| Class | AdmNo |
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Candidate Name: ______________________________

H

millennia institute

# 2014 Preliminary Exam 2
Pre-university 2

**H1 PHYSICS** **8866 / 02**

Wednesday Markscheme **17 September 2014**

**2 hours**

Additional Materials: Nil

**READ THESE INSTRUCTIONS FIRST**

**Do not turn over this page until you are told to do so.**

Write your full name, class and index number in the spaces at the top of this page and on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

**Section A**
Answer all questions. Write your answers in the spaces provided on the question paper.

**Sections B**
Answer **TWO** questions. Write your answers in the spaces provided on the question paper. **Circle the 2 questions attempted on this cover page.**

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

The use of a calculator is expected, where appropriate.
You are reminded of the need for clear presentation in your answers.

| FOR EXAMINER'S USE | |
|---|---|
| **Section A (40 marks)** | |
| 1 | / 8 |
| 2 | / 6 |
| 3 | / 6 |
| 4 | / 10 |
| 5 | / 10 |
| **Section B (40 marks)** | |
| 6 | / 20 |
| 7 | / 20 |
| 8 | / 20 |
| TOTAL | / 80 |

This question paper consists of **19** printed pages.

**[Turn over**

**Data**

| | | | |
|---|---|---|---|
| speed of light in free space, | $c$ | = | $3.00 \times 10^{8}$ m s$^{-1}$ |
| elementary charge, | $e$ | = | $1.60 \times 10^{-19}$ C |
| the Planck constant, | $h$ | = | $6.63 \times 10^{-34}$ J s |
| unified atomic mass constant, | $u$ | = | $1.66 \times 10^{-27}$ kg |
| rest mass of electron, | $m_e$ | = | $9.11 \times 10^{-31}$ kg |
| rest mass of proton, | $m_p$ | = | $1.67 \times 10^{-27}$ kg |
| 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, | $p$ | = | $\rho g h$ |
| resistors in series, | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel, | $\frac{1}{R}$ | = | $\frac{1}{R_1} + \frac{1}{R_2} + \ldots$ |

**Section A (40 marks)**
Answer all the questions in this section.

For Examiner's Use

**1** Randell set up the experiment as shown in Fig. 1.1 to determine the spring constant *k* of the spring. He obtained the following readings

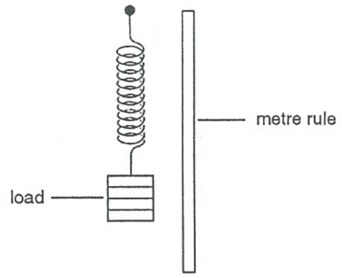



**Fig. 1.1**

Reading on the rule for the lower end of the unextended spring = 13.60 ± 0.05 cm

Reading on the rule for the lower end of the extended spring = 17.95 ± 0.05 cm

Load = 6.0 ± 0.2 N

It may be assumed that the spring obeys Hooke's law.

**(a)** Estimate the percentage uncertainty in the determination of *k*. [4]

From Hooke's law, F = kx

**$x = x_{final} - x_{initial} = 17.95 - 13.60 = 4.35$ cm [1]**
**$\Delta x = \Delta x_{final} + \Delta x_{initial} = 0.1$ cm [1]**

$$\frac{\Delta k}{k} = \frac{\Delta F}{F} + \frac{\Delta x}{x} = \frac{0.2}{6.0} + \frac{0.1}{4.4}$$ **[1]**

**=0.056**
**Percentage uncertainty = 5.6% [1]**

Percentage uncertainty = …………………… %

**(b)** Calculate *k* and express it with its actual uncertainty to the appropriate number of significant figures. [2]

**$k = F/x = 6.0 / 0.0435 = 138$ N m$^{-1}$**
**$\Delta k = 0.056 \times 138 = 7.7 = 8$ N m$^{-1}$ (1sf) [1]**
**$k \pm \Delta k = (138 \pm 8)$ N m$^{-1}$ [1]**

*k* = …………………… ± ……………… N m$^{-1}$

For Examiner's Use

**(c)** Give one example of a systematic error and one example of a random error that could occur in this experiment. [2]

Systematic error – wrong calibration of the metre rule [1]

……………………………………………………………………………………

Random error – parallex error in the reading of the values from the metre rule [1] ……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

**2** A police car of mass 1300 kg is travelling along a straight and horizontal road at 20 m $s^{-1}$. The police car is overtaken by a motorcycle travelling at a constant speed of 30 m $s^{-1}$. Immediately upon being overtaken, the police car accelerates. The police car catches up with the motorcycle 9.00 s after being overtaken.

**(a)** What is the distance travelled by the motorcycle in 9.00 s?

**Distance travelled by the motorcycle = 30 x 9 = 270 m**

distance travelled = ……………………… m [1]

**(b)** What is the distance travelled by the police car in 9.00 s?

**Distance travelled by the police car = 30 x 9 = 270 m**

distance travelled = ……………………… m [1]

**(c)** Determine the acceleration of police car by assuming that the acceleration is constant throughout the 9.00 s.

**$s = ut + ½ at^2$**

**$270 = 20 (9) + ½ a (9)^2$ [1]**

**$a = 2.22$ m $s^{-2}$ [1]**

acceleration = ……………………… m $s^{-2}$ [2]

**(d)** What is the speed of the police car when it catches up with the motorcycle?

**$v = u + at$**

**$= 20 + (2.22)(9)$ [1]**

**$= 40.0$ m $s^{-1}$ [1]**

speed = ……………………… m $s^{-1}$ [2]

| | | | For Examiner's Use |
|---|---|---|---|
| 3 | A man decides to take the elevator from the ground level to the top level of the building. He has a mass of 95 kg, and the elevator together with all its parts has a mass of $1.1 \times 10^3$ kg. From the ground level, the elevator starts to accelerate at a uniform rate of $2.0\ m\ s^{-2}$. | | |
| | **(a)** | What is the kinetic energy gained 3.0 s after the elevator starts to accelerate?<br><br>**v = u + at = 0 + 2 (3) = 6 m $s^{-1}$ [1]**<br><br>**Kinetic energy gained = ½ (95 + 1100) $(6)^2$**<br>**= 21510 J [1]**<br><br>kinetic energy gained = ……………………… J [2] | |
| | **(b)** | On its way to the top floor, the elevator consumes 0.198 kW h of useful energy. If the engine has an efficiency of 77%, what is the total energy input?<br><br>**0.198 kW h = 198 x 60 x 60 J = 712800 J [1]**<br><br>**Useful energy = 712800 / 77 x 100 = 92600 J [1]**<br><br>Total energy input = ……………………… J [2] | |
| | **(c)** | Starting with an expression for work done, derive a relation for the constant power P required moving against a force F at constant speed v. [2]<br><br>**Work done = Force x displacement in the direction of the force**<br>**power = W / t = Fs / t and s / t is velocity. [1]**<br>**P = Fv [1]** | |
| | | | |
| 4 | **(a)** | Distinguish between longitudinal wave and transverse wave.<br>**For transverse waves, the direction of the particles displacement will be perpendicular to the direction of wave's propagation. [1]**<br><br>**For longitudinal waves, the particles displacement will be parallel to the direction of the wave's propagation.** [1]<br>……………………………………………………………………………………………<br>……………………………………………………………………………………………<br>……………………………………………………………………………………………<br>……………………………………………………………………………………………[2] | |

For Examiner's Use

**(b)** The figure 5.1 below represents, at time t = 0 s, the positions of particles A, B, C, D, E, F and G in a transverse wave moving to the right.

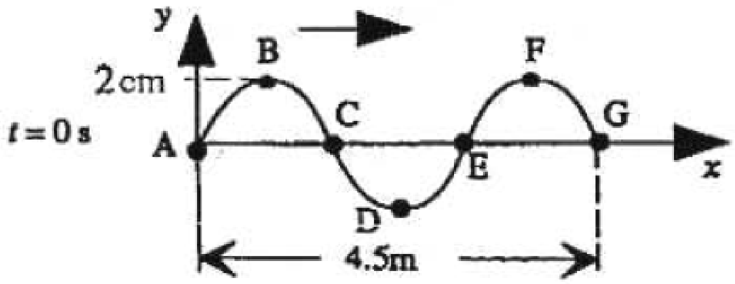
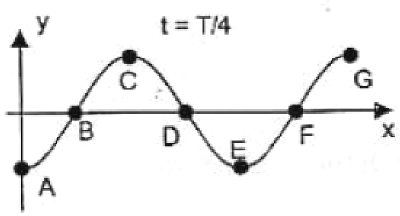



**figure 5.1**

**(i)** Sketch y-x graph to show the position of particles in the wave at a later times T/4 where T is the period of the wave. [2]


correct shape and points stated [2]

**(ii)** In figure 5.1 , name the pairs of particles in phase.

Particles in phase are A and E, B and F, C and G.

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

**(iii)** What is the wavelength of the wave?

**$\lambda$= 4.5 / 1.5 = 3m**

wavelength = ……………………… m [1]

**(iv)** State the amplitude of the wave

**A = 0.02 m**

amplitude = ……………………… m [1]

**(v)** Calculate the velocity of the wave given that its frequency is 500 Hz

**$V = f\lambda = 500 \times 3$**
**$= 1500\ m\ s^{-1}$**

velocity = ……………………… $m\ s^{-1}$ [1]

For Examiner's Use

**5** Solar cells are used in some appliances for the generation of electrical energy. When light energy is incident on the surface of such a cell, an e.m.f. is generated between the terminals of the cell. Connection of a resistor between these terminals will result in current and electrical power dissipation in the resistor

The variation with output potential difference *V* of the current *I* from a solar cell may be investigated using the circuit of Fig. 5.1.

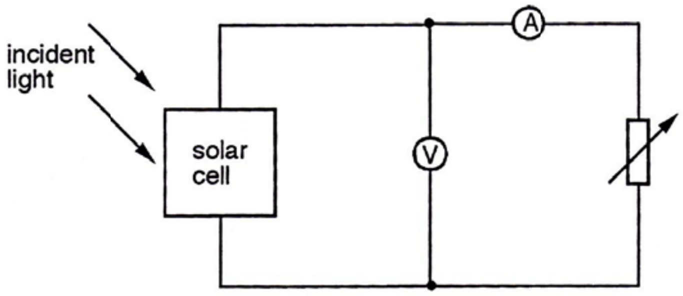



**Fig. 5.1**

The ammeter has negligible internal resistance and the voltmeter has a very high resistance. Light of constant intensity is incident on the solar cell.

The *I-V* characteristic of one type of solar cell, when it is illuminated with a certain intensity of light, is shown in Fig. 5.2.

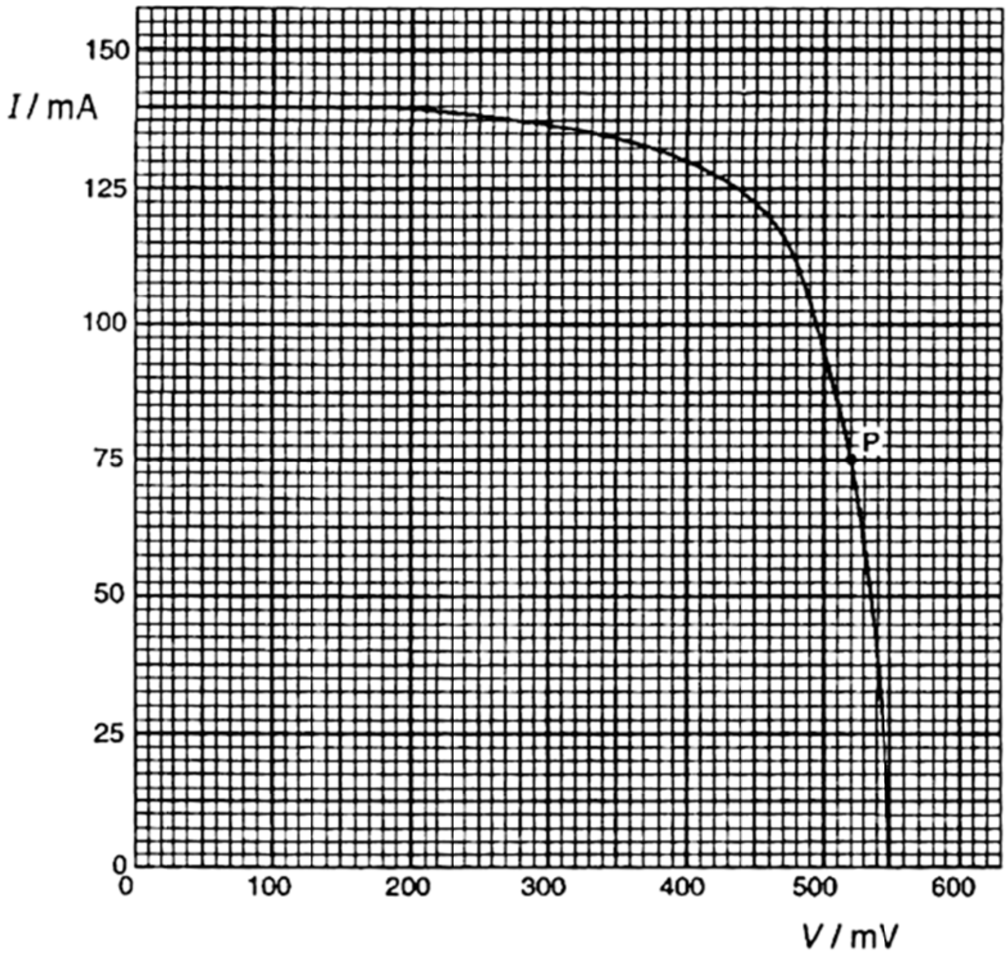


**Fig. 5.2**

**(a)** **(i)** Determine the current from the solar cell for an output potential difference of 400 mV. [1]

**current = 130 mA = 0.130 A** ...............................[1]

current = ........................ A

**(ii)** Explain how the graph shows that the e.m.f. of the solar cell is 550 mV. [2]

**It is the value of the terminal potential when no current is flowing from the solar cell [1], so that the voltmeter only measures the emf of the solar cell [1].**

**(iii)** Use your answers to **(i)** and **(ii)** to determine the internal resistance of the cell at an output potential difference of 400 mV. [2]

**E = IR + Ir** ...............................[1]

**E = V + Ir**

**0.550 = 0.400 + (0.130)r**

**Thus, r = 1.15 Ω** ...............................[1]

internal resistance = ............................... Ω

**(b)** Determine the power dissipation in the load resistor of point **P** on **Fig. 5.2**. [3]

**At point P, I = 75 mA,** ...............................[1]

**V = 520 mV .** ...............................[1]

**–1 MARK FOR GIVING TO THE WRONG PREFIX.**

**P = IV**

**= $(75 \times 10^{-3})(520 \times 10^{-3})$**

**= 0.039 W** ...............................[1]

power dissipation = ............................... W

For Examiner's Use

| | | | For Examiner's Use |
|---|---|---|---|
| | (c) | A number of identical solar cells of a different type each produce an output power of 75 mW at an output potential difference of 0.50 V. | |

Each cell may be represented by the symbol shown in **Fig 5.3**.

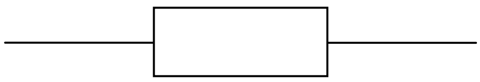
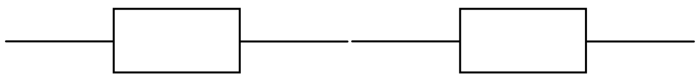


**Fig. 5.3**

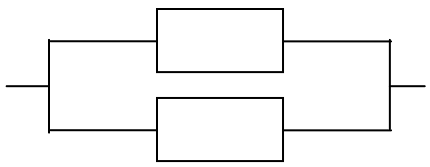
Draw suitable arrangements of solar cells so that the cells may be used to provide:

**(i)** a power of 150 mW at a potential difference of 1.0 V, [1]



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

**(ii)** a power of 150 mW at a potential difference of 0.50 V. [1]



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

| | | For Examiner's Use |
|---|---|---|
| | **Section B (40 marks)**<br>Answer **two** of the questions in this section. | |

**6 (a)** Define acceleration. [1]

Acceleration is the rate of change of velocity.

**(b) (i)** Use your definition in **(a)** to show that v = u + at, where v is the final velocity, u is the initial velocity and a and t are the acceleration and the time interval respectively. [1]

$$a = \frac{v - u}{t}$$

v = u + at [1]

**(ii)** State the conditions that must be satisfied for the equation to be valid. [2]

Constant acceleration [1] and motion is linear[1].

..........................................................................................

..........................................................................................

**(c)** The graph of **Fig. 6.1** shows the variation with time t of the velocity v of a ball from the moment it is thrown with a velocity of 26 m $s^{-1}$ vertically upwards.

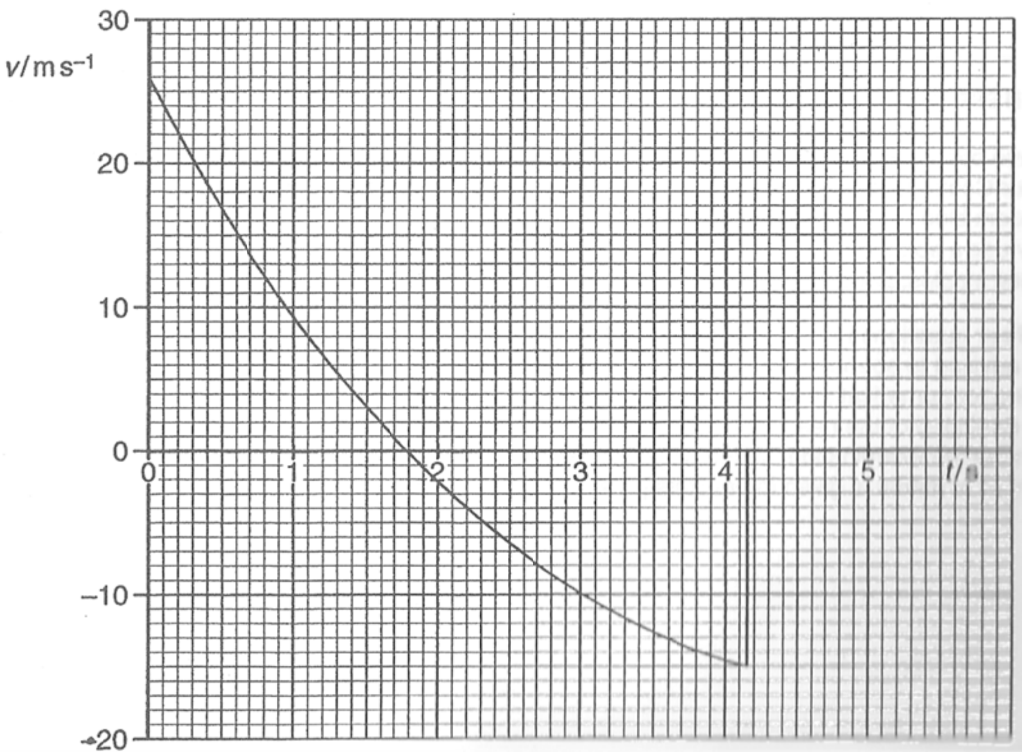



**Fig. 6.1**

For Examiner's Use

**(i)** State the time at which the ball reaches its maximum height.

t = ........ 1.8..................... s [1]

**(ii)** State the feature of a velocity-time graph that enables the acceleration to be determined. [1]

Gradient of the graph

..........................................................................................

**(iii)** Just after the ball leaves the thrower's hand, it has a downward acceleration of approximately 20 m $s^{-2}$.

Explain how this is possible. [2]

There is air resistance in this situation.
When the ball just leaves the thrower's hand, it has a very high speed. Since air resistance increases with speed, there is an air resistive force that is acting against the motion. [1]

[1] for either
The total downward force acting on the ball is gravitational force and air resistive force.
or
Hence the ball's downward acceleration is the sum of the acceleration of free fall (9.81 m $s^{-2}$) and acceleration due to air resistance (approximately 10.19 m $s^{-2}$).

**(iv)** State the time at which the acceleration is *g*.

t = ......... 1.8 ..................... s [1]

**(v)** Explain why the acceleration has this value only at this particular time. [2]

At this instant, the ball reaches its maximum height and is instantaneously at rest.[1]

[Since the ball is at rest momentarily, the air resistance is zero. Hence, the only force acting the ball is the gravitational force. Therefore, its acceleration is the acceleration due to free fall, g).[1]

For Examiner's Use

**(d)** Particle **A** travelled with a velocity $1.88 \times 10^{3}$ m s$^{-1}$ collides elastically and head-on with another particle **B** of mass $5.31 \times 10^{-27}$ kg with velocity 405 m s$^{-1}$, as illustrated in Fig. 8.2.

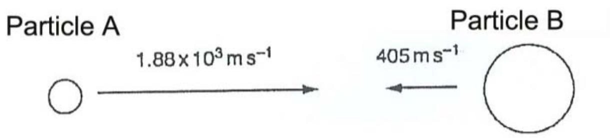



**Fig. 8.2**

**(i)** State the principle of conservation of momentum. [2]

The principle of conservation of momentum states that in the *absence of external forces*, *total momentum before* the interaction is equal to the *total momentum after* their interaction.

**(ii)** State the difference between an elastic collision and an inelastic collision. [2]

In an elastic collision the total kinetic energy of the system is conserved while in an inelastic collision the total kinetic energy of the system is not conserved.

**(iii)** Determine the velocity of separation of the two particles after the collision,

$v_2 - v_1 = u_1 - u_2 = 1.88 \times 10^3 - (-405) = 2285$ m s$^{-1}$

velocity of separation = …………………. m s$^{-1}$[1]

**(iv)** Hence, determine the velocities of both particles after the collision. [4]

Using $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$1.82 \times 10^{-28} (1.88\times10^{3}) + 5.31\times10^{-27}(-405) = 1.82\times10^{-28}v_1 + 5.31\times10^{-27}v_2$ (eqn 1) [1]

$v_2 = 2285 + v_1$ (eqn 2) [1]

Solve eqn 1 and 2 simultaneously,

$-1.808 \times 10^{-24} = 1.82 \times 10^{-28} v_1 + 5.31 \times 10^{-27} (2285 + v_1)$

$v_1 = -2540$ m s$^{-1}$ [1] and $v_2 = -253$ m s$^{-1}$ [1]

velocity of particle **A** = …………………. m s$^{-1}$

velocity of particle **B** = …………………. m s$^{-1}$

| | | | For Examiner's Use |
|---|---|---|---|
| 7 | (a) | A student makes a solenoid with insulated copper wire.<br>The solenoid has length 12.0 cm and the average length of one turn of wire on the solenoid is 8.8 cm, as shown in Fig. 7.1. | |

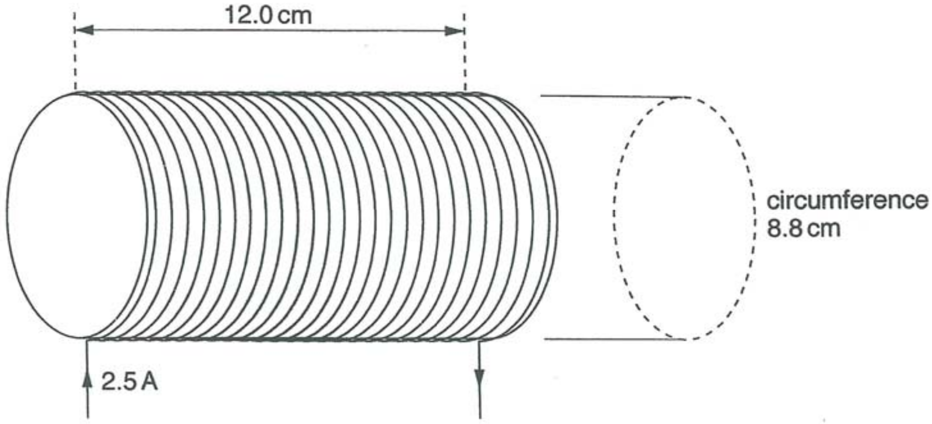



**Fig. 7.1**

Fig. 7.2 illustrates the top view of the solenoid. Draw the flux patterns of the solenoid. [2]

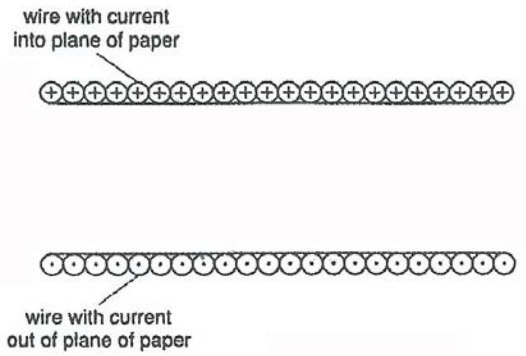
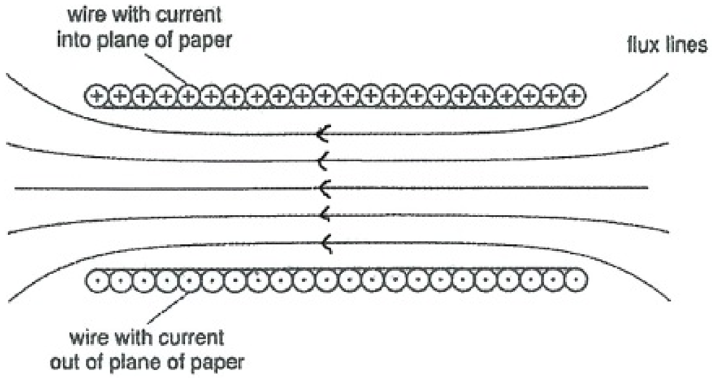



**Fig. 7.2**




Correct direction of field and spacing of lines[2]

**(b)** The copper wire has a circular cross-section of diameter 0.60 mm. The resistivity of copper is $1.6 \times 10^{-8}\ \Omega$ m.

It is found that the current in the solenoid is 2.5 A when the potential difference across its terminals is 4.5 V.

**(i)** Calculate, for the solenoid, the resistance of the wire.

$R = V/I = 4.5 / 2.5 = 1.8\ \Omega$

Resistance = ……..............……… Ω[1]

For Examiner's Use

**(ii)** Use your answers in **b(i)** in order to calculate the total number of turns of wire on the solenoid.

R = ρl /A

$$1.8 = \frac{1.6 \times 10^{-8} l}{\pi (0.30 \times 10^{-3})^2} \quad [1]$$

l = 31.8 m [1]

since the circumference = 0.088 m,

no. of turns = 31.8/0.088

= 361.5 (361) [1]

number = ……...............………[3]

**(v)** Use your answer in **b(ii)** to show that the number of turns per metre length of the solenoid is 3000. [1]

No. of turns per metre length = 361/0.12 = 3000

**(c)** A wire frame ABCD is supported on two knife-edges P and Q so that the section PBCQ of the frame lies within the solenoid, as shown in Fig. 7.3. A current of 2 A is flowing in the frame PBCQ.

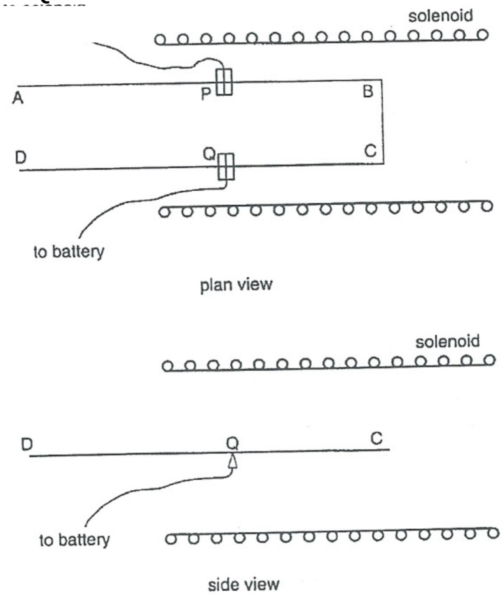



**Fig.7.3**

**(i)** State two ways in which you could reverse the direction of the force on side BC. [2]

Reverse the direction of B-field [1]

Reverse the direction of current in frame QCBP [1]

……………………………………………………………………………………

……………………………………………………………………………………

For Examiner's Use

**(ii)** The magnetic flux density B (in tesla) inside the solenoid and parallel to its axis is given by the expression $B = \mu_0 n I$,
where n is the number of turns per metre length of the solenoid, I is the current in the solenoid expressed in amperes and $\mu_0$ is the permeability of free space. $\mu_0$ has a value of $4\pi \times 10^{-7}$ H $m^{-1}$.

**1.** Define the tesla. [2]

One **tesla** is the flux density of a field in which a conductor of length 1m carrying a current of 1A at right-angles to the field experiences a magnetic force of 1N.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

**2.** Calculate the magnetic flux density in the solenoid.

$B = \mu_o nI = 4\pi \times 10^{-7} \times 3000 \times \mathbf{2.5} = 9.425 \times 10^{-3}$ T

flux density = ……………………T[1]

**3.** Side BC has length 5.0 cm. Calculate the force acting on BC due to the magnetic field in the solenoid.

$F = BIL = 9.425 \times 10^{-3} \times 2 \times 0.05$ [1]
$= 9.425 \times 10^{-4}$ N [1]

force = ……………………T[2]

**4.** A small piece of paper of mass 0.10 g is placed on the side DQ and positioned so as to keep the frame horizontal. Given that QC is of length 10.0 cm, how far from the knife-edge must the paper be positioned?

Applying the principle of moments,
$9.425 \times 10^{-4} \times 0.10 = 0.10 \times 10^{-3} \times 9.81 \times d$ [1]
$d = 0.096$ m [1]

Distance from the knife-edge = ……………………m[2]

For Examiner's Use

**(d)** A cell of e.m.f. 1.5 V and internal resistance 0.25 Ω is connected in series with the solenoid of resistance found in **(b)(i)**, as shown in Fig. 7.4.

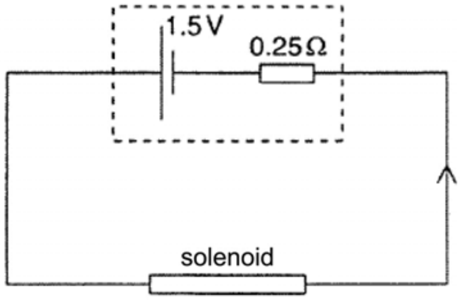



**Fig 7.4**

If the current passes through the solenoid for a time of 5.0 minutes,

**(i)** Calculate the current that passes through the solenoid.

$emf = I\,(R_{solenoid} + r)$

$1.5 = I\,(1.8 + 0.25)$ [1]

$I = 0.732$ A [1]

Current = ……………………A [2]

**(ii)** calculate the charge that passes through the cell.

$Q = It = 0.732 \times (5 \times 60) = 219.5$ C

Charge = ……………………C [1]

**(iii)** the energy transferred in the solenoid.

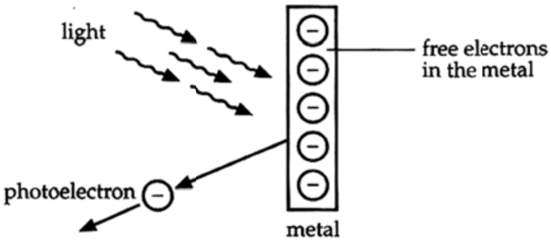
$E = Pt = I^2R\,(t) = 0.732^2 \times 1.8 \times (5 \times 60)$

$= 289.3$ J

Energy = ……………………J [1]

| 8 | (a) | (i) Describe the photoelectric effect. [3] | For Examiner's Use |
|---|---|---|---|

**The photoelectric effect refers to the phenomenon whereby electrons are emitted [1] from a metal surface [1] when light of a minimum frequency [1] strikes the clean metal surface.**




**(ii)** Explain how the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation using two of the observations from the experiment. [4]

**Evidence 1: Threshold frequency $f_0$**

**If the frequency of a wave is lower than the threshold frequency fo value, such that the energy of the photon is lower than the work function $\phi$ of the metal[1] , the electron will not have enough energy to escape even after the absorption of photon.[1]**

**Evidence 2: Intensity of light and the time taken for emission**

**Since a photon transfers all the energy to an electron and the electron needs to absorb only one photon of energy hf ( > work function $\phi$) to escape [1] and each photon travels with speed c, it follows that there should not be any time lag between the shining of light and emission of electron. [1]**

**Evidence 3: Intensity of light and photoelectric current**

**On increasing the intensity, the number of photon per second per cross-sectional area of the beam is increased and thus more electrons in the metal would have the share of photons [1] and this would increase the number of electrons emitted per second and hence the photoelectric current.[1]**

For Examiner's Use

**(b)** Fig 8.1 is a simplified representation of the energy levels of a mercury atom.

**Fig. 8.1**

**(i)** By considering transitions between these energy levels, state the spectral transition, in terms of the energy level numbers, which **emits** the shortest wavelength.

Since $E - E' = hf = hc/\lambda$ , the shortest wavelength results from transition between the largest difference in energy levels, i.e. from level **5** to level **1**.