RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 02
PAPER 2

12 SEPTEMBER 2024

2 HOURS

CANDIDATE NAME										
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	2	3	J							

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

Write in dark blue or black pen on both sides of the paper.
You may use an 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.

Candidates answer on the Question Paper.
No Additional Materials are required.

Answer ***all*** *questions*.

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

FOR EXAMINERS' USE	
Paper 2	
1	**/ 4**
2	**/ 8**
3	**/ 10**
4	**/ 14**
5	**/ 10**
6	**/ 9**
7	**/ 10**
8	**/ 15**
Deduction	
TOTAL	**/ 80**

This document consists of **23** printed pages and 1 blank page.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_{0}	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_{0}	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_{e}	=	9.11×10^{-31} kg
rest mass of proton,	m_{p}	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_{A}	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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 / K = T / °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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A student wishes to calibrate his 3D printer. His 3D printer ejects and deposits molten plastic material to form a physical object based on a digitally designed model. He prints multiple copies of a cube designed to have length of 2.0 cm.

Using a well-calibrated vernier caliper, he measures the length along each side of a cube.

(a) With reference to the precision of the vernier calipers and the required lengths of each cube, explain how he can check whether the length of one particular printed cube is accurate.

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(b) Explain how he can check whether the length of his various printed cubes is precise.

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2 An object P of mass 400 g of initial speed 5.0 m s^{-1} travels towards a stationary object Q and undergoes an elastic collision with it. After the collision, object P rebounds in the opposite direction with a speed of 0.40 m s^{-1}.

(a) State the *principle of conservation of linear momentum*.

....

....

.... [2]

(b) State what is meant by an *elastic collision*.

....

.... [1]

(c) Calculate the momentum of object Q after the collision.

momentum = …………………………… kg m s^{-1} [2]

(d) Hence, determine the mass and velocity of object Q.

mass = …………………………… kg

velocity = …………………………… m s^{-1} [2]

(e) Given that P and Q were in contact over a time of 60 ms, determine the average force exerted by P on Q.

force = …………………………… N [1]

3 **(a)** Two planets, A and B, have the same diameter but different masses. The masses of planets A and B are 5.07×10^{24} kg and 3.23×10^{24} kg respectively, and the distance between the centres of both planets is 3.85×10^{8} m.

(i) Determine the resultant gravitational field strength at the midpoint between planets A and B.

gravitational field strength = …………………………… N kg^{-1} [2]

(ii) On Fig. 3.1 below, sketch the variation of the resultant gravitational potential Φ with the displacement along a straight line from the surface of planet A to the surface of planet B.

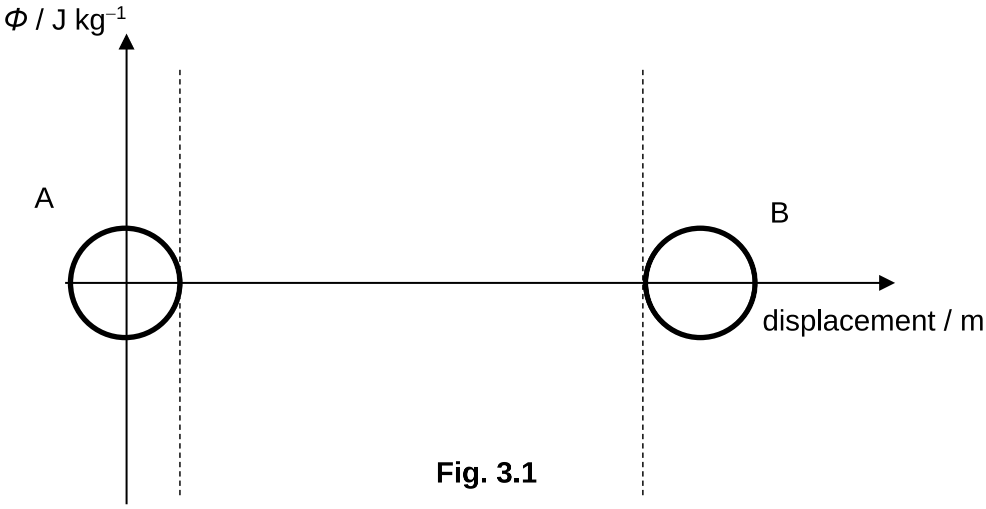

Fig. 3.1

[1]

(iii) On Fig. 3.2 below, sketch the variation of the resultant gravitational field strength g with the displacement along a straight line from the surface of planet A to the surface of planet B.

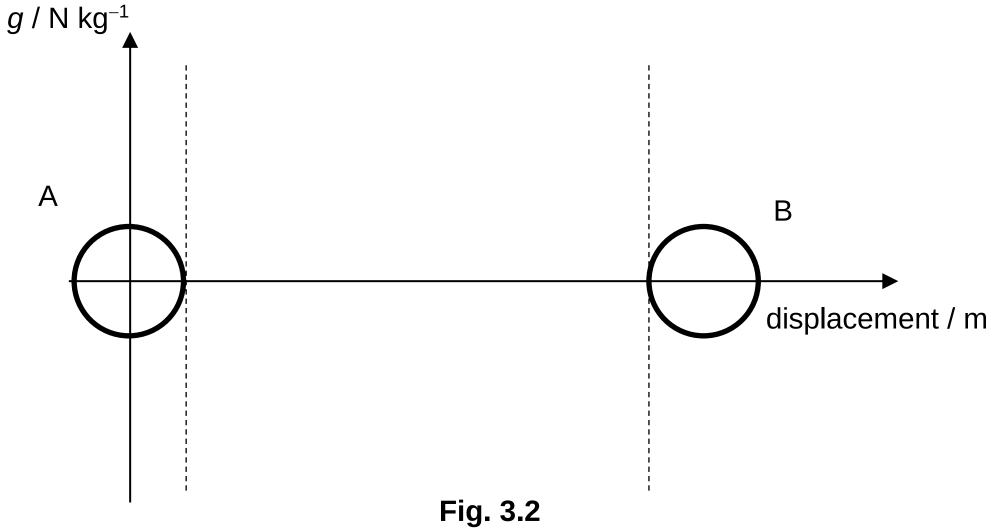

Fig. 3.2

[2]

(b) Fig. 3.3 shows a binary star system with stars C and D orbiting at different distances about a common point P with the same angular velocity in a circular path. The mass of star C, M_C, is twice of that of star D. The distances from point P to stars C and D are r_C and r_D respectively.

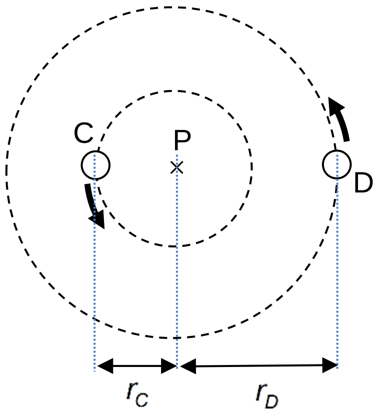

Fig. 3.3

(i) Show that $\frac{r_C}{r_D} = \frac{1}{2}$.

[1]

(ii) Show that the gravitational force F_G on star C is given by the expression

$$F_G = \frac{GM_C^{\,2}}{18r_C^{\,2}}$$

[1]

(iii) Given that the time taken for star C to complete one rotation of the circle is 3.84×10^9 s and the distance between the two stars is 7.20×10^{12} m, determine the mass of star C, M_C.

M_C = …………………………….. kg [3]

4 **(a)** A block of wood of mass *m* floats in still water as shown in Fig. 4.1.

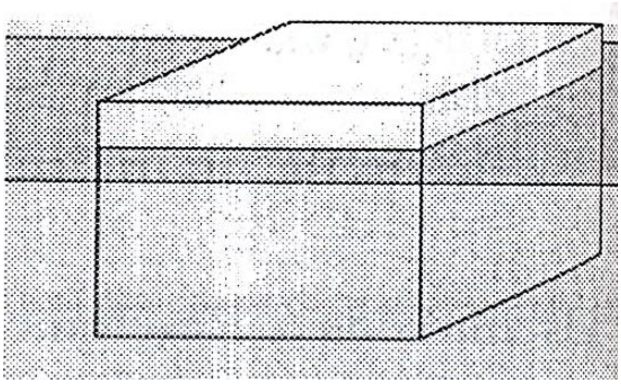

Fig. 4.1

When the block is pushed down into the water, without totally submerging it, and is then released, it bobs up and down in the water with a frequency *f* given by the expression

$$f = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$$

where *f* is measured in Hz and *m* in kg.

Surface water waves of speed 0.90 m s^{-1} and wavelength 0.30 m are then incident on the block. These cause resonance in the up-and-down motion of the block.

(i) Calculate the frequency of the water waves.

frequency = ………………….. Hz [1]

(ii) Calculate the mass of the block.

mass = ………………….. kg [1]

(iii) Describe and explain what happens to the amplitude of the vertical oscillations of the block after the following changes are made independently:

1. water waves of larger amplitude are incident on the block,

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……………………………………………………………………………………………..

…………………………………………………………………………………… [2]

2. the distance between the wave crests increases,

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…………………………………………………………………………………… [2]

3. the block now bobs in a more viscous liquid.

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……………………………………………………………………………………………..

…………………………………………………………………………………… [2]

(b) **(i)** Explain what is meant by *polarised* light.

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

(ii) Explain why two coherent sources of light that are polarised in planes perpendicular to each other will not produce observable interference fringes.

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……………………………………………………………………………………………

…………………………………………………………………………………… [2]

(iii) A narrow, parallel beam of unpolarised light of intensity I and amplitude A is directed towards three ideal polarising filters.

The beam meets the first filter with its plane of polarisation vertical. The plane of polarisation of the second filter is at an angle of 45° to the first filter. The third filter has its plane of polarisation at 90° to the first filter, as shown in Fig. 4.2.

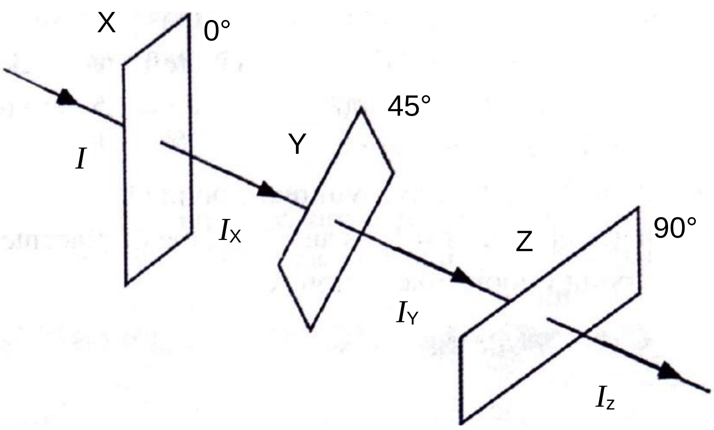

Fig. 4.2

Determine the intensity of the beam, in terms of I, after passing through the third filter.

[3]

5 **(a)** A dust particle is suspended in air in a uniform electric field of strength 2.0×10^3 V m^{-1}. The particle has charges of $+1.2 \times 10^{-15}$ C and -1.2×10^{-15} C near its ends. The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 5.1.

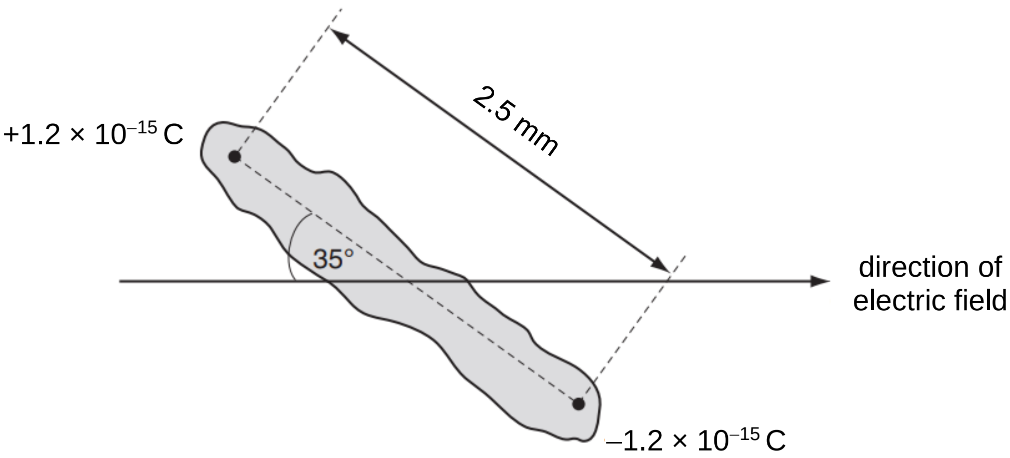

Fig. 5.1

The particle makes an angle of 35° with the direction of the electric field.

(i) On Fig. 5.1, draw arrows to show the direction of force on each charge due to the electric field. [1]

(ii) Calculate the magnitude of the force on each charge due to the electric field.

force = …………………. N [1]

(iii) Determine the magnitude of the couple acting on the particle

couple = …………………. N m [2]

(iv) Suggest the subsequent motion of the particle in the electric field.

……………………………………………………………………………………….

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

(b) Two small spherical charged particles G and H may be assumed to be point charges located at their centres. The particles are in a vacuum. Particle G is fixed in position. Particle H is moved along the line joining the two charges, as illustrated in Fig. 5.2.

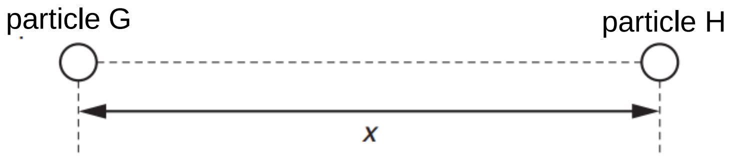

Fig. 5.2

The variation with separation x of the electric potential energy E_P of particle G is shown in Fig. 5.3.

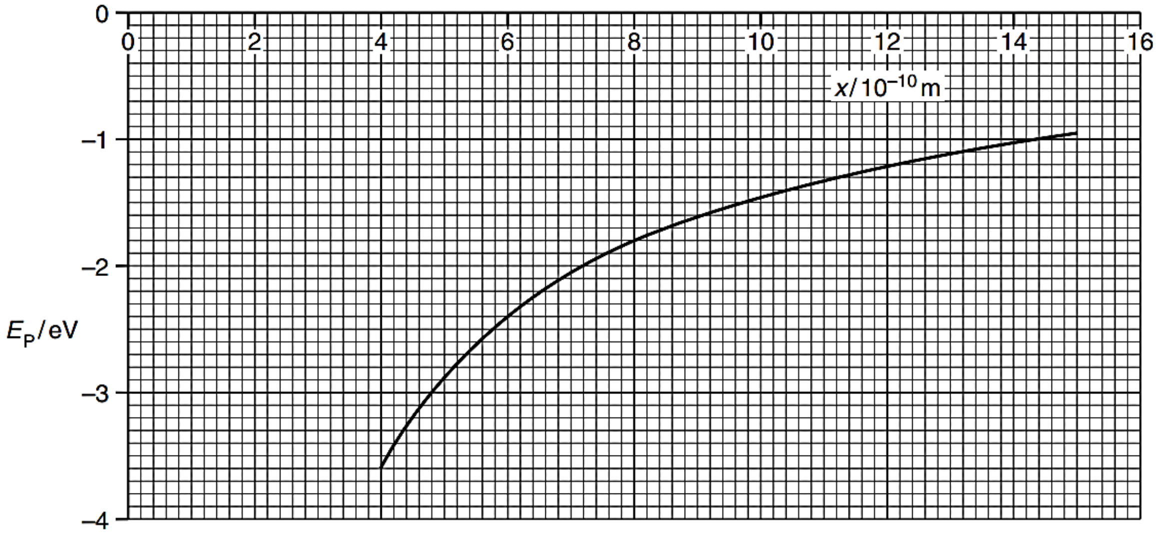

Fig. 5.3

(i) With reference to Fig. 5.3, state the relationship between electric force and electric potential energy.

……………………………………………………………………………………….

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

(ii) With reference to the direction of the electric force between the particles, state whether the two charges have the same, or opposite, polarity.

……………………………………………………………………………………….

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

(iii) Hence, determine the electric force acting on particle H at a distance of 6.0×10^{-10} m.

force = …………………. N [3]

6 **(a)** Fig. 6.1 shows a potentiometer circuit for determining the resistance of resistor R. The uniform wire XY, of length 1.20 m, has a resistance of 20.0 Ω. The balance length XJ is 0.48 m. At the balance length, a voltmeter connected across the 1.0 Ω resistor reads 0.50 V. Determine the resistance of resistor R.

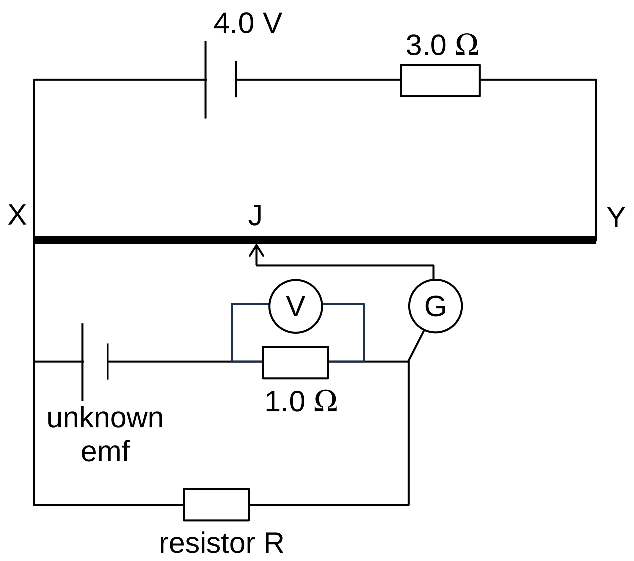

Fig. 6.1

resistance = …………………………… Ω [3]

(b) A copper wire has a length of 3.0 m and a uniform cross-sectional area of 0.20 mm^2. It carries a current of 2.8 A when a potential difference of 0.72 V is applied across it.

(i) Given that the charge carrier in the copper wires are electrons, and that the number density of electrons is 8.49×10^{28} m^{-3}, determine its drift velocity.

velocity = …………………………… m s^{-1} [2]

(ii) Determine the resistivity of the copper wire.

resistivity = …………………………… Ω m [2]

(iii) Explain, in microscopic terms, why the resistance of the copper wire increases as the current through it increases.

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…………………………………………………………………………… [2]

7 **(a)** Briefly describe the concept of a photon.

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.... [1]

(b) Explain how line spectra of gases at low pressure provide evidence for discrete electron energy levels in atoms.

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.... [2]

(c) Fig. 7.1 shows the energy levels of hydrogen atoms.

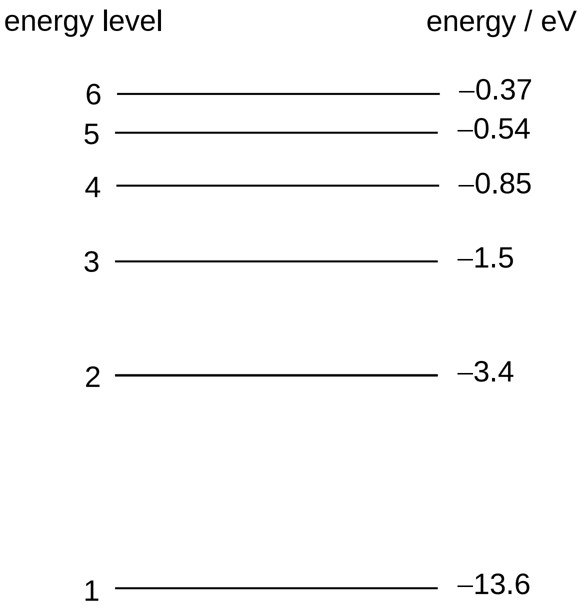

Fig. 7.1

Cool hydrogen atoms in a discharge tube are bombarded with electrons of energy 13.2 eV. Determine the frequency of the most energetic photons emitted during the subsequent transition between the energy levels.

highest frequency = ……………..…………..……..Hz [3]

(d) The hydrogen emission spectrum produced in **(c)** is used to illuminate the surface of Caesium metal by passing through a diffraction grating as shown in Fig. 7.2.

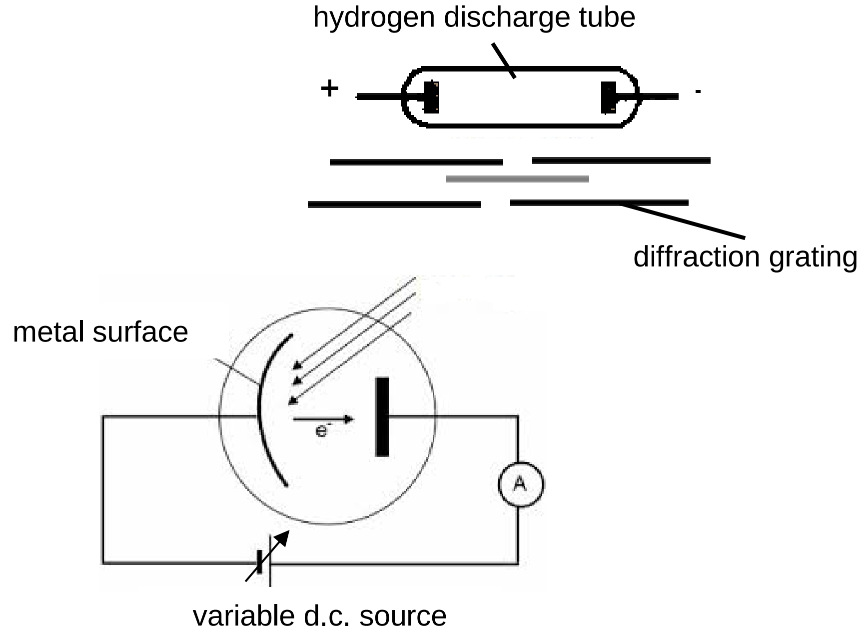

Fig. 7.2

When the Caesium metal surface is illuminated with visible light corresponding to the transition from level 5 to level 2, the minimum collector voltage required to reduce the ammeter reading to zero is –0.72 V.

(i) Explain why a minimum negative potential difference between the electrodes needs to be applied to reduce the current to zero.

…………………………………………………………………………………………….

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

(ii) Calculate the work function of the Caesium metal surface.

work function = ……………..…………..…….. J [2]

(iii) When the magnitude of the collector voltage is decreased, the ammeter reading becomes 0.21 μA.

If on average one electron is emitted for every 10^5 incident photons, show that the estimated number of photons hitting the Caesium surface per second is 1.31×10^{17} s^{-1}.

[1]

8 The popularity of electric vehicles (EVs) is rapidly increasing, driven by advances in battery technology and growing environmental awareness. EVs rely on electricity stored in batteries for propulsion. However, challenges such as high electricity consumption and inadequate charging infrastructure can limit their range and practical usability.

Regenerative braking is an energy recovery system that slows a vehicle by converting kinetic energy into a form that can be stored or used later, unlike conventional brakes that waste energy as heat through friction. It uses electromagnetic induction, where a motor acts as a generator during braking as shown in Fig. 8.1

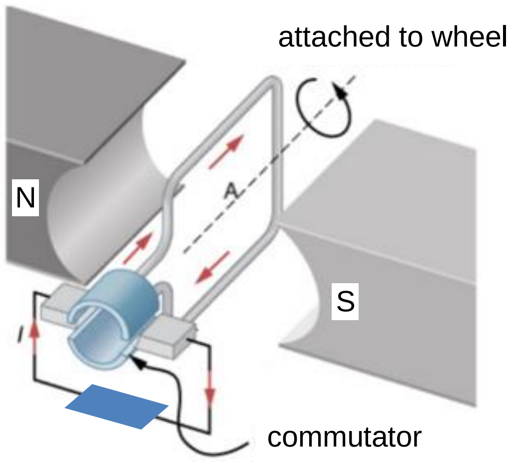

Fig. 8.1

In EVs, this technology improves efficiency and can potentially extend the driving range by up to 30%. It is especially effective during downhill driving or deceleration, capturing energy that would otherwise be wasted. Fig. 8.2 shows the percentage of electrical energy savings by vehicle type. It can be seen that heavier vehicles tend to have a greater percentage of their energy saved.

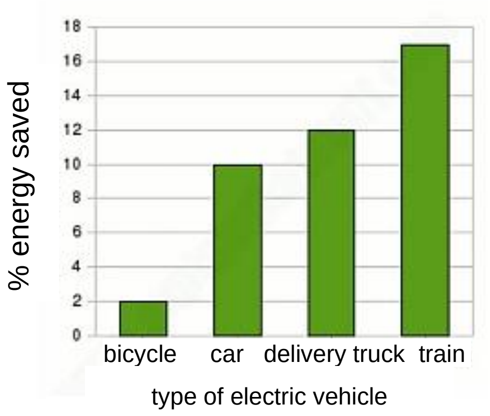

Fig. 8.2

While regenerative braking provides significant benefits, it still has its limitations. The system's effectiveness decreases at lower speeds, where a substantial amount of kinetic energy is dissipated through friction braking. Additionally, the system's overall efficiency and the need for comprehensive charging infrastructure are important challenges. The most efficient driving approach involves minimizing the use of both the motor and brakes by anticipating traffic conditions, thereby optimizing energy use and improving the practicality of electric vehicles.

(a) **(i)** With reference to Fig. 8.1 and using Faraday's law of electromagnetic induction, explain how regenerative braking improves fuel efficiency.

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…………………………………………………………………………….. [3]

(ii) Hence, explain why the efficiency of the regenerative system decreases at lower speeds.

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…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………….. [2]

(iii) Define magnetic flux

……………………………………………………………………………………….

……………………………………………………………………………….. [1]

(iv) Hence, derive an expression for the magnetic flux linkage through a coil with N turns, area A when its normal makes an angle of θ with the uniform magnetic field of flux density B as shown in Fig. 8.3.

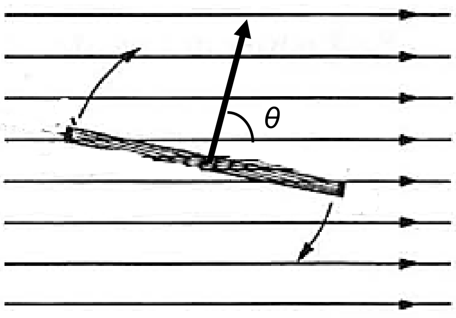

Fig. 8.3

[1]

(v) Hence, if the coil shown in Fig. 8.3 has 75 turns, an area of 200 cm^2 and that the magnetic flux density of the field is 0.70 T, calculate the maximum induced e.m.f. E if the coil is rotating at a rate of 30 turns per second.

E = …………………. V [4]

(vi) Fig. 8.4 shows the variation of induced e.m.f. E with time t.

Sketch on the same axis how the graph will look like if the speed of rotation of the coil were halved.

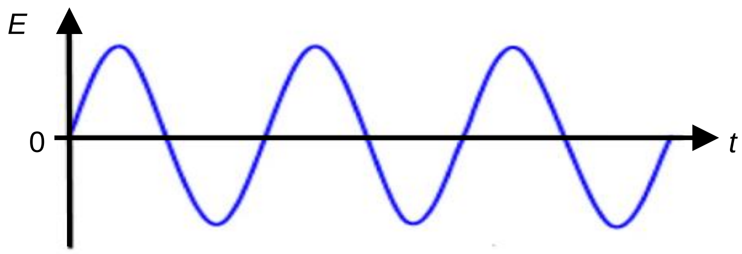

Fig. 8.4

[2]

(b) The passage mentions that regenerative braking improves fuel efficiency and extends the vehicle's range, state one more advantage of the regenerative braking system.

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

(c) Fig. 8.2 shows that heavier vehicles recover a greater percentage of their energy via regenerative braking, suggest why this is the case.

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……………………………………………………………………………………… [1]

END OF PAPER

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