

[2]

(c) The mean kinetic energy E_k of an atom of an ideal gas is given by

$$E_k = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

(i) Using the equation in **(b)(ii)**, estimate the temperature at the Earth's surface such that helium atoms of mass 6.6×10^{-27} kg could escape to infinity.

You may assume that helium gas behaves as an ideal gas and that the radius of Earth is 6.4×10^6 m.

temperature = ... K [3]

(ii) The temperature estimated in **(i)** is measured in thermodynamic scale. Explain what is absolute zero in the thermodynamic scale.

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

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

[Total: 10]

[Turn over

2 A container contains an ideal gas at a thermodynamic temperature T. The kinetic theory of gas assumes that the molecules of the gas behave as hard, identical spheres that are in continuous random motion. The theory shows that

- the pressure exerted on the wall of the container by the gas is due to the elastic collisions of the molecules with the wall of the container
- the pressure is proportional to the mean-square speed of the molecules
- the mean translational kinetic energy of a molecule is $E_K = \frac{3}{2}kT$ where k is the Boltzmann constant.

(a) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules of the gas.

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.... [3]

(b) A container with 1.2 mol of an ideal gas. The gas has a mass of 0.0384 kg.

During the heating of the gas,

- the volume of the gas increases (the container does not have a fixed volume)
- the pressure of the gas remains constant
- the temperature of the gas changes from 280K to 460K
- the gas does 1.3×10^3 J of work.

(i) Explain, in terms of the force produced by the molecules of the gas, how the pressure remains constant as the volume increases.

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.... [3]

(ii) Use the first law of thermodynamics to determine the specific heat capacity of the gas.

specific heat capacity = ……………………………………….. J kg^{-1} K^{-1} [4]

(c) The container in **(b)** is now replaced with one that has a fixed volume. Thermal energy is supplied to the gas to increase its temperature from 280K to 460K.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(b)(ii)**.

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

[Total: 12]

3 Hydrogen gas at low pressure can be made to emit photons in a discharge tube using a high voltage supply, as shown Fig. 3.1.

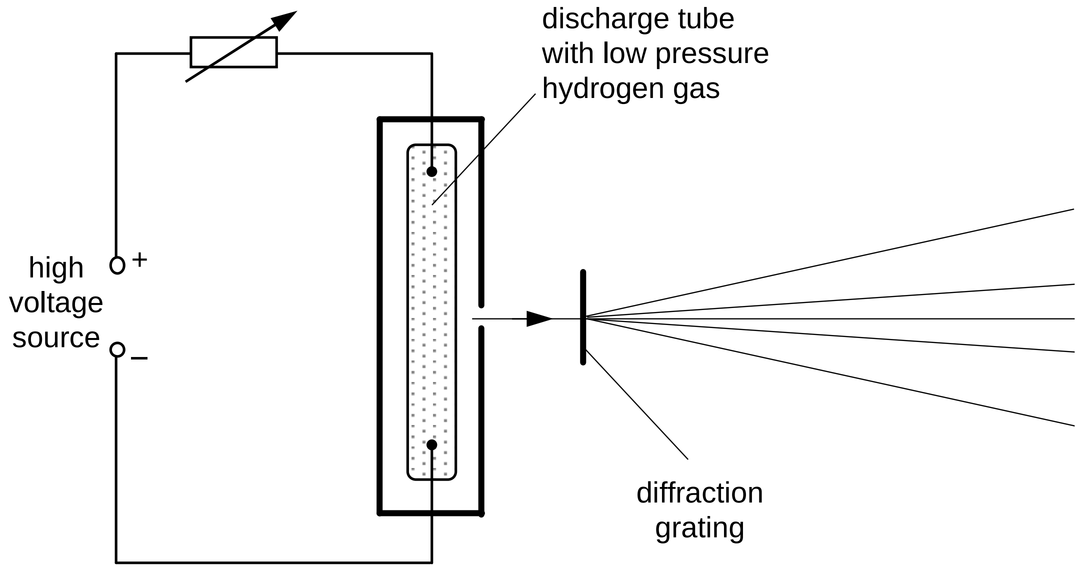

Fig. 3.1

The photons are incident normally on a diffraction grating and projected on a screen.

An emission line spectrum is observed.

(a) Explain what is meant by emission line spectrum.

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.... [1]

(b) Explain how the line spectrum of the hydrogen provides evidence for the existence of discrete energy levels in atoms.

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.... [3]

(c) Some electron energy levels in atomic hydrogen are illustrated in Fig. 3.2.

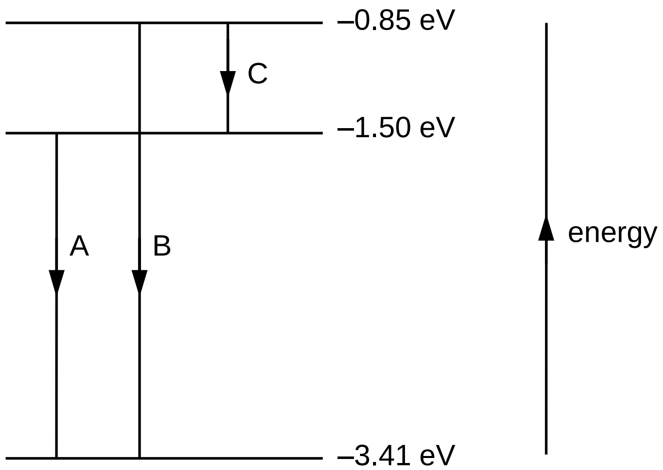

Fig. 3.2 (not to scale)

The electron transitions A and B cause light of visible wavelengths 654 nm and 488 nm to be emitted.

Explain why the third transition C in Fig. 3.2 cannot be observed.

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.... [3]

(d) The central maximum and the first order maxima of the two visible wavelengths from the hydrogen gas in **(c)** on the screen is shown in Fig. 3.3.

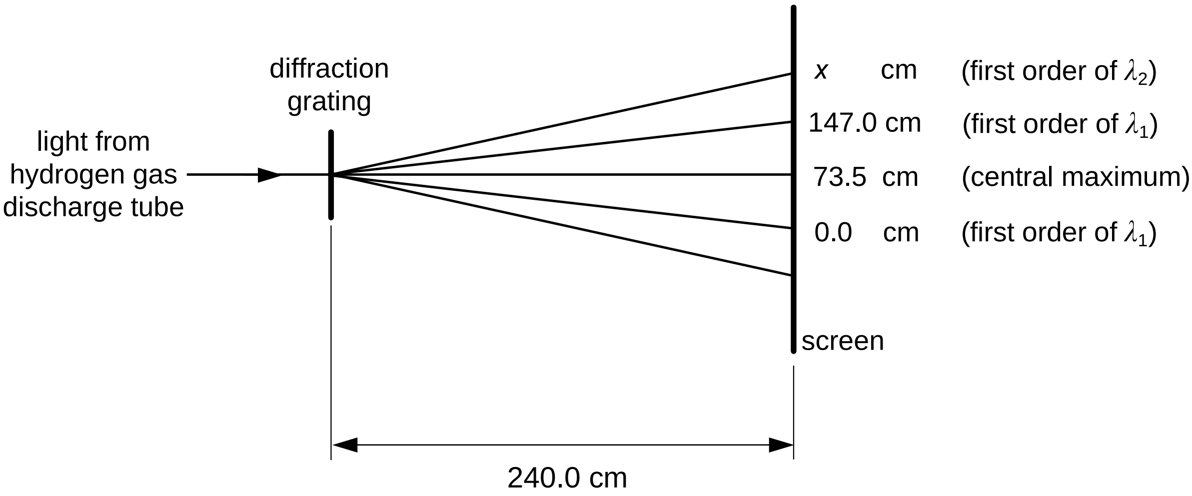

Fig. 3.3 (not to scale)

The screen is placed 240.0 cm from the diffraction grating.
The maxima positions on a scale on the screen is shown.

(i) Explain how the diffraction and the interference of light at the diffraction grating leads to the first order maxima for λ_1.

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.... [3]

(ii) Determine the position x on the scale for λ_2.

x = ... cm [4]

[Total: 14]

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4 (a) State what is meant by the *photoelectric effect.*

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(b) Use the theory of the particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.

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(c) A circuit was used to investigate the photoelectric effect as shown in Fig. 4.1

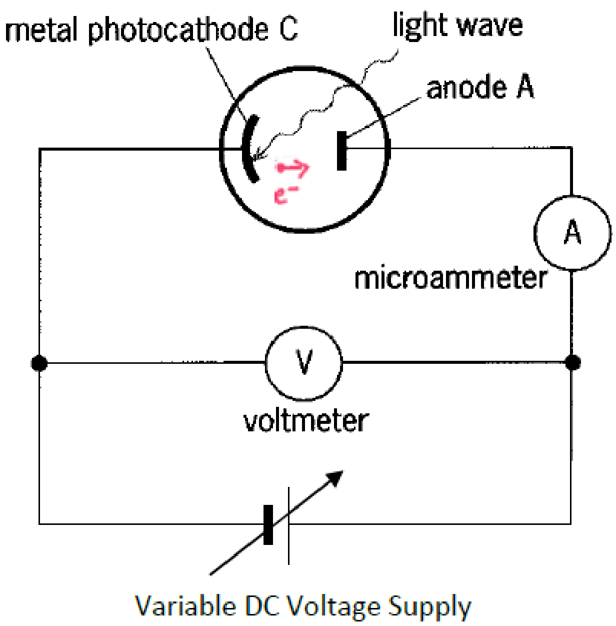

Fig 4.1

The variation with potential difference V of current I is shown in Fig. 4.2

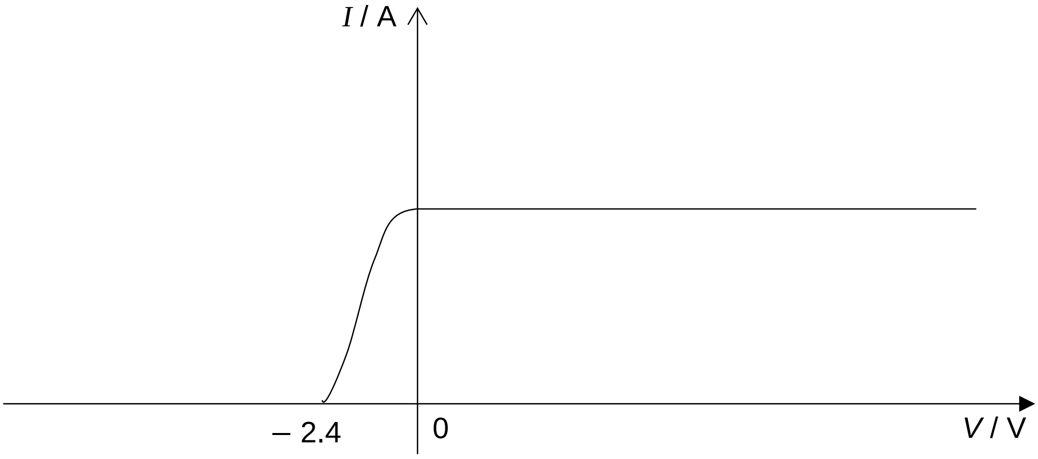

Fig. 4.2

(i) Explain why there is a minimum stopping potential difference V_s to reduce the current to zero.

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

(ii) Explain why the current does not continue to increase for positive values of V.

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

(iii) The work function of anode A is 1.6 eV. Use Fig. 4.2 to calculate the frequency of the electromagnetic radiation used.

frequency = ……………………………………………….. Hz [2]

(iv) The frequency of the electromagnetic radiation is kept constant as its intensity is doubled. On Fig. 4.2 sketch a graph to show the variation with V of I for this increase in intensity. [2]

[Total: 10]

5 A long straight wire carries a steady direct current. A circular loop of conducting wire is placed directly below the straight wire such that the wire is in the plane of the loop.

The loop falls vertically due to gravity from the wire as shown in Fig. 5.1.

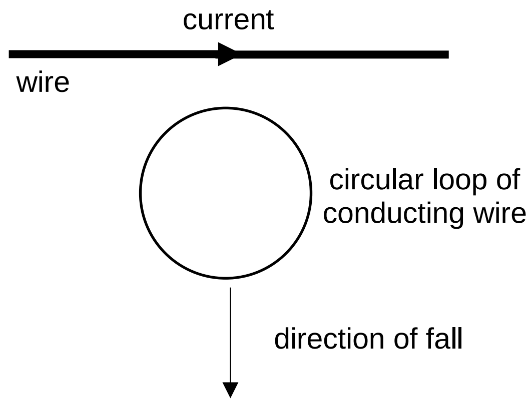

Fig 5.1

(a) **(i)** Explain why an e.m.f. is induced in the loop.

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

(ii) Determine and explain the direction of induced current in **(i).**

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…………………………………………………………………………………………………… [3]

(b) The circular loop has a radius of 5.0 cm, The magnetic flux density within the loop decreases from 120 mT to 30 mT in 0.040 s.

Show the magnitude of the average e.m.f. induced in the loop during this time is 18 mV.

[1]

[Total: 6 m]

6 The variation with time t of the sinusoidal current I in a resistor $450\,\Omega$ is shown in Fig. 6.1.

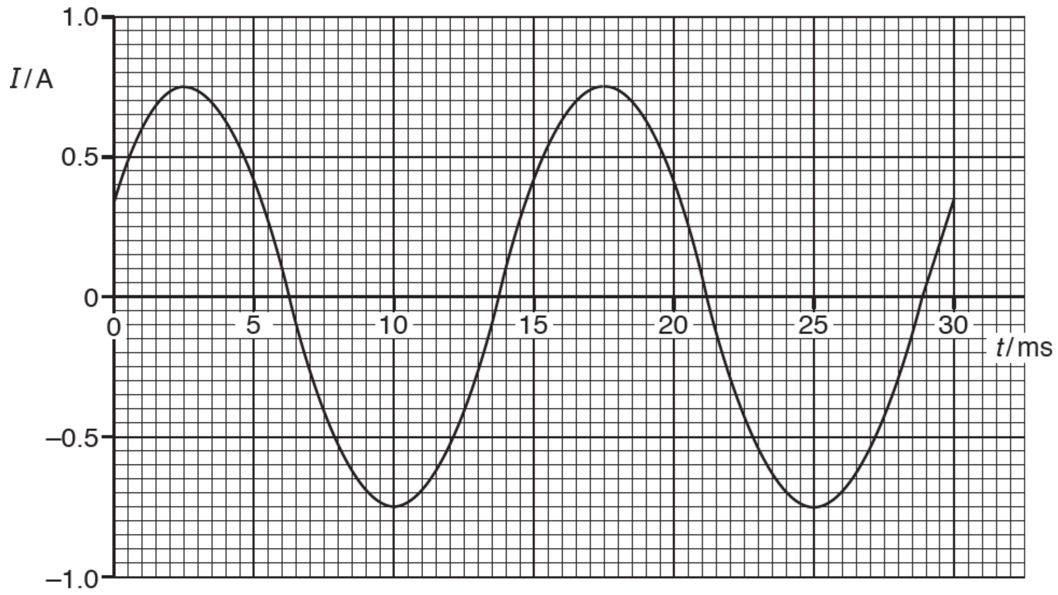

Fig. 6.1

Use data from Fig. 6.1 to determine, for the time t = 0 to t = 30 ms,

(i) the frequency of the current,

frequency = …………………..…………………………… Hz [2]

(ii) the root-mean-square (r.m.s) current,

r.m.s current = ………………………………………………… A [2]

(iii) the energy dissipated by the resistor.

energy = ……………………..……………………………… J [2]

(iv) The average current in the resistor is zero.

Explain why there is a heating effect in the resistor.

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

[Total: 8]

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** Explain what is meant by a *progressive longitudinal wave*

Progressive ……………………………………………………………………………………………..

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.

Longitudinal ……………………………………………………………………………………………..

……[2]

(b) Fig. 7.2 shows the variation of displacement *y* with time *t* of a sound wave incident on a person's ear drum.

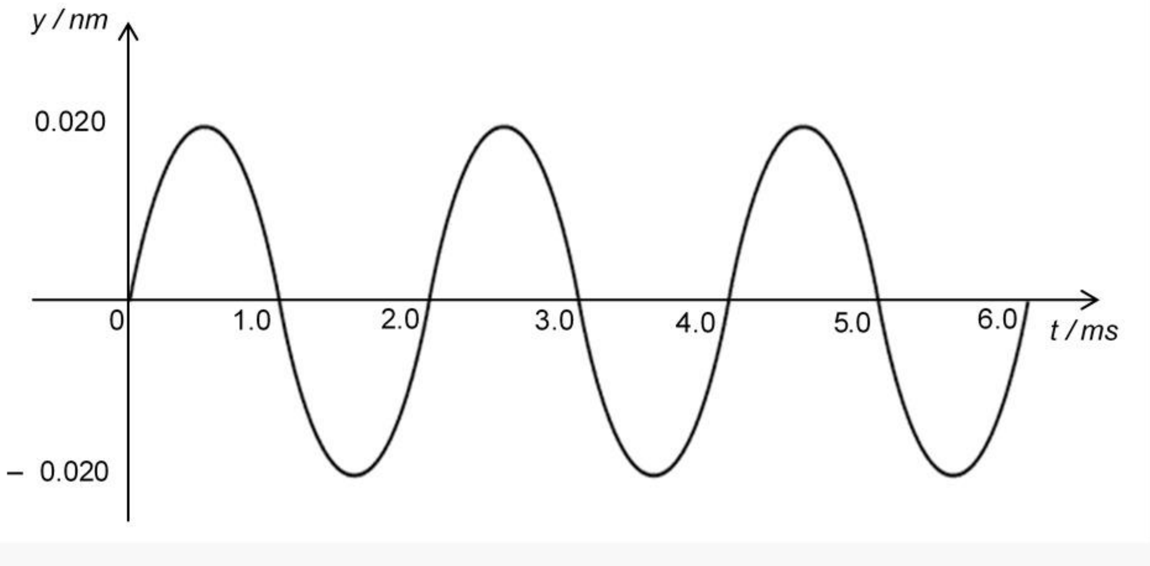

Fig. 7.2

Assume that the eardrum vibrates with simple harmonic motion and with the same frequency and amplitude as the incident sound wave.

(i) Determine the amplitude and frequency of the oscillating eardrum.

amplitude = ………………………………………………. m [1]

frequency = ………………………………………………. Hz [1]

(ii) Show maximum speed of the oscillating eardrum is 6.3×10^{-8} m s^{-1}.

[1]

(iii) Determine the mass of a human eardrum if the maximum kinetic energy of the oscillating eardrum is 2.4×10^{-19} J.

mass = …………………………………………………. kg [2]

(iv) On the axes of Fig. 7.3, sketch a clearly labelled graph to show the variation of the velocity of the ear drum v with displacement y.

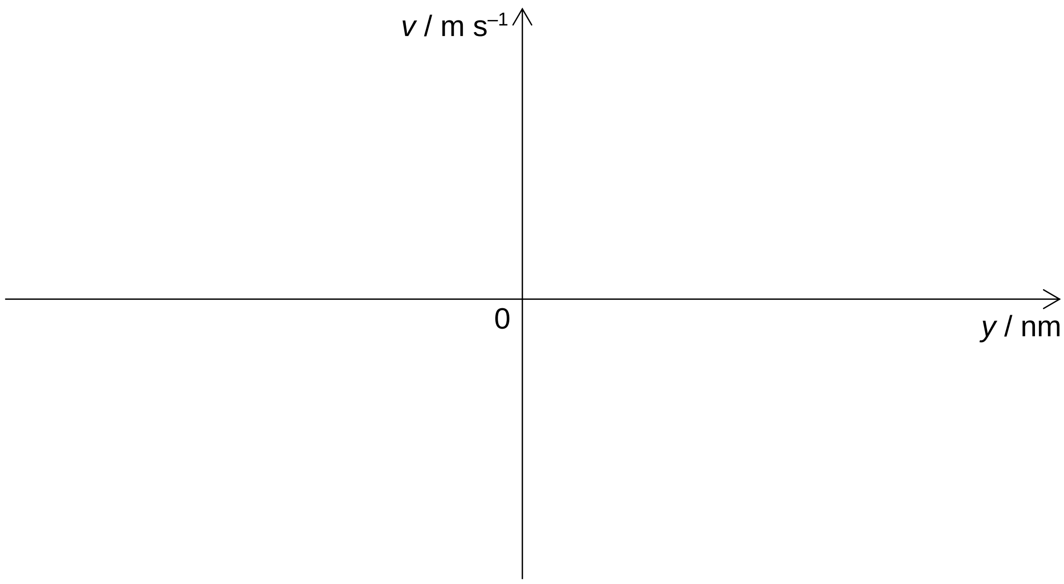

Fig. 7.3

[2]

(c) Hummingbirds can hover around flowers by beating their wings at a frequency between 20 and 80 times per second. It can be assumed that the air molecules around the birds vibrate at the same frequency.

(i) Deduce why a person standing near a hovering hummingbird may hear a buzzing sound.

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

(ii) A bird watcher is initially 2.0 m from a hummingbird. To pick up a louder buzz, the bird watcher moves nearer to the bird by a distance *x*. Determine the value of *x,* in metres, for an increased intensity of 60%.

x = ……………………..……………………………….. m [3]

(iii) It is assumed that for a hummingbird which beats its wings at 75 times per second, the air molecules around it can vibrate in simple harmonic motion at an amplitude of 5.0×10^{-9} m. Calculate the distance covered by an air molecule over the duration in which the hummingbird beats its wings for 1800 times.

distance = ………………………………………………… m [2]

(iv) Another bird watcher dislikes the buzzing sound and uses noise-cancelling technology to generate certain frequencies to cancel out the buzzing sound. Explain how the generation of such frequencies could cancel out the buzzing sound.

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[Total:20]

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8 **(a)** **(i)** Force-fields may be represented using lines that have direction. Conventionally, arrows on the field lines define the direction of a force acting on a test object.

State the property of the object that experiences a force in this direction for

1. gravitational field,

....[1]

2. an electric field

....[1]

(ii) Suggest why, when defining electric field strength, the object must be stationary.

....

....[1]

(b) Two long wires *X* and *Y* carrying the same current 290 A but in opposite direction is placed parallel to each other as shown in Fig. 8.1. Distance between each wire is 5.0 cm.

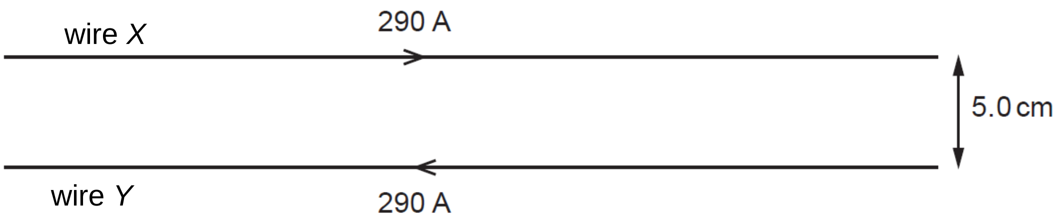

Fig. 8.1

(i) Show that the magnitude of magnetic flux density at wire *X* is 1.2×10^{-3} T.

[1]

(ii) Calculate the force per unit length on wire *X*.

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

(c) An electron is halfway between the wires *X* and *Y* in **(b)**, travelling at a speed of 2.9×10^{7} m s^{-1} parallel to the wires as shown in Fig. 8.2.

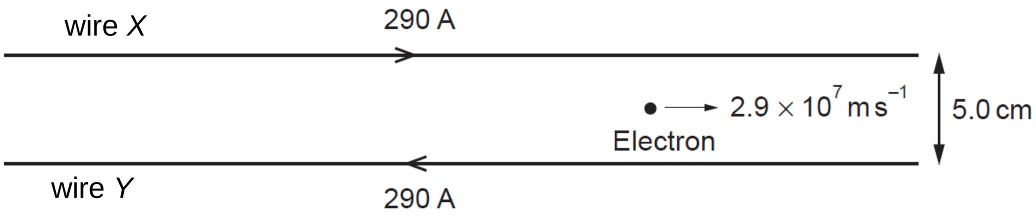

Fig. 8.2

(i) The magnetic flux density halfway between the wires is 4.64 mT. Show that the resultant force acting on the electron is 2.2×10^{-14} N.

Explain your working.

[2]

(ii) A student claims that this electron will perform a circular motion between the wires.

Explain why the student's claim is incorrect.

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....[2]

(iii) Sketch the motion of the electron in Fig. 8.3.

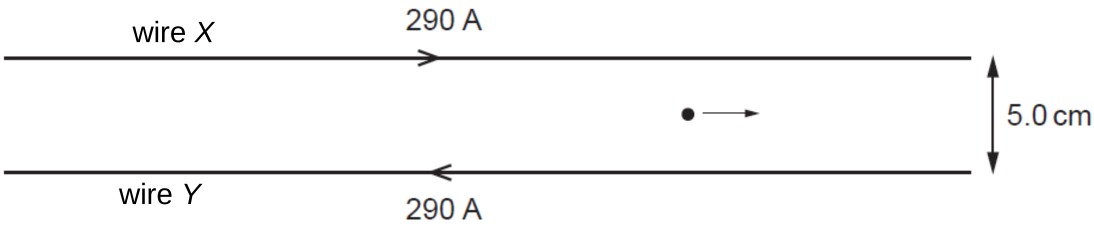

Fig. 8.3

[1]

(d) Suppose that an electron travels in a region with a magnetic field and an electric field due to two parallel metal plates as shown in Fig. 8.4.

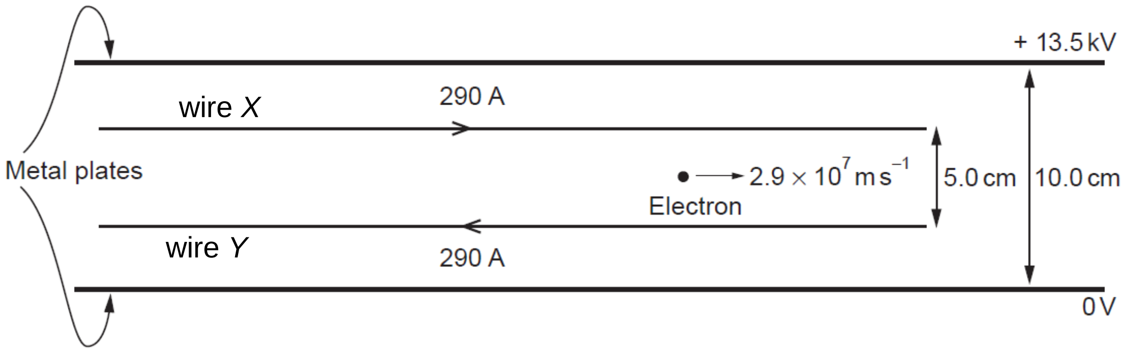

Fig. 8.4

Deduce whether the electron continues with constant velocity.

....[2]

(e) Assume that the Earth is an isolated perfect sphere as shown in Fig. 8.5, draw its gravitational field lines with solid line and equipotential surfaces with dashed line.

Fig. 8.5

[3]

(f) The Earth E and the Moon M can be considered as isolated point masses at their centres. The mass of the Earth is 5.98×10^{24} kg and the mass of the Moon is 7.35×10^{22} kg. The Earth and Moon are separated by a distance of 3.84×10^{5} km as shown in Fig. 8.6.

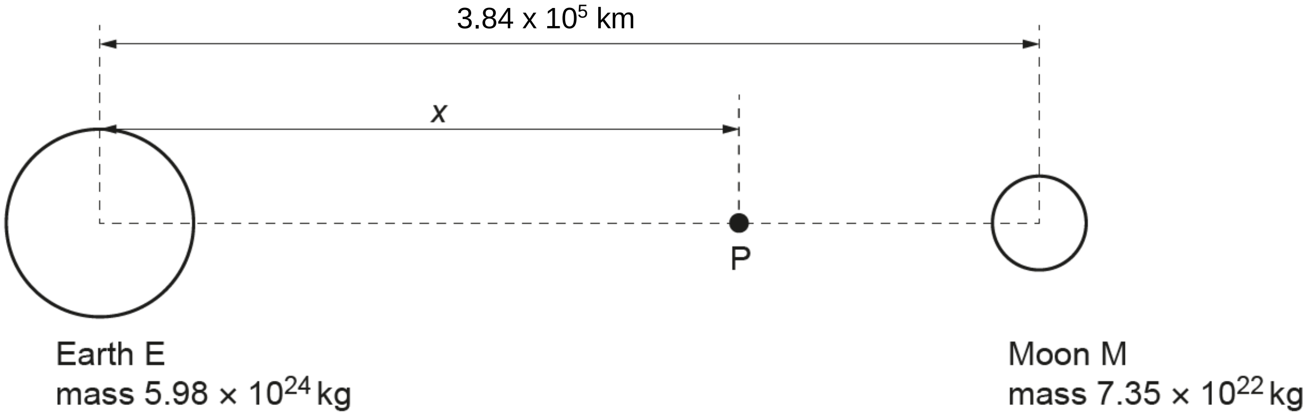

Fig. 8.6 (not to scale)

Point P is a point along the line joining the centres of E and M, where the resultant gravitational field strength is zero. Point P is at a distance x from centre of the Earth.

(i) Show that x is approximately 3.5×10^{8} m.

[2]

(ii) The resultant force on a 2.5×10^{4} kg spaceship is zero at point P. The force would increase by approximately 0.50 N for every 10 km moved away from point P towards the Earth.

A student claims that the spaceship will perform simple harmonic motion about point **P.** Deduce whether or not the student's claim is correct. (No further calculations are required.)

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……[2]

[Total: 20 m]

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