| CANDIDATE NAME | |
|---|---|
| CLASS | 2T |

INDEX NUMBER

# PHYSICS
**Paper 2**

**8866/2**
**23 August 2016**
**2 hours**

Additional Materials: Answer Papers

## READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in **Section A**, and **TWO** out of **three** questions in **Section B.**

A **maximum** of **2 marks** will be **deducted** for wrong significant figures and incorrect/lack of units.

At the end of the examination, fasten all work securely together.
The number of marks is given in brackets [ ] at the end of each question or part of the question.

| FOR EXAMINER'S USE | |
|---|---|
| Q1 | / 6 |
| Q2 | / 10 |
| Q3 | / 10 |
| Q4 | / 14 |
| SECTION A | / 40 |
| Q5 | / 20 |
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| Q7 | / 20 |
| SECTION B | / 40 |
| PAPER 1 | / 30 |
| SF/UNITS | |
| TOTAL | / 110 |

| DIFFICULTY | | |
|---|---|---|
| L1 | L2 | L3 |
| | | |

| SKILL | | | |
|---|---|---|---|
| S1 | S2 | S3 | S4 |
| | | | |

This document consists of **22** printed pages

**[Turn over]**

**PHYSICS 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$^{-2}$ |

**PHYSICS FORMULAE:**

uniformly accelerated motion, $\quad s = ut + \dfrac{1}{2}at^2$

$$v^2 = u^2 + 2as$$

work done on / by a gas, $\quad W = p\Delta V$

hydrostatic pressure $\quad p = \rho g h$

resistors in series, $\quad R = R_1 + R_2 + ...$

resistors in parallel, $\quad \dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + ...$

## SECTION A (40 marks)

**Answer all questions in Section A.**

1  **(a)** A student wants to find the number of moles of nitrogen molecules in a reactor. In the high pressure reactor, a sample of nitrogen gas is kept at a pressure of $(5.0 \pm 0.2) \times 10^5$ Pa, with a volume of $(100 \pm 5)$ cm$^3$ and a temperature of $(523 \pm 5)$ K. The nitrogen in the reactor obeys the Ideal Gas Law, which is

$$PV = nRT$$

where $P$ is the pressure of the gas, $V$ is the volume of the gas, $n$ is the number of moles of the gas, $R$ is a constant and $T$ is the temperature of the gas.

Determine the percentage uncertainty in calculating the number of moles of nitrogen molecules present in the reactor.

percentage uncertainty = ………………………… % **[2]**

**(b)** Tempered glass screen protectors are made up of silicon dioxide (one silicon atom with two oxygen atoms) molecules.

Estimate the number of silicon atoms in a 0.5 mm thickness tempered glass screen protector for a mobile phone. Show your working and reasoning clearly.
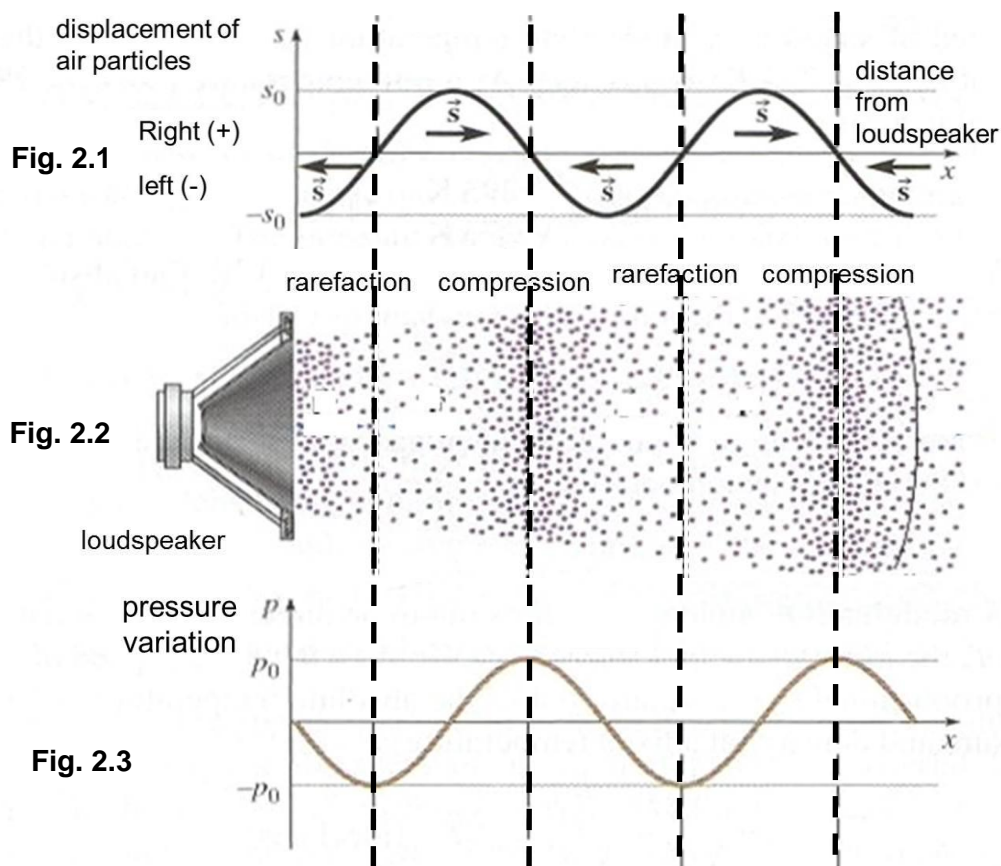
number of silicon atoms = ………………………… **[4]**

**2** A loudspeaker operating at 86 Hz is producing a wave of wavelength 4.0 m.

For a particular instant of time,

Fig. 2. shows the graph of displacement, *s*, against distance, *x*, of the air particles.
Fig. 2.2 shows the regions of rarefaction and compression.
Fig. 2.3 shows the pressure variation with position along the wave



**(a)** Determine the speed of the wave.

speed of wave = ………………….. m s⁻¹ **[2]**

**(b)** State the velocity of the rarefaction and compression regions. Explain your answer.

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

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

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

**(c)** Another identical loudspeaker is now placed 20 m away to the right of the first loudspeaker shown in Fig. 2.2. Both loudspeakers are facing each other.

**(i)** Explain the formation of the stationary (standing) wave between the loud speakers.

…………………………………………………………………………………………………

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

**(ii)** Determine the distance between any two consecutive nodes in the stationary wave created.

distance = …………………….. m **[2]**

**(iii)** By describing the movement of molecules in a stationary sound wave, explain where the air pressure varies the least.

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

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

**3** **(a)** Define *potential difference*.

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

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

**(b)** A potential divider circuit consists of two resistors of resistances *P* and *Q*, as shown in Fig. 3.1. The total current flowing throught the circuit is *I*.
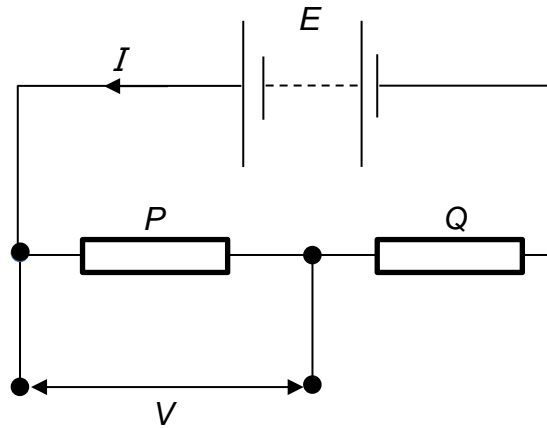


**Fig. 3.1**

The battery has e.m.f. *E* and negligible internal resistance.

Deduce that the potential difference *V* across the resistor of resistance *P* is given by the expression

$$V = \frac{P}{P+Q}E$$

**[2]**

**(c)** The resistances *P* and *Q* are 2000 Ω and 5000 Ω respectively. A voltmeter is connected in parallel with the 2000 Ω resistor and a thermistor is connected in parallel with the 5000 Ω resistor, as shown in Fig. 3.2.
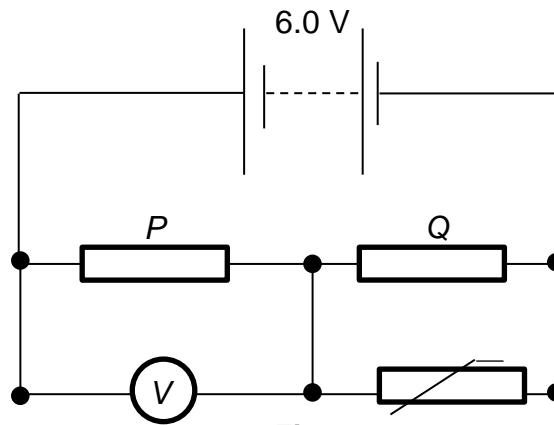


**Fig. 3.2**

The battery has e.m.f. 6.0 V and negligible internal resistance. The voltmeter has infinite resistance.

**(i)** State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised.

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

..................................................................................................................... **[3]**

**(ii)** The voltmeter reads 3.6 V when the temperature of the thermistor is 19 °C.
Calculate the resistance of the thermistor at 19 °C.

resistance = ........................... Ω **[4]**

**4** Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 4.1 have been used since 1870, particularly for pumping water on farms.
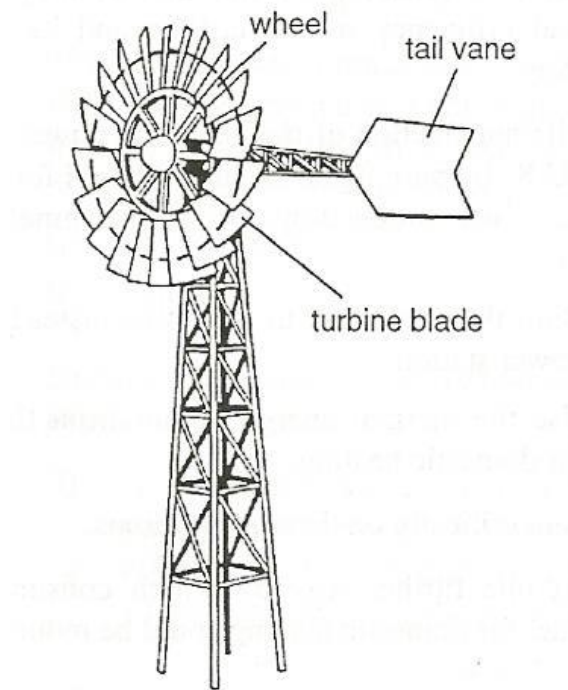


**Fig. 4.1**

The turbine blades cover almost the whole surface of the wheel and a tail vane behind the windmill keeps the wheel facing the wind. The diameters of the wheel of windmills of this type vary from 2 m to a practical maximum of about 12 m. Because of this size limitation, they are not suited to large power outputs. They will start freely with wind speeds as low as 2 m s$^{-1}$ and, at these low speeds, can produce large torques.

Fig. 4.2 shows how $P$, the output power of windmills similar to that shown in Fig. 4.1, varies with the diameter of the wheel for different wind speeds, $v$.
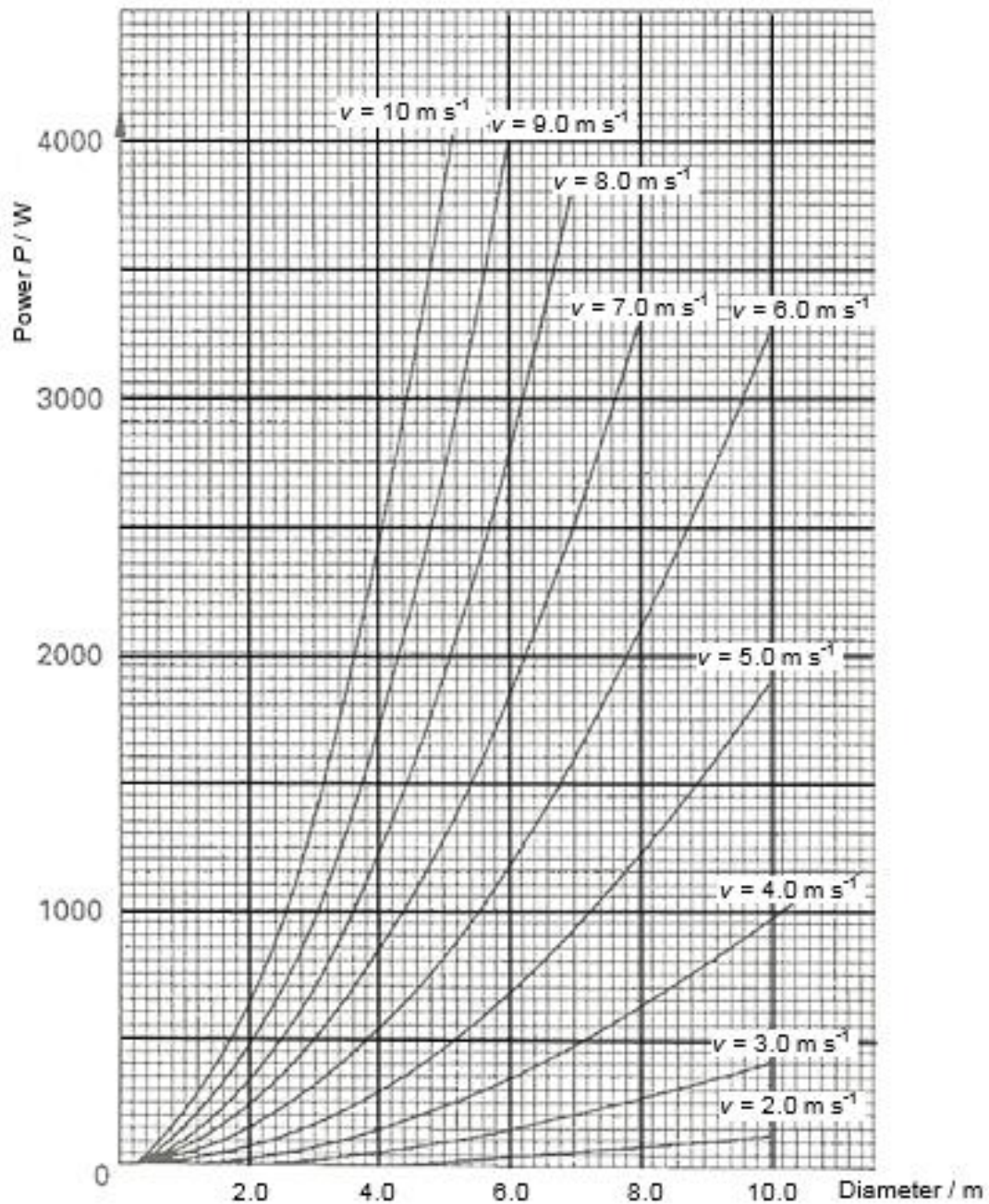


**Fig. 4.2**

**(a)** It is thought that, for a given diameter, the output power is related to the wind speed by the equation

$$P = k v^n,$$

where $n$ and $k$ are constants.

**(i)** Use Fig. 4.2 to determine lg $P$ for a particular multi-bladed low-speed windmill with a wheel of diameter 6.0 m and wind speed 3.0 m s$^{-1}$.

lg $P$ = ………………… **[1]**

**(ii)** The graph of lg ($P$ / W) against lg ($v$ / m s$^{-1}$) is plotted on Fig. 4.3.
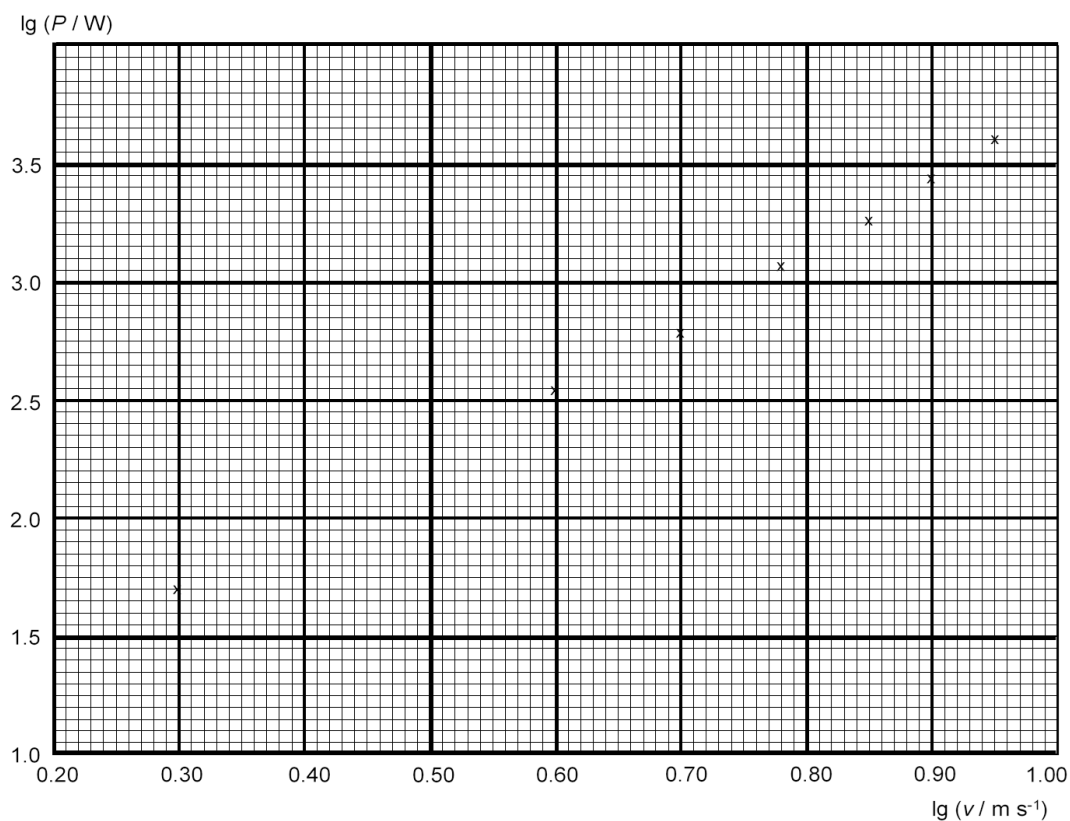


**Fig. 4.3**

On Fig. 4.3,

**1.** plot the point corresponding to a wheel diameter of 6.0 m and a wind speed of 3.0 m s$^{-1}$, and **[1]**

**2.** hence, draw the line of best fit for the points

**[1]**

**(iii)** Use the line drawn in **(c)(ii)** to determine the magnitudes of

**1.** the constant $n$, and

$n$ =……………………………….. **[2]**

**2.** the constant, $k$.

$k$ = …………………………… **[2]**

**(b)** On a particular day, the wind speed is 8.0 m s$^{-1}$.

**(i)** Estimate the volume of air that reaches the 6.0 m diameter wheel of the windmill per second.

volume of air per second =……………………..m$^3$ s$^{-1}$ **[2]**

**(ii)** The density of air is about 1.3 kg m$^{-3}$. Estimate the kinetic energy of the volume of moving air in **(b)(i)**.

kinetic energy of the air = ……………………….. J **[2]**

**(iii)** Use Fig. 4.2 to find the fraction of the power from the moving air in **(b)(ii)** that is converted in useful power

fraction of power = …………………. **[2]**

**(c)** State one other factor, besides wind speed and diameter of wheel that are likely to influence the output power of the windmill.

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

## SECTION B (40 marks)

## Answer TWO out of three questions in Section B

**5 (a)** Define

  **(i)** electrical resistance

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

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

  **(ii)** electrical resistivity

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

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

**(b)** A 60 cm long copper wire XZ of diameter 2 mm and resistivity of 1.7 x 10⁻⁸ Ω m is connected to a movable connector Y in the circuit shown in Fig. 5.1. The movable connector Y is able to slide across the entire copper wire.
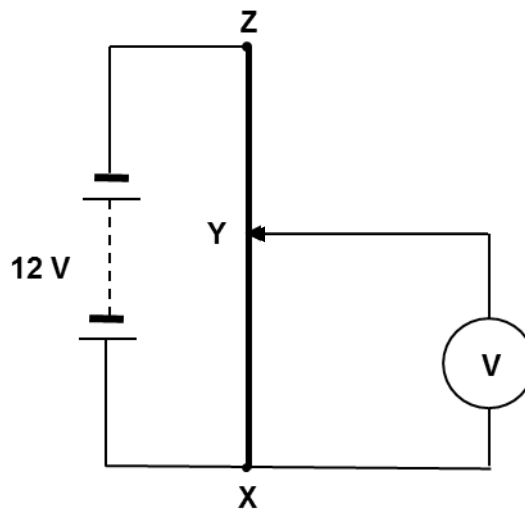


**Fig. 5.1**

  **(i)** Show that $V_{XY}$, the voltmeter reading across XY can be expressed as

$$V_{XY} = 20 I_{XY}$$

  where $I_{XY}$ is the length of the resistance wire segment XY.

  **[3]**

**(ii)** Hence calculate the length of wire segment XY that would give a voltmeter reading of 4.36 V.

length = …………….. cm  **[2]**

**(c)** The set up in **(b)(ii)** is then integrated into the apparatus used in an experiment involving a photocell to demonstrate the photoelectric effect. Scientists were interested on the effects of the *intensity* and *frequency* of the electromagnetic radiation on the current (measured by the ammeter **A**) due to the emission of the photoelectrons.
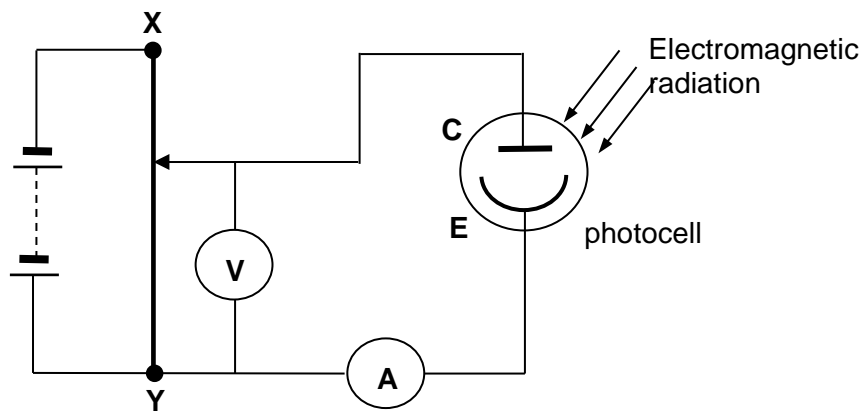


**Fig. 5.2**

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

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

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

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

**(ii)** The Einstein's Equation for the photoelectric effect can be written as

$$E = \Phi + E_K$$

State what is meant by each symbol in the equation.

*E* :…………………………………………………………………………………………...

…………………………………………………………………………………………

*Φ* :…………………………………………………………………………………………...

…………………………………………………………………………………………

$E_K$ :…………………………………………………………………………………………...

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

**(iii)** For a *given intensity* and *frequency* of EM radiation, the following graph of current, $I$ against the applied potential difference, $V$ was obtained as shown in Fig. 5.4.



**Fig. 5.4**

Suggest

**1.** why there is a current registered in the ammeter even though the applied voltage across the photocell is zero.

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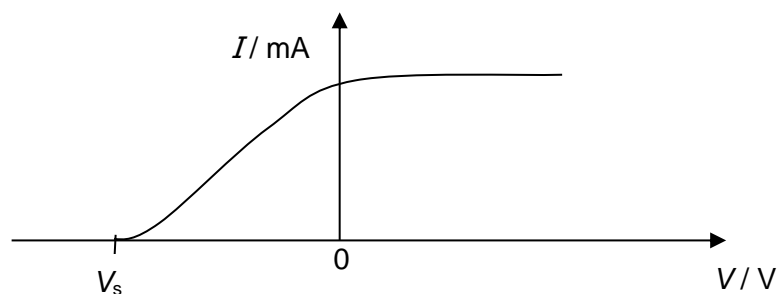
............................................................................................................... **[3]**

**2.** why there is no change in the current despite an increasing positive applied voltage after the current reaches a maximum value

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**3.** the changes, if any, in the graph in Fig. 5.4 when the copper resistance wire is now replaced with one made of gold.

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............................................................................................................... **[3]**

**6** A simple bow can be modelled to obey Hooke's law. When the bowstring of a certain spring constant is stretched by a horizontal force $F$, the bowstring will be displaced by a horizontal distance $x$ from the unstretched position as shown in Fig. 6.1(a) and Fig. 6.1(b).
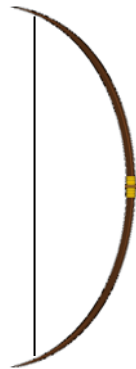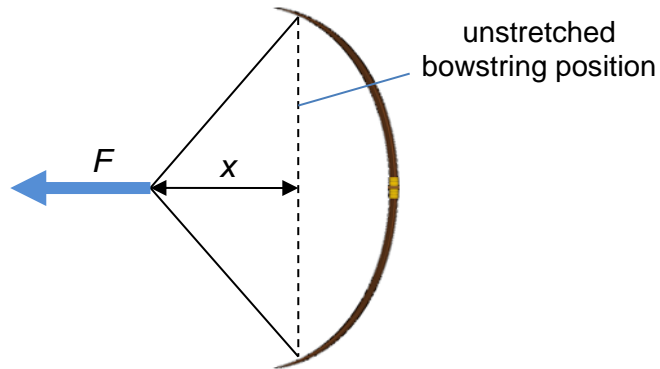


**Fig. 6.1(a)**
(Unstretched bowstring)

**Fig. 6.1(b)**
(Stretched bowstring)

A force of $F = 2100$ N is required to pull the bowstring for $x = 10.0$ cm from the unstretched position.

**(a)** Define *Hooke's law*.

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

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

**(b) (i)** State what is meant by the *spring constant* of the bowstring.

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

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

**(ii)** Calculate the spring constant of the bowstring.

spring constant = ............................. N m$^{-1}$ **[1]**

**(c)** An archer shoots the arrow using the bow to hit a target board secured firmly on a stand as shown in Fig. 6.2. The point where the arrow leaves the bowstring is where the bowstring is at the unstretched position.
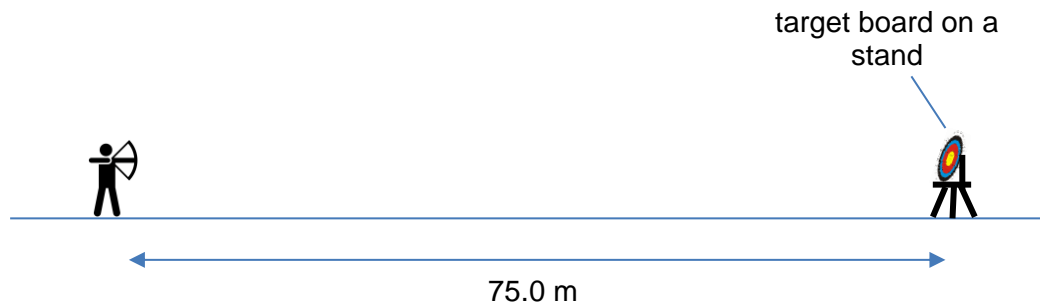
target board on a
stand

75.0 m

**Fig. 6.2**

The archer is standing still and is 75.0 m away from the target.

**(i)** Explain why, in order for the arrow to hit the bull's eye, the archer has to aim the arrow at an angle above the target, and not directly at the target.

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................................................................................................................................. **[2]**

**(ii)** The archer holds the uniform arrow of mass 900 g and length 71.0 cm in place as shown in Fig. 6.3. The tail of the arrow is at the middle of the bowstring, making length PQ = QR. The bowstring is stretched by x = 55.0 cm and the arrow makes an angle of 5.8° with the horizontal.

P   unstretched bowstring position
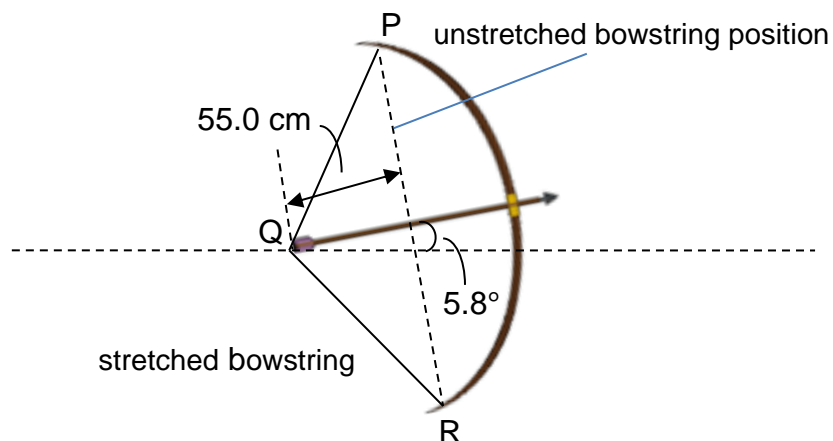
55.0 cm

Q

5.8°

stretched bowstring

R

**Fig. 6.3**

There are only three forces acting on the arrow – the weight of the arrow, the force on arrow by the bowstring that acts along the arrow and the force on the arrow by the archer acting on the tail end of the arrow (at Q) – to keep the arrow in equilibrium.

**1.** Calculate the magnitude of the force on the arrow by the archer on the tail end of the arrow in order for the arrow to stay in equilibrium as shown in Fig. 6.3.

magnitude of the force = …………………………. N **[3]**

**2.** Show that the speed of the arrow is 84.0 m s$^{-1}$ when it just leaves the bowstring after it is released. At this point, the bowstring is at the unstretched position.

**[2]**

**(iii)** Determine the time of fight of the arrow from the moment it just leaves the bow when the bowstring is at the unstretched position to the instant when it strikes the target. The position where the arrow just leaves the bow is levelled horizontally to the target.

time = ………………………..s **[2]**

**(d)** Suppose the target board and its stand are resting on a smooth ground. When the arrow strikes the target board, the collision between arrow and the target is completely inelastic. The friction on the archer by the ground is significant - throughout his shot, there is no change in the archer's position along the ground.

**(i)** Define *linear momentum*.

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

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

**(ii)** State the relation between force and momentum.

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

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

**(iii)** Explain why the total momentum for the system consisting of the target board, stand and arrow in the horizontal direction along the ground is conserved before and after the arrow strikes the target board, whereas the total momentum of this system in the vertical direction is not conserved.

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

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

**(iv)** The target board and the stand has a total mass of 12.2 kg and are initially at rest before the arrow strikes them.

Determine the final speed of the arrow after it has struck the target board.

speed = …………………………. m s$^{-1}$ **[2]**

**(v)** Suggest the change of the speed in part (iv), if any, if the archer is now standing on a frictionless ground for the same extension of the bowstring. Explain your answer.

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…………………………………………………………………………………………………….. **[3]**

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

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

.......................................................................................................................... **[2]**

**(b)** **(i)** Fig. 7.1 shows a long wire X carrying a current $I_1$. Sketch the pattern of the magnetic field that is caused by the current in the wire.
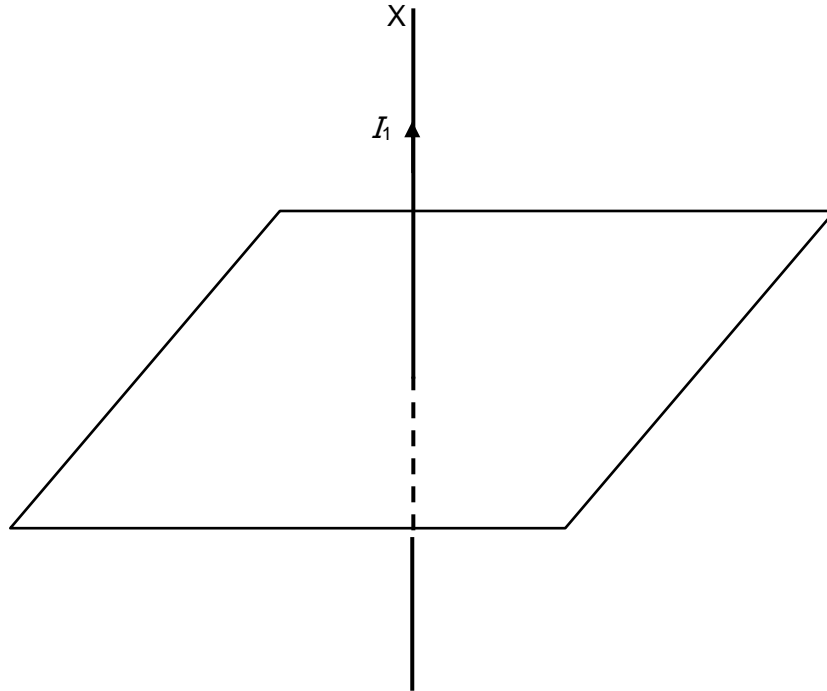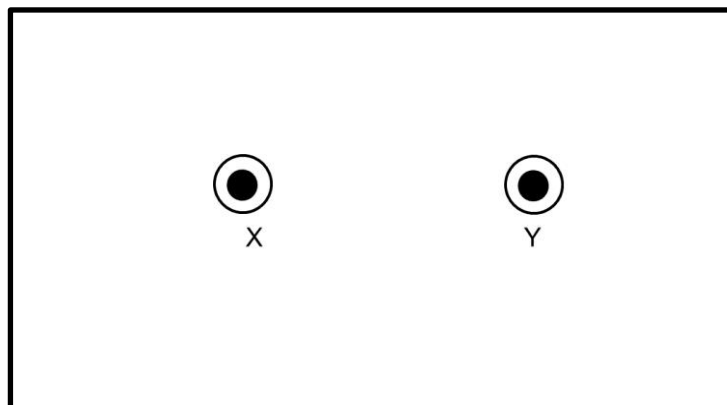


**Fig. 7.1** **[2]**

**(ii)** A long straight wire Y is brought near wire X such that it is parallel to wire X. Fig. 7.2 represents the top view of the wires indicating current coming out of the page. Sketch the resultant field lines on Fig. 7.2.



top view

**[2]**

**Fig. 7.2**

**(iii)** A third wire Z is brought near wire X and Y such that all three wires are parallel to one another and in the same plane as shown in Fig. 7.3. All three wires are in a vacuum.
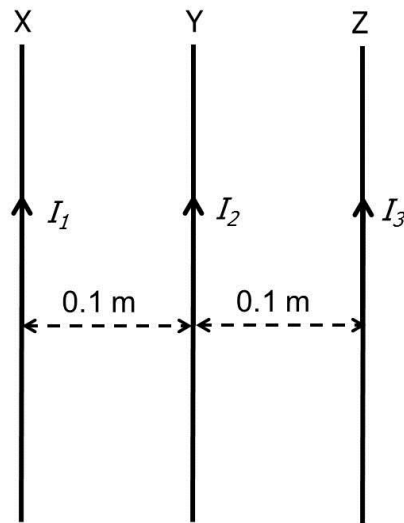


**Fig. 7.3**

The current in $I_1$ is 1.0 A, $I_2$ is 2.0 A and $I_3$ is 1.0 A. The force per unit length between two long, parallel, straight wires place 0.1 m apart, each carrying a current of 1 A, is $2 \times 10^{-6}$ N m$^{-1}$.

The magnetic flux density B at a distance $d$ from a current carrying long wire of current $I$ is given by

$$B = \frac{\mu_o I}{2\pi d}$$

where the value of $\mu_0$ is $4\pi \times 10^{-7}$.

Determine the net force per unit length acting on Z. State the direction of the net force on Z.

net force per unit length = …………………. N m$^{-1}$

direction  of net force =  ………………………………… **[4]**

**(c)** Fig. 7.4 shows a wire frame ABCD supported on two knife-edges P and Q so that the section PBCQ of the frame lies within a solenoid. Side BC has a length of 5.0 cm and QC has a length of 12.0 cm.
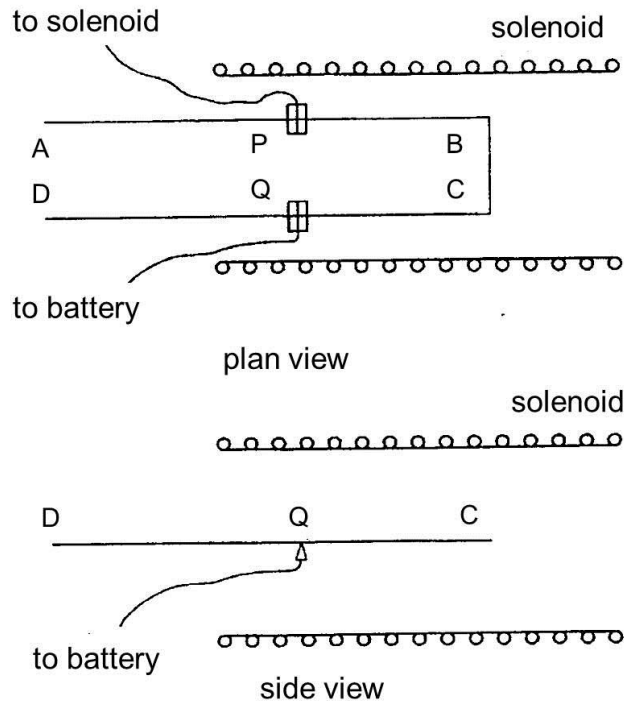


**Fig. 7.4**

Electrical connections are made to the frame through the knife-edges so that the part PBCQ of the frame and the solenoid can be connected in series with a battery. When there is no current in the circuit, the frame is horizontal.

**(i)** When the frame is horizontal and a current passes through the frame and solenoid, deduce the direction of the force, if any, due to the magnetic field of the solenoid acting on

**1.** side BC,

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

................................................................................................................. **[2]**

**2.** side PB,

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

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

**(ii) 1.** The solenoid has 700 turns m$^{-1}$ and carries a current of 3.5 A. The magnetic flux density B on the axis of a long solenoid is B = $\mu_0 nI$, where $n$ is the number of turns of the coil per unit length.

Determine the magnetic flux density in the region of side BC of the frame.

magnetic flux density = ………………….. T **[1]**

**2.** Determine the force acting on BC due to the magnetic field in the solenoid.

force on BC = ……………………. N **[2]**

**3.** 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. Determine the distance from the knife-edge the paper must be positioned.

distance = ……………….. cm **[2]**

**4.** The current through the solenoid and frame is doubled. State and explain the changes that must be made to the mass of the piece of paper in order to keep the frame horizontal.

…………………………………………………………………………………………

…………………………………………………………………………………………

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