CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME			
CLASS	**2T**	**INDEX NUMBER**	

PHYSICS [SOLUTIONS]

8866/2

Paper 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.

DIFFICULTY		
L1	L2	L3

SKILL			
S1	S2	S3	S4

FOR EXAMINER'S USE	
Q1	/ 6
Q2	/ 10
Q3	/ 10
Q4	/ 14
SECTION A	/ 40
Q5	/ 20
Q6	/ 20
Q7	/ 20
SECTION B	/ 40
PAPER 1	/ 30
SF/UNITS	
TOTAL	/ 110

This document consists of **38** printed pages

[Turn over]

PHYSICS DATA:

speed of light in free space,	c	=	3.00×10^{8} m s^{-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
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS FORMULAE:

uniformly accelerated motion,	s	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2 a s$
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 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 ± 5) cm^3 and a temperature of (523 ± 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]**

Solution:

$$PV = nRT$$

$$n = \frac{1}{R}\frac{PV}{T}$$

Therefore, percentage uncertainty,

$$\frac{\Delta n}{n} = \frac{\Delta P}{P} + \frac{\Delta V}{V} + \frac{\Delta T}{T}$$ (R is constant and assumed to have no absolute uncertainty) **M1**

$$\frac{\Delta n}{n} = \frac{0.2}{5.0} + \frac{5}{100} + \frac{5}{523}$$

$$\frac{\Delta n}{n} = 0.0996$$

$$\frac{\Delta n}{n} = 10\%$$ **A1**

(b) Tempered glass screen protector is 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]**

Solution: **M1**

An estimated area of a mobile phone screen is about 6 cm by 11 cm.
(Accept 5 to 12 cm by 10 to 19 cm. ±1 cm at both ends)
Volume of tempered glass screen protector,

$$V = 0.06 \times 0.11 \times 0.0005$$

$V = 3.30 \times 10^{-6}$ m^3 (smallest = 2.5×10^{-6} m^3, largest = 1.14×10^{-5} m^3)

The size of 1 atom is approximately 0.1 nm. Therefore, the estimated volume of a spherical atom, **M1**

$$V_{atom} = \frac{4}{3}\pi r^3$$

$$V_{atom} = \frac{4}{3}\pi \left(0.05 \times 10^{-9}\right)^3$$

$V_{atom} = 5.23 \times 10^{-31}$ m³

Therefore, the total number of atoms in the screen protector, **A1**

$$n = \frac{V}{V_{atom}} = \frac{3.30 \times 10^{-6}}{5.23 \times 10^{-31}} = 6.31 \times 10^{24}$$ (smallest = 4.77 x 10^{24}, largest = 2.18 x 10^{25}) **C1**

Hence, the number of silicon atoms,

$$N_{Silicon} = \frac{6.30 \times 10^{24}}{3} = 2.10 \times 10^{24}$$ (smallest = 1.59 x 10^{24}, largest = 7.27 x 10^{24})

General method of finding number of silicon atoms is worth 1 mark.

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

For a particular instant of time,

Fig. 2.1 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

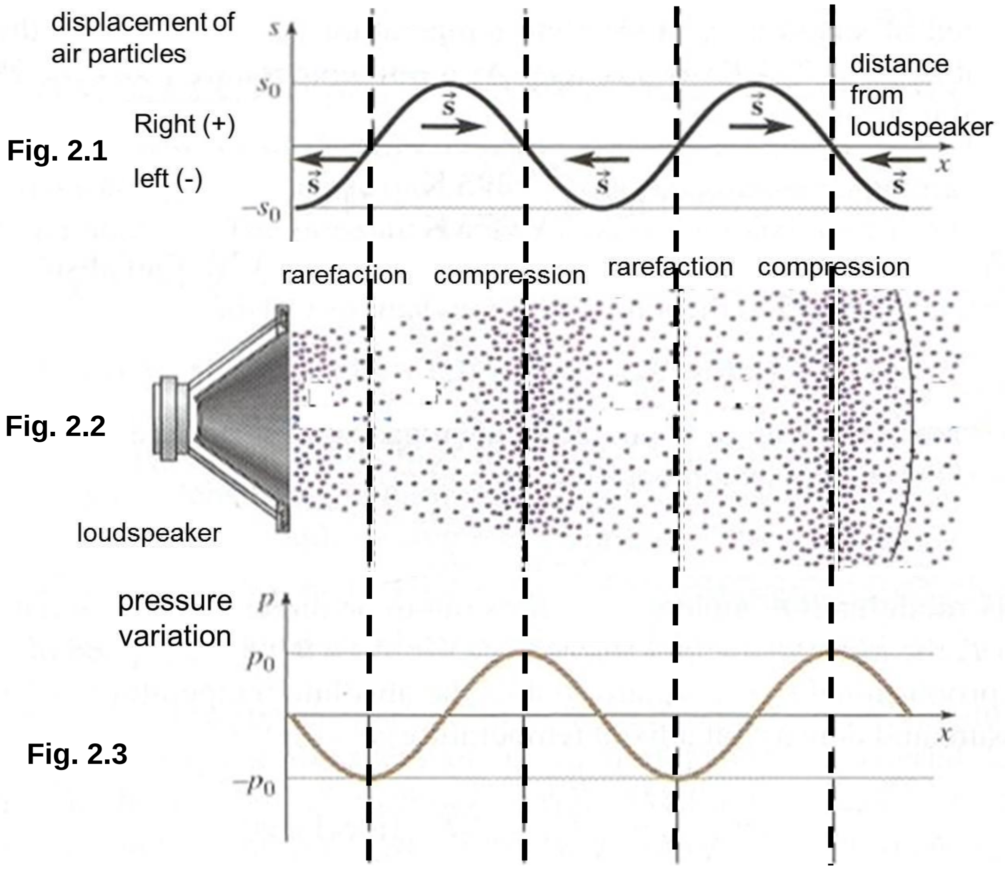


Fig. 2.1

Fig. 2.2

Fig. 2.3

(i) Determine the speed of the wave.

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

Solution:

$v = f\lambda$

$= 86 \times 4$ **M1**

$= 344$ m s^{-1} **A1**

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

[2]

Solution:
Rarefactions and compressions are produced when the air particles are displaced by the wave.
Rarefactions and compressions **move in the direction** in which the **energy of the wave travels**. Their speed is the speed of the wave found in part (i) or **344 m s^{-1}**. **B1** **B1**

(iii) 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.

1. Explain the formation of the stationary (standing) wave between the loud speakers. **[2]**

Solution:
The waves from the two loud speakers **travelling in opposite directions undergo superposition** to produce the stationary wave since they have the **same frequency, speed, type and amplitude**. **B1** **B1**

2. Determine the distance between any two consecutive nodes. **[2]**

distance = ………………….. m

Solution:

Inter-nodal distance = $\dfrac{\lambda}{2}$ **M1**

$= \dfrac{4}{2} = 2\text{m}$ **A1**

3. By describing the movement of molecules in a stationary sound wave, explain where the air pressure varies the least. **[2]**

Solution:
The molecules at the **displacement antinode** **B1**
At the displacement antinode, **the relative separation of neighbouring air molecules are about the same** and hence this coincides with the pressure node where air pressure varies the least. **B1**

3 **(a)** Define *potential difference*. **[1]**

work done per unit charge to convert electrical energy to other forms of energy. **B1**

OR **OR**

energy transferred from (electrical to other forms) per unit charge **B1**

(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*.

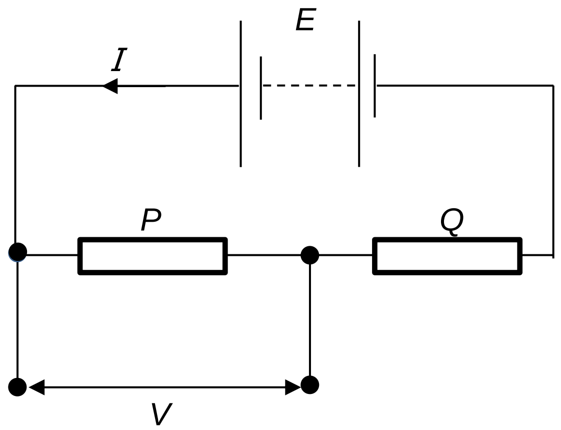


Fig. 3.1

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]

either V = IP **B1**

current in circuit, $I = \frac{E}{P+Q}$ **B1**

hence V = $\frac{P}{P+Q}E$ **A0**

or current is the same throughout the circuit

$I = \frac{V}{P} = \frac{E}{P+Q}$ **M1**

hence $V = \frac{P}{P+Q}E$ **A1**

(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.

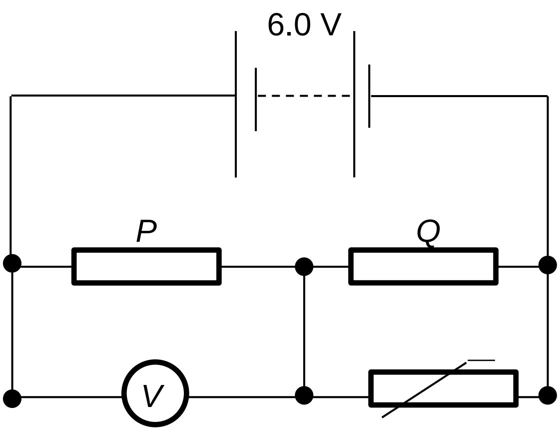


Fig. 3.2

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. **[3]**

(as temperature rises), resistance of (thermistor) decreases **M1**

EITHER resistance of parallel combination decreases **M1**

OR p.d. across 5000 Ω resistor / thermistor decreases

p.d. across 2000 Ω resistor / voltmeter reading increases **A1**

(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]**

if R is the resistance of the parallel combination,

3.6 = [2000/(2000 + R)] × 6 OR current in 2000 Ω R = V/R = 3.6/2000 = 1.80 mA **C1**

R = 1330 Ω current in 5000 Ω R = (6-3.6)/5000 = 0.48 mA **C1**

$$\frac{1}{1330} = \frac{1}{5000} + \frac{1}{T}$$ current in thermistor = 1.80 – 0.48 = 1.32 mA **C1**

T = 1820 Ω T = $\frac{2.4}{1.32}$ = 1820 Ω **A1**

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.

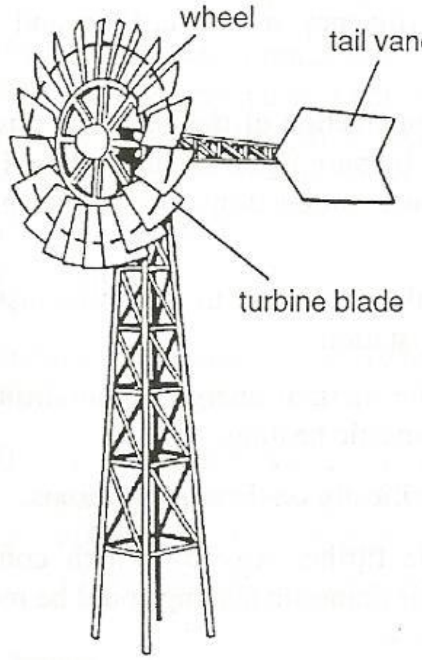


Fig. 4.1

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.

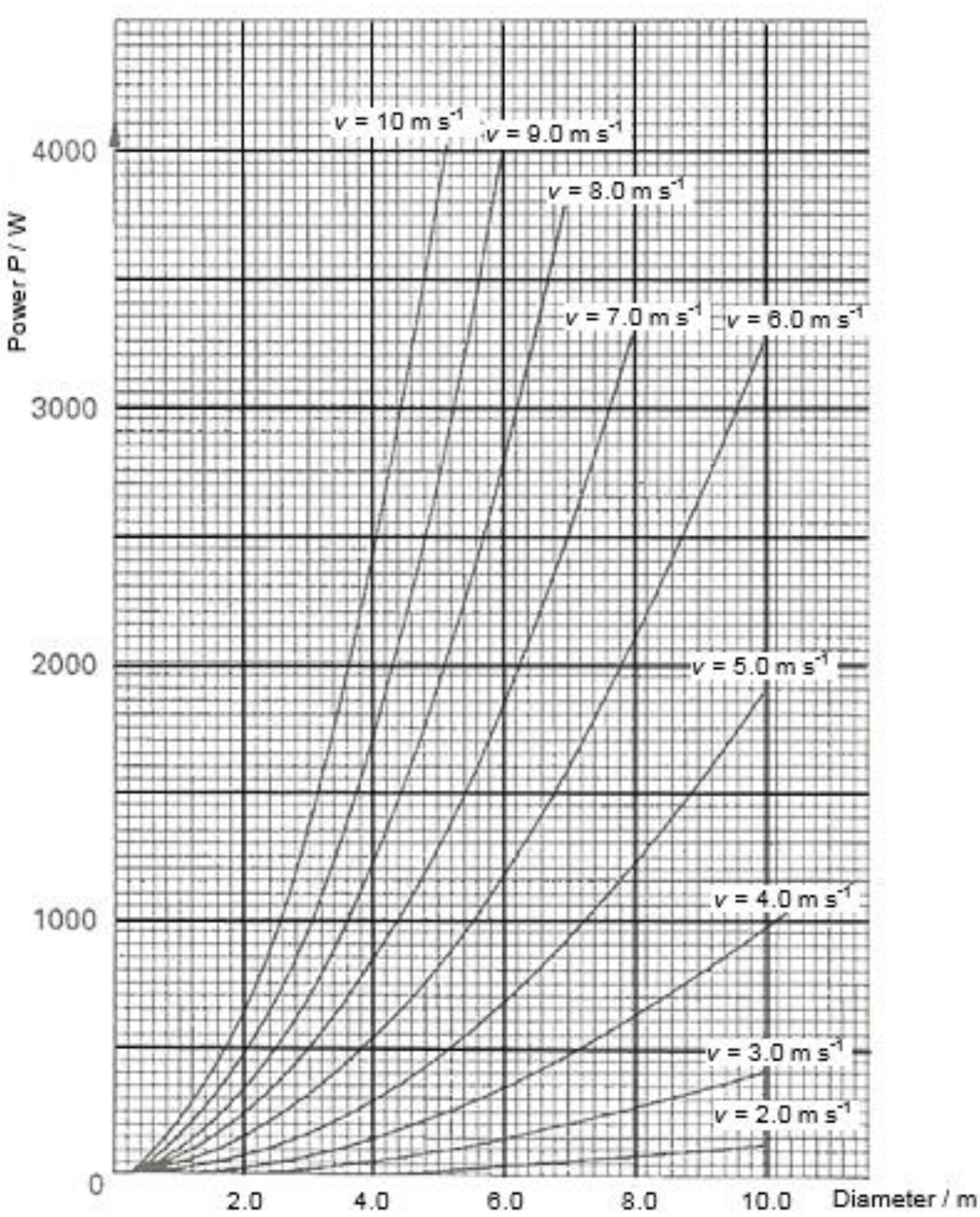


Fig. 4.2

(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]**

For diameter = 6.0 m and v = 3.0 m s^{-1},

P = 150 W

lg P = 2.2

B1

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

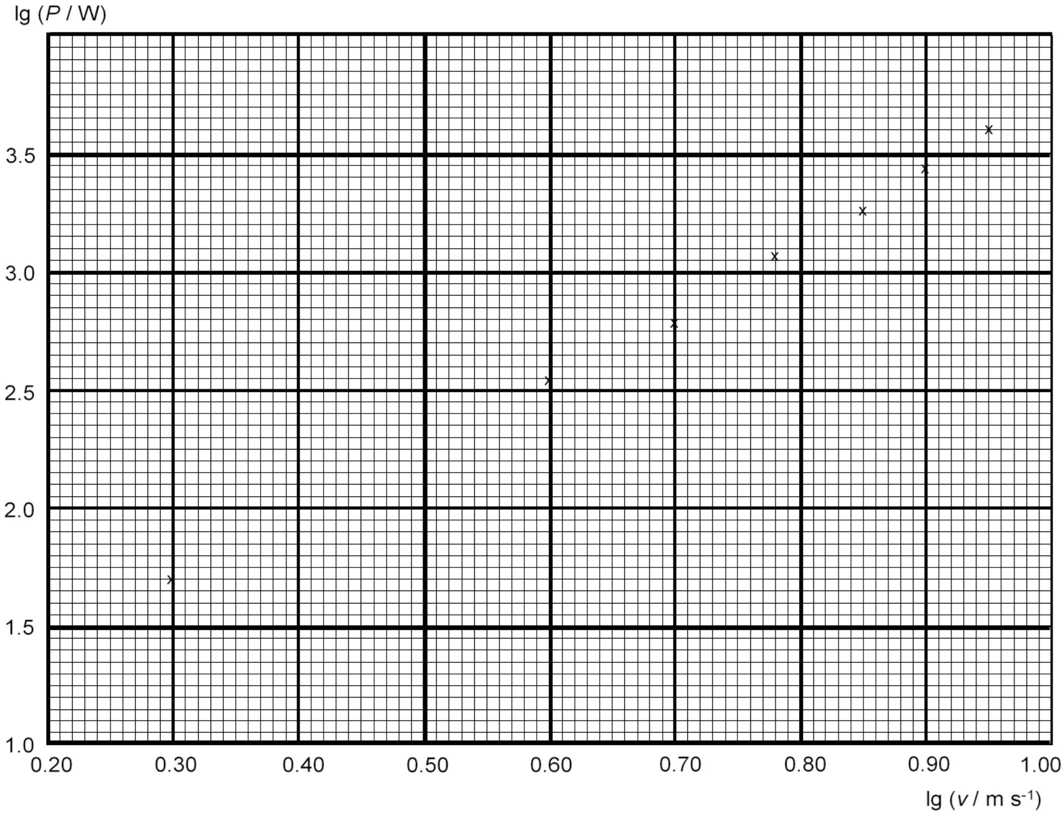


Fig. 4.3

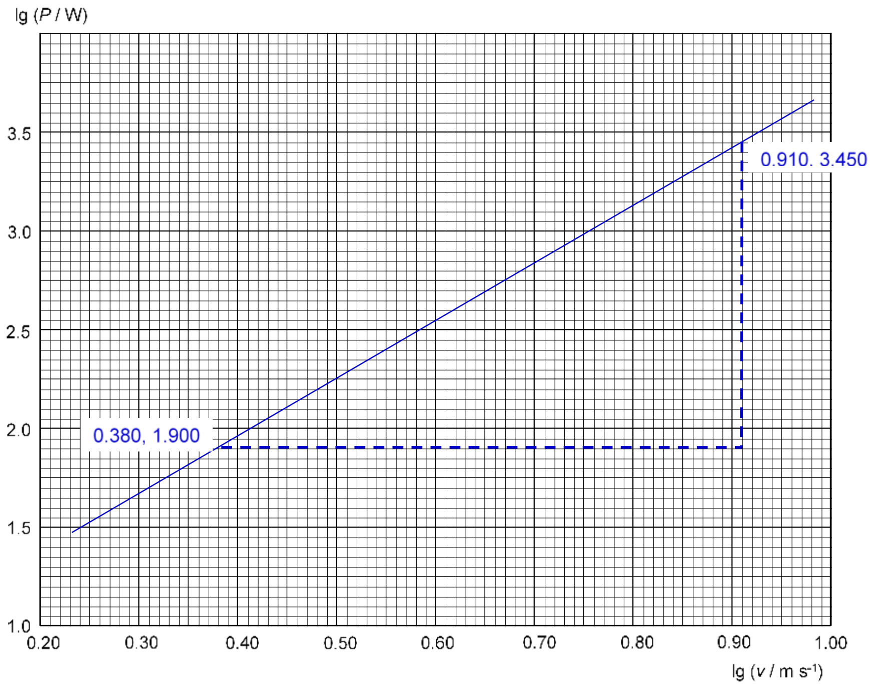
On Fig. 4.3,

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]**

Solution:

lg v = lg (3.0) = 0.48 **B1**
[B1] for correct point (0.48, 2.2) plotted.
[B1] for suitable best-fit-line drawn. **B1**



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

1. the constant *n*, and

n =.................................. **[2]**

Solutions: **M1**

n = Gradient = $\frac{3.450-1.900}{0.910-0.380}$

= 2.93 **A1**

2. the constant, *k*.

k = ... **[2]**

Solutions: **M1**

Sub (0.380, 1.900) and gradient = 2.93,
1.900 = (2.93) (0.380) + y-intercept
y-intercept = 0.7866
lg k = 0.7866
k = 6.12 **A1**

(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]**

Solution:

Considering the air moving through the blades of the windmill is approximately of a cylindrical volume,

$$\frac{\text{volume}}{\text{time}} = \frac{\pi r^2 x}{t}$$ **M1**

$$\frac{\text{volume}}{\text{time}} = \pi r^2 v$$

$$\frac{\text{volume}}{\text{time}} = \pi\left(\frac{6.0}{2}\right)^2 8.0$$ **A1**

$$\frac{\text{volume}}{\text{time}} = 226.2 = 230 \text{ m}^3 \text{ s}^{-1}$$

(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]**

Solution:

Per second,

Kinetic energy of the air moving past

$$= \frac{1}{2}mv^2 = \frac{1}{2}(\rho V)v^2$$ **M1**

$$= \frac{1}{2}(1.3)(226.2)(8)^2$$

= 9409.92 = 9400 J **A1**

(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]**

Solution: **M1**

Part of the kinetic energy of the moving air is converted into rotational kinetic energy of the turbines which is then converted into electrical energy.

From Fig. 4.2, at v = 8.0 m s^{-1}, diameter = 6.0 m,

Actual useful power output, P = 2750 W

Assuming the air loses *all* its KE to the turbines,

Total power input = 9409.92 W (from (b)(ii))

$$\frac{\text{useful power output}}{\text{total power}} = \frac{2750}{9409.92} = \mathbf{0.29\ (2\ s.f.)}$$ **A1**

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

[1]

Solution:

[B1] marks for any of the points:

- Height of the windmill.
- Location of the windmill.
- Type of material used for the blades.
- Shape of the blades.
- Surface area of the blade.
- Friction between the wheel and the axle.

B1

SECTION B (40 marks)

Answer TWO out of three questions in Section B

5 (a) Define

(i) electrical resistance

[1]

Solution

It is the ratio of the potential difference across the component to the current through it. **B1**

(ii) electrical resistivity

[1]

Solution

It is a relationship between the dimensions of a specimen of a material and its resistance at constant temperature. **B1**

(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.

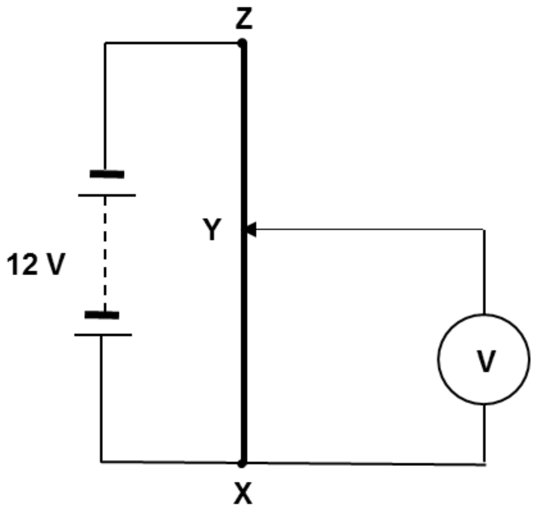


Fig. 5.1

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

$$V_{XY} = 20l_{XY}$$

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

[3]

Solution

Using the potential divider principle,

$$V_{XY} = \frac{R_{XY}}{R_{XZ}}$$ **M1**

$$= \frac{\frac{\rho l_{XY}}{A}}{\frac{\rho l_{XZ}}{A}} E$$

$$= \frac{l_{XY}}{l_{XZ}} E$$ **M1**

$$= \frac{l_{XY}}{60 \times 10^{-2}} (12)$$ **M1**

$$= 20\ l_{XY}$$ **A0**

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

length = ……………. cm **[2]**

Solution

$$V_{XY} = 20\ l_{XY}$$

$$4.36 = 20\ l_{XY}$$ **M1**

$$l_{XY} = 21.8\ cm$$ **A1**

(c) The set up in (a)(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.

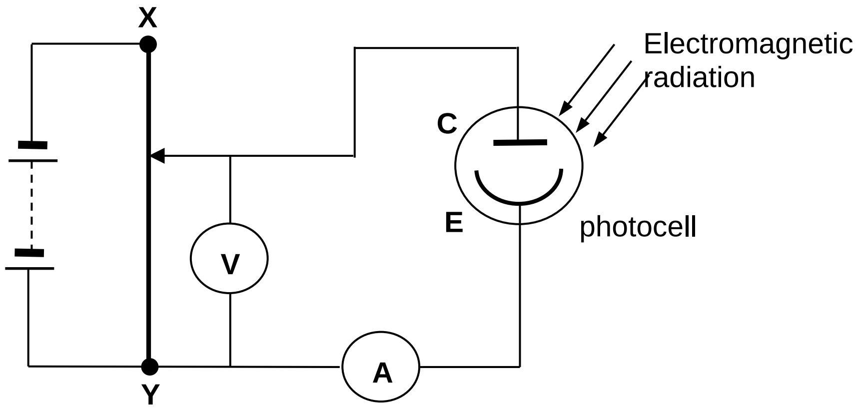


Fig. 5.2

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

[1]

Solution

B1

It is a phenomenon that results in the **ejection of electrons** from a **metal surface** when electromagnetic radiation of **high enough frequency** is shone on it.

(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.

[3]

Solution

E: the energy of a photon **B1**

Φ: work function energy **B1**

E_K: the maximum kinetic energy that an electron will possess after leaving the metal surface **B1**

(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.

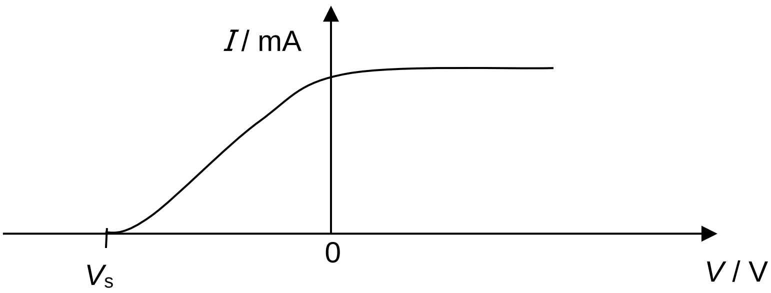


Fig. 5.4

Suggest

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

[3]

Solution

As **EM radiation is still incident on the emitter plate** (*or* as photons are still incident on the emitter plate), the surface electrons will still be gaining energy from the photons. So long as the **photoelectrons are emitted with a non-zero kinetic energy**, there is **a possibility of them reaching the collector plate** and hence a non-zero current will be registered in the ammeter. **B1** **B1** **B1**

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

[3]

Solution

At a given intensity, the **rate of photons incident onto the emitter is fixed**. Since the **rate of photoelectron emission is proportional to the rate of photon incidence, the rate of photoelectron emission is also fixed**. **B1**

B1

At **maximum current value, increasing positive applied voltage will thus not affect the rate of photoelectrons reaching the collector** if the intensity of radiation is fixed. **B1**

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.

[3]

Solution

The value of the **maximum current is proportional to the intensity** and the **stopping potential is dependent on the maximum KE of the photoelectrons, which is in turn dependent on the frequency of the EM radiation**. **M1**

By changing the material of the resistance wire, it **only affects the potential gradient of the wire**. **M1**

Since there is no change to the intensity and frequency of the EM radiation, there will **not be a change to the graph in any way**. **A1**

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).

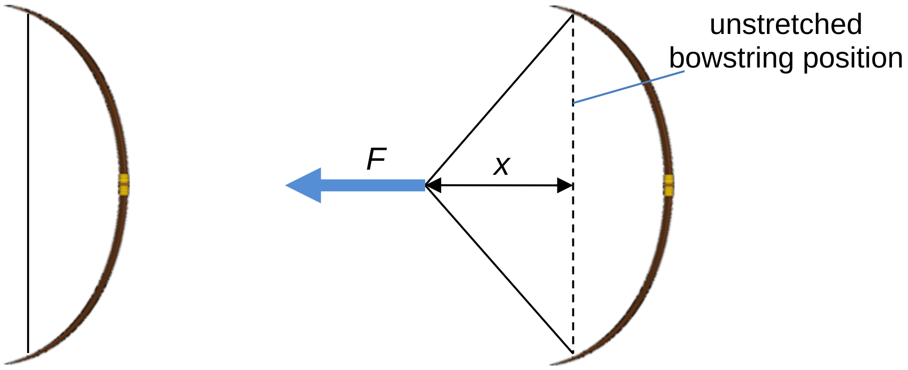


Fig. 6.1(a)
(Unstretched bowstring)

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]

Solution:
It states that the force is proportional to its extension, provided the limit of proportionality has not been exceeded.

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

[1]

Solution:
It is a constant of proportionality between force and extension of the bowstring that has not been stretched to such an extent that it has exceeded the elastic limit.

(ii) Calculate the spring constant of the bowstring.

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

Solution:
Applying Hooke's law,

$$F = kx$$

$$k = \frac{F}{x} = \frac{2100}{0.100}$$

$k = 21000$ N m^{-1} **B1**

(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.

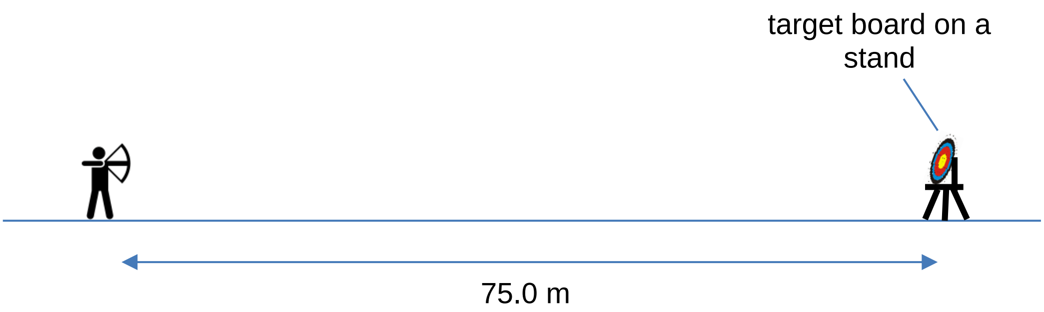


Fig. 6.2

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.

[2]

Solution:
There will be a **constant downward force** on the arrow as it travels through the range of 75.0 m to hit the target, thus, changing the arrow's vertical velocity. **B1**

Aiming the arrow at an angle above the target allows the arrow to go in a **projectile motion**, such that the arrow's vertical speed can decrease as It moves upwards initially, reach zero, and then increase downwards through the 75.0 m range before landing at the levelled target. **B1**

Aiming directly would cause the arrow to increase in the downward velocity and hit below the target.

(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.

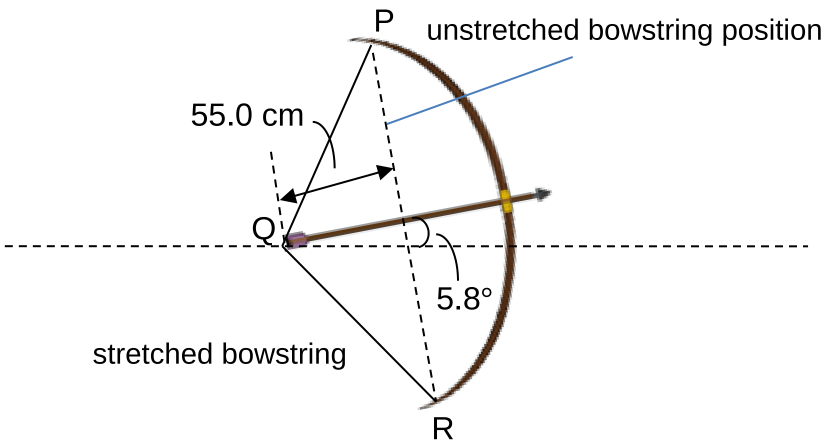


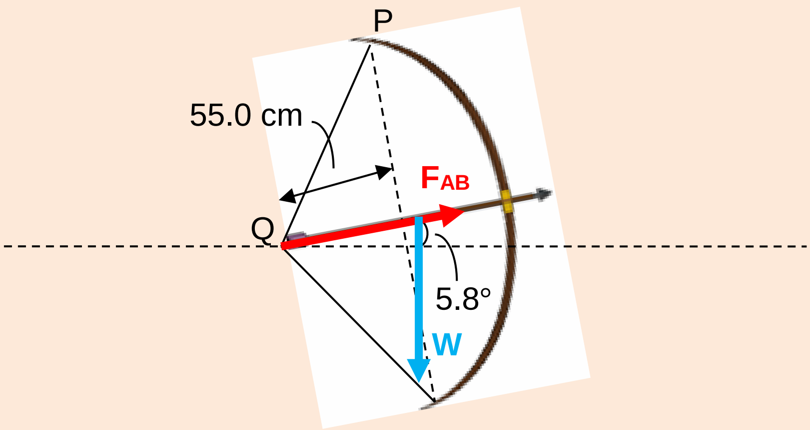
Fig. 6.3

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.

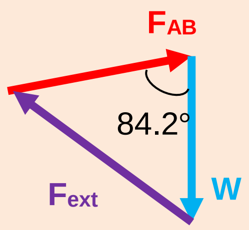
1. Calculate the magnitude of the force on the arrow by the archer on the tail end of the arrow in order for the arrow to stay in equilibrium as shown in Fig. 6.3.

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

Solution:



F_{AB} is the force on the arrow by the bowstring
W is the weight of the arrow, acting at the centre of gravity of the arrow.
As the arrow is in equilibrium, the external force F_{ext} by the archer balances the sum of F_{AB} and W.



$$F_{ext} = \sqrt{|F_{AB}|^2 + |W|^2 - 2|F_{AB}||W|\cos\theta}$$ **M1**

$$F_{ext} = \sqrt{|(21000)(0.55)|^2 + |(0.900)(9.81)|^2 - 2|(21000)(0.55)||(0.900)(9.81)|\cos 84.2°|}$$ **M1**

$$F_{ext} = 11550 \approx 1.16 \times 10^4 \text{ N}$$ **A1**

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]

Solution: **M1**
By conservation of energy,
sum of initial energy = sum of final energy

$$EPE = GPE + KE$$

$$\frac{1}{2}kx^2 = mgh + \frac{1}{2}mv^2$$ **M1**

$$v = \sqrt{\frac{2\left(\frac{1}{2}kx^2 - mgh\right)}{m}}$$ **A0**

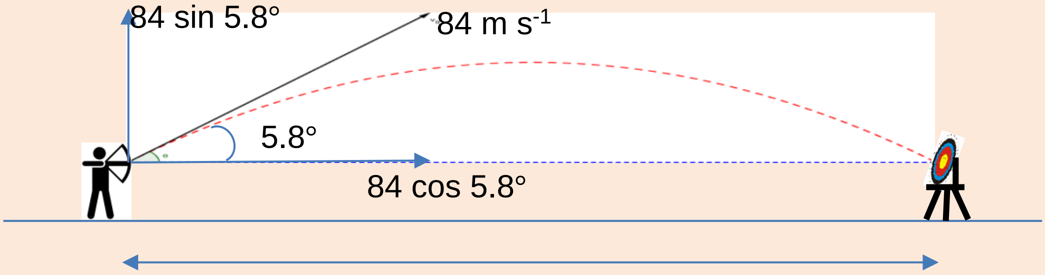
$$v = \sqrt{\frac{2\left(\frac{1}{2}(21000)(0.55)^2 - (0.900)(9.81)(0.55\sin 5.8°)\right)}{0.900}}$$

$v = 84.0$ m s^{-1} (Shown)

(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]**

Solution:



Let θ be the angle above horizontal that the archer is aiming as shown above (angle shown is exaggerated).
Consider the vertical direction only, taking up as positive,

$$s_y = u_y t + \frac{1}{2}a_y t^2$$ **M1**

$$0 = 84\sin 5.8° t - 4.905t^2$$

$$t = \frac{84\sin 5.8°}{4.905}$$ **A1**

$$t = 1.73\text{s}$$

Will also accept:

$$t = \frac{75}{84\cos 5.8°} = 0.897\text{s}$$

(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]

Solution:
It is the product of the mass of an objective and its velocity.

(ii) State the relation between force and momentum.

[1]

Solution:
The rate of change of momentum of an object is proportional to the resultant force on the object and takes place in the same direction as the net force.

(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.

[1]

Solution:
There is no external force in the horizontal direction, but **<u>there is an external force</u>** – normal contact force on the stand by the ground – **<u>in the vertical direction</u>**. **B1**

(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]**

Solution:
By Principle of Conservation of Linear Momentum, taking right as positive,

$$m_{arrow}u_1 + m_{Target}u_2 = m_{Total}v$$

$$v = \frac{m_{arrow}u_1 + m_{Target}u_2}{m_{Total}}$$

$$v = \frac{(0.900)(84\cos 5.8°)+(12.2)(0)}{0.900+12.2}$$ **M1**

$v = 5.74$ m s^{-1} **A1**

(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.

[3]

Solution:
When the archer is now on a frictionless ground, the original stored elastic potential energy of the bowstring is converted to the kinetic energy and gain in gravitational potential energy of the arrow, as well as the **<u>gain in kinetic energy of the archer</u>**. **B1**

Therefore, the **<u>KE of the arrow is lesser</u>** now as compared to the case when archer remains stationary. **B1**

The lesser KE, which consequently means less momentum of the arrow would cause the **<u>total momentum of the arrow, target board and stand to be lower than in part (iv)</u>**, hence the final speed is lesser than that calculated in part (iii). **B1**

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

[2]

Solution:
It is the force experienced per unit length of wire carrying per unit electric current when placed inside a uniform magnetic field, **B1**
with the force perpendicular to both the magnetic field and the current. **B1**

(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.

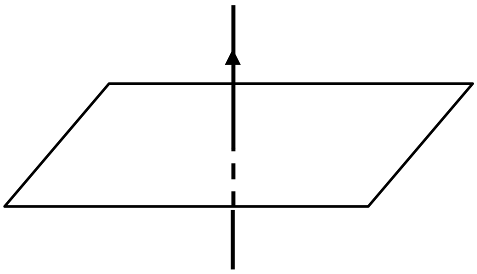
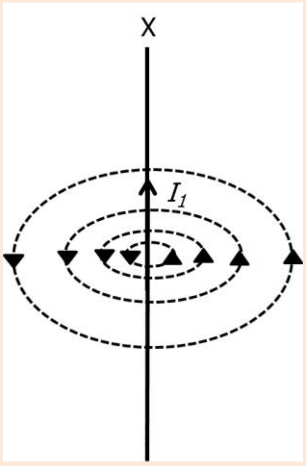


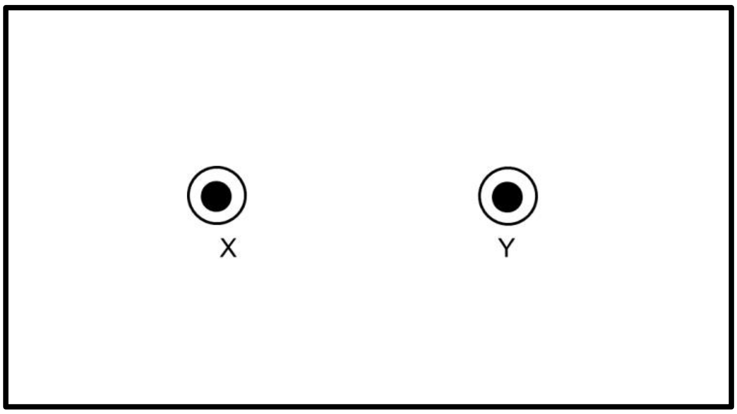
Fig. 7.1 **[2]**

Solution:



B1 – increasing spaces between rings to show weakening field strength the further away from the wire
B1 – correct direction of field lines represented by arrows

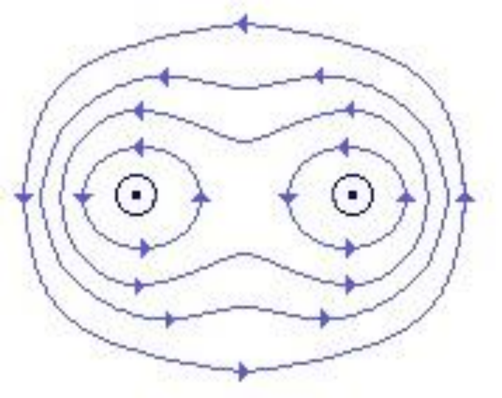
(ii) A long straight wire Y is brought near wire X such that it is parallel to wire X. Fig. 7.2 represents the top view of the wires indicating current coming out of the page. Sketch the resultant field lines on Fig. 7.2.



top view

Fig. 7.2 **[2]**

(ii) Solution:



B1 for direction of field lines
B1 for overall shape of field

(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.

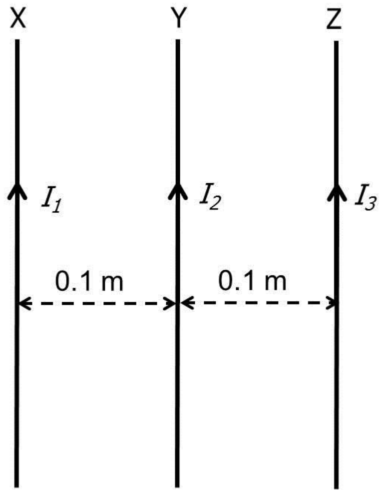


Fig. 7.3

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 2×10^{-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 μ_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}

[4]

direction of net force = …………………………………

Solution:
Leftward force per unit length on Z by X, F_{ZX}

$\frac{F_{ZX}}{L} = \frac{1}{2}(2x10^{-6})$ [Since $\frac{F}{L} \propto \frac{1}{d}$] **M1**

= 1×10^{-6} N m^{-1}

Leftward force per unit length on Z by Y, F_{ZY}

$$\frac{F_{ZY}}{L} = 2(2x10^{-6}) \text{ [Since } \frac{F}{L} \propto I]$$ **M1**

$= 4 \times 10^{-6}$ N m^{-1}

Hence, net leftward force on Z due to currents in X and Y = 5×10^{-6} N m^{-1}. **A1**

Force direction is to the left **A1**

(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.

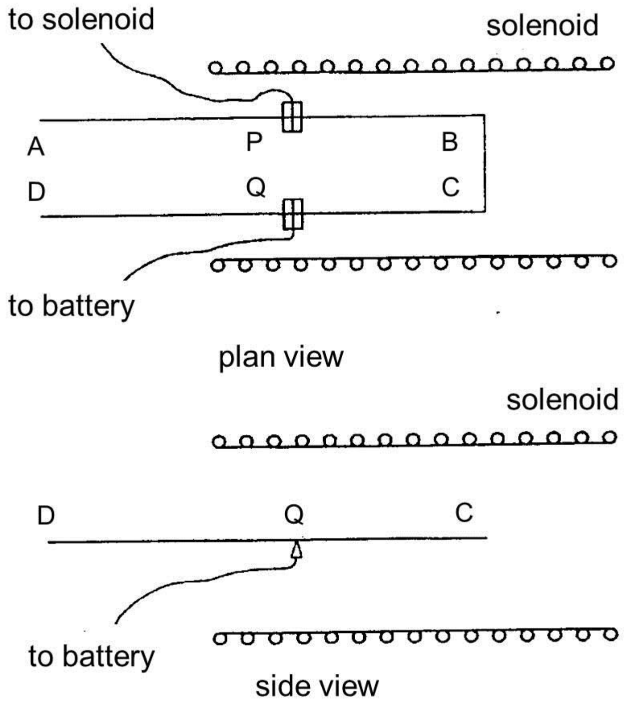


Fig. 7.4

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,

[2]

Solution:

On side BC which is perpendicular to the magnetic field of the solenoid, a **vertical force is expected**. **B1**

As predicted by **Fleming's Left Hand Rule,** the force is **perpendicular to the direction of the current flow and the magnetic field.** **B1**

2. side PB,

[1]

Solution:
Since side PB is **parallel with the magnetic field of the solenoid**, **no magnetic force** is expected.

B1

(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]**

Solution:
B = $\mu_0 nI$ = $4\pi \times 10^{-7} \times 700 \times 3.5$ **B1**
= 3.08×10^{-3} T

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

force on BC = ……………………. N **[2]**

Solution:
Force acting on BC
F = BIL
= $3.08 \times 10^{-3} \times 3.5 \times 5.0 \times 10^{-2}$ **M1**
= 5.39×10^{-4} N **A1**

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]**

Solution:
Let d be the distance from the knife edge
Since frame is horizontal
By principle of moments,
Sum of anti-clockwise moments = Sum of clockwise moment
$mgd = Fd_{QC}$
$0.1 \times 10^{-3} \times 9.81 \times d = 5.39 \times 10^{-4} \times 12$ **M1**
d = 6.59 cm **A1**

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]

Solution:
The **clockwise moment will increase by 4 times** as magnetic field strength through solenoid and current is doubled. **B1** The mass of the paper must be **increased by 4 times** so that the anticlockwise moment will be increased by 4 times. **B1**