JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME			
CLASS	2T	**INDEX NUMBER**	

PHYSICS

9646/2

Paper 2

23 August 2016
1 h 45 min

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.

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	/ 11
Q3	/ 10
Q4	/ 6
Q5	/ 13
Q6	/ 14
Q7	/ 12
SF/UNITS	
TOTAL	/ 72

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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	=	$\rho g h$
gravitational potential,	ϕ	=	$-Gm/r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_0^2 - x^2}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q/4\pi\varepsilon_0 r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\pm\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

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]**

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

Estimate the number of moles of silicon atoms in a 0.5 mm thickness tempered glass screen protector for a mobile phone. Show your working and reasoning clearly.

2 An archer shoots an arrow to hit a target board secured firmly on a stand as shown in Fig. 2.1. The point where the arrow is released is considered to be levelled with the target as measured from the ground.

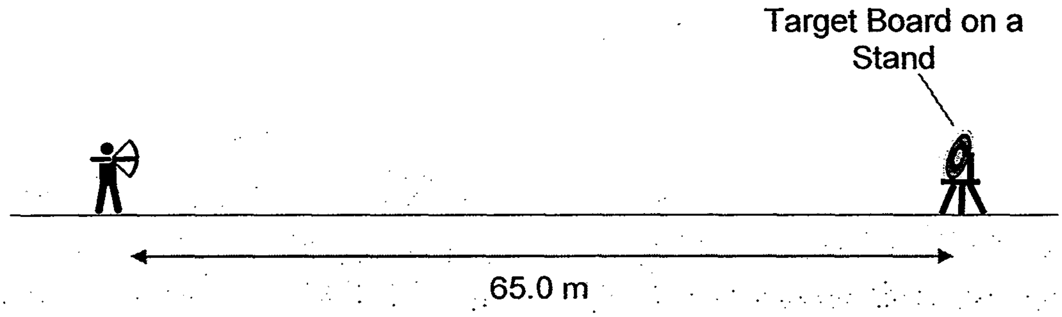


Fig. 2.1

The archer is standing still 65.0 m away from the target. The arrow has a mass of 880 g.

(a) (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]

(ii) The arrow leaves the archer's bow at an angle less than 45° and with an initial velocity of 90.0 m s^{-1}. Determine the angle above the horizontal that the archer has to release the arrow such that it can hit the centre of the target.

You may find the following equation useful: $\sin 2x = 2\sin x\cos x$

(b) The target board and its stand are resting on a frictionless ground. When the arrow strikes the target board, the arrow, target boards and stand move together as one body along the ground.

(i) Explain why the total momentum of 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 the system in the vertical direction is not conserved.

....

.... **[1]**

(ii) The target board and the stand have 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]**

(iii) State the momentum of the archer along the frictionless ground immediately after the arrow is shot off from the archer. Explain your answer.

....

....

....

.... **[2]**

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

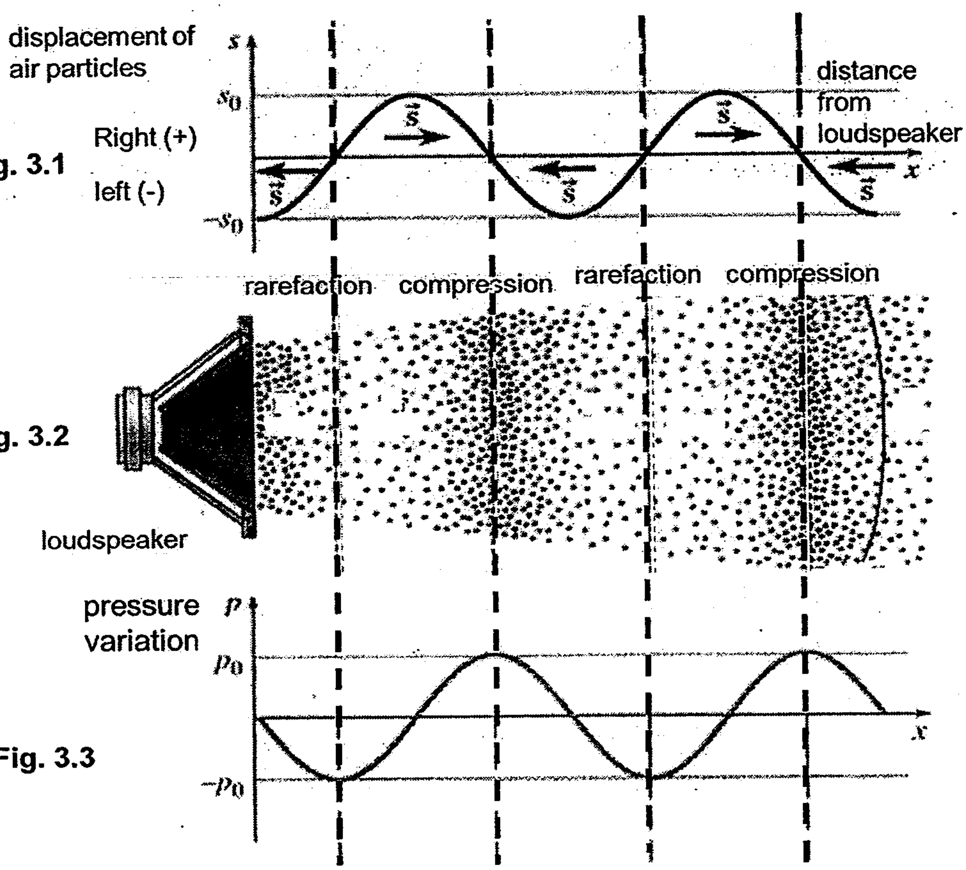
For a particular instant of time,

Fig. 3.1 shows the graph of displacement, s, against distance, x, of the air particles.
Fig. 3.2 shows the regions of rarefaction and compression.
Fig. 3.3 shows the pressure variation with position along the wave at an instant of time.

Fig. 3.1

Fig. 3.2

Fig. 3.3



(i) Determine the speed of the wave.

speed of wave = ... m s⁻¹ **[2]**

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

....

....

....

.... **[2]**

(iii) Another identical loudspeaker is now placed 20 m away to the right of the first loudspeaker shown in Fig. 3.2. Both loudspeakers are facing each other.

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

....

....

....

.... **[2]**

2. Determine the distance between any two consecutive nodes in the stationary wave formed.

distance = ... m **[2]**

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

....

....

.... **[2]**

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

....

.... **[1]**

(b) The circuit shown in Fig. 4.1 is used to compare potential differences of cells.

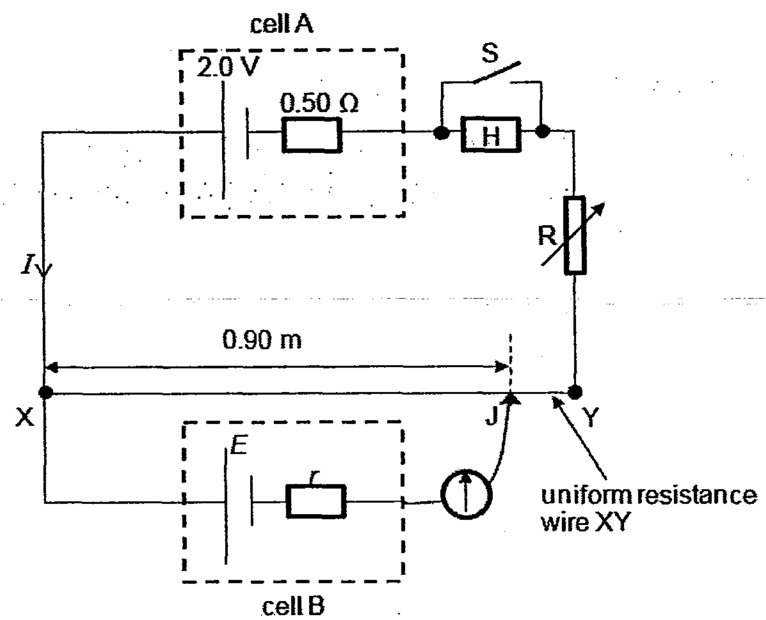


Fig. 4.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. When switch S is closed, the current through cell A is I. Cell B has e.m.f. E and internal resistance r.

The current through cell B is made zero when the movable connection J is adjusted such that the length of XJ is 0.90 m. The variable resistor R has resistance 1.5 Ω while the fixed resistor H has resistance 1.0 Ω

(i) Determine the value of E.

E = ... V **[3]**

(ii) When switch S is opened, determine quantitatively if the balance length XJ exists for this setup with no change in the values of cell B.

[2]

5 Fig. 5.1 shows a simplified circuit diagram of the apparatus used in an experiment involving a photocell and a copper resistance wire XY to demonstrate the photoelectric effect. Scientists were particularly interested in 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.

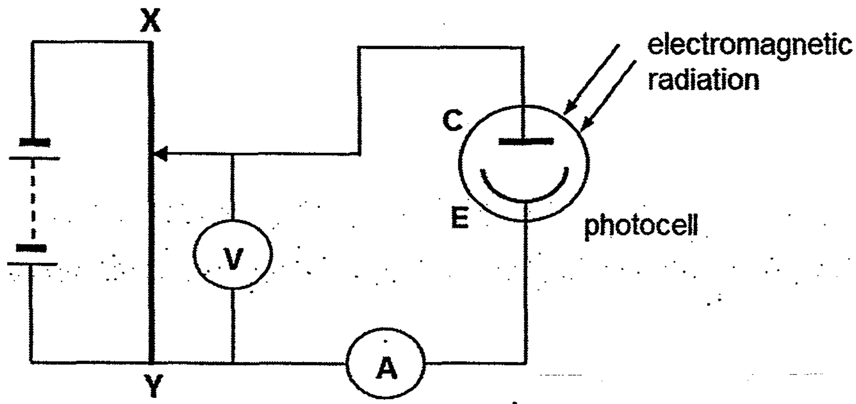


Fig. 5.1

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

....

....

.... [1]

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

$$E = \Phi + E_K$$

State the quantity represented by each symbol in the equation.

E : ....

....

Φ : ....

....

E_K : ....

.... [3]

(c) 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. 5.2.

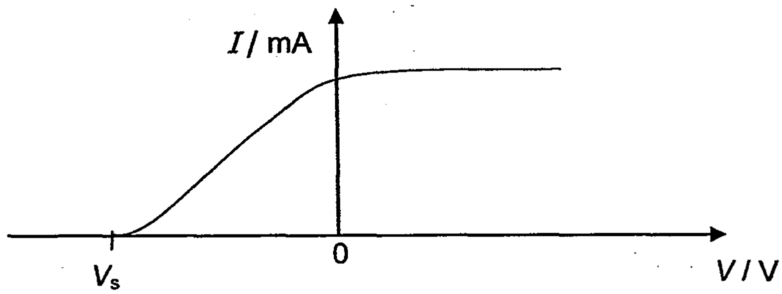


Fig. 5.2

Explain

(i) why there is a current registered in the ammeter even though the applied voltage across plates E and C is zero.

....

....

....

.... **[3]**

(ii) why there is no change in the current despite an increasing positive applied voltage when the current reaches a maximum value.

....

....

....

.... **[3]**

(iii) the changes, if any, in the graph in Fig. 5.2 when the copper resistance wire is now replaced with one made of gold.

....

....

....

.... **[3]**

6 Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 6.1 have been used since 1870, particularly for pumping water on farms.

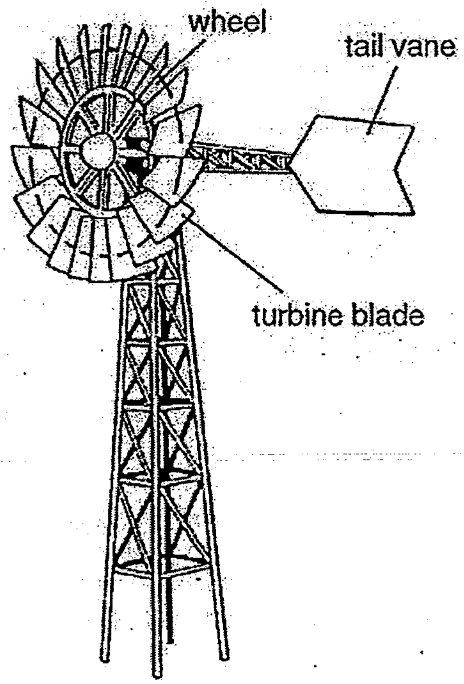


Fig. 6.1

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. 6.2 shows the variation of P, the output power of windmills similar to that shown in Fig. 6.1 with the diameter of the wheel for different wind speeds, v.

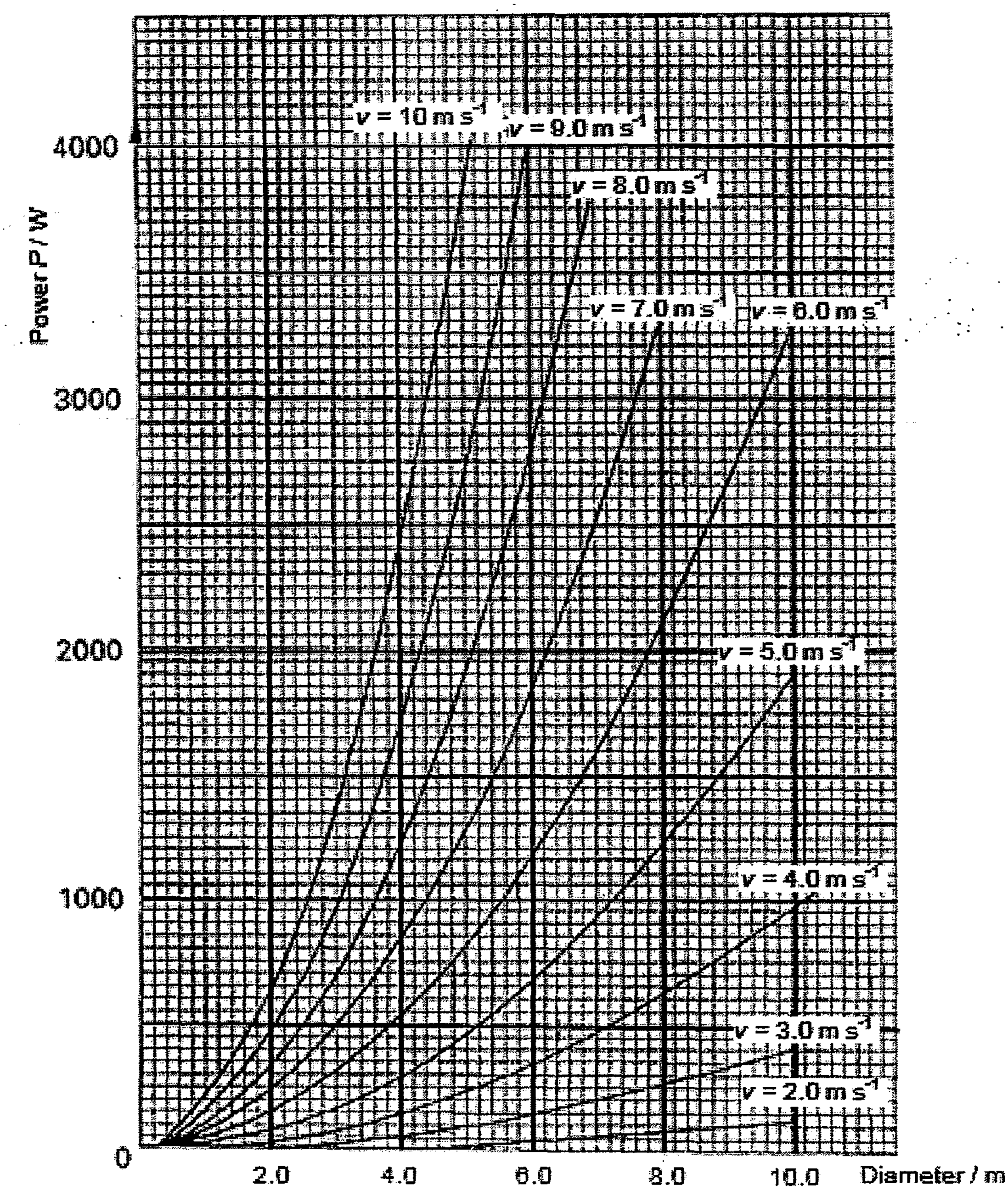


Fig. 6.2

(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. 6.2 to determine lg (P / W) for a particular multi-bladed low-speed windmill with a wheel of diameter 6.0 m and wind speed 3.0 m s^{-1}.

(ii) The graph of lg (P / W) against lg (v / m s^{-1}) is plotted on Fig. 6.3.

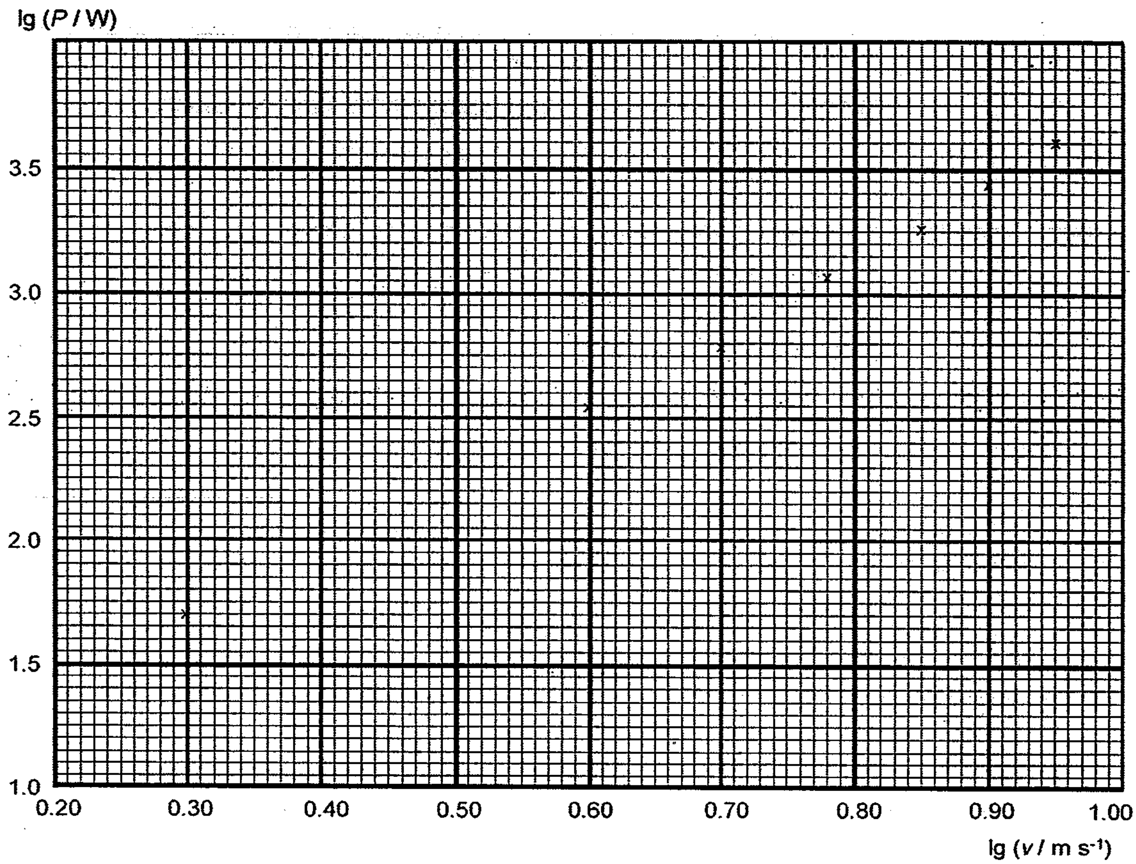


Fig. 6.3

On Fig. 6.3,

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.

(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. 6.2 to find the fraction of the power from the moving air in **(b)(ii)** that is converted into 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.

....

.... **[1]**

7 Gamma ray (γ-ray) is a type of ionising radiation. The absorption of γ-ray as it passes through a metallic material increases as the thickness of the material increases. The count rate of the γ-ray, *C*, penetrating through a material depends on the thickness *d* of the material.

You are provided with a Cobalt-60 source, a Geiger-Müller Tube connected to a datalogger that measures the total number of counts in a fixed time period and a number of lead slabs with standard business card dimensions to act as absorbers of γ-rays. Cobalt-60 is a radioactive source that emits both β rays and γ-rays at the same time. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between *C* and *d*.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay special attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,.
(d) how the relationship between *C* and *d* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment. **[12]**

Diagram

....

....

....

....

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Higher 2

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SKILL			
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velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^2 - x^2}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q/4\pi\varepsilon_0 r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\pm\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

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)

$\frac{\Delta n}{n} = \frac{0.2}{5.0} + \frac{5}{100} + \frac{5}{523}$ **M1**

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

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

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

Estimate the number of moles of silicon atoms in a 0.5 mm thickness tempered glass screen protector for a mobile phone. Show your working and reasoning clearly.

moles of silicon atoms = ... mol **[4]**

Solution: **M1**

An estimated area of a mobile screen is about 6 cm by 11 cm.
(Accepts 5 to 7 cm by 10 to 12 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

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

$V_{atom} = \frac{4}{3}\pi r^3$ **M1**

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

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

$$n = \frac{V}{V_{atom}} = \frac{3.30\times10^{-6}}{5.23\times10^{-31}} = 6.30\times10^{24}$$ **A1**

Hence, the number of moles of silicon atoms, **C1**

$$n_{silicon} = \frac{6.30\times10^{24}}{3\times6.02\times10^{23}} = 3.49$$

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

2 An archer shoots an arrow to hit a target board secured firmly on a stand as shown in Fig. 2.1. The point where the arrow is released is considered to be levelled with the target as measured from the ground.

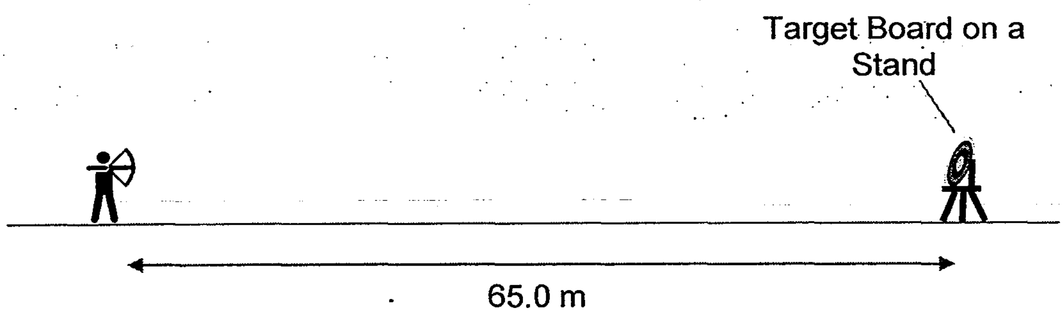


Fig. 2.1

The archer is standing still 65.0 m away from the target. The arrow has a mass of 880 g.

(a) (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 65.0 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 65.0 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.

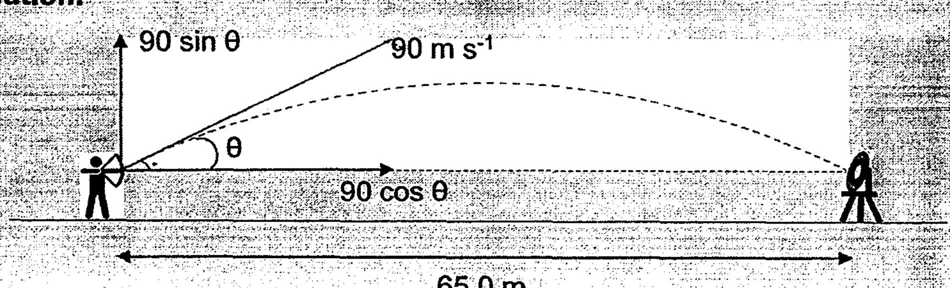
(ii) The arrow leaves the archer's bow at an angle less than 45° and with an initial velocity of 90.0 m s^{-1}. Determine the angle above the horizontal that the archer has to release the arrow such that it can hit the centre of the target.

You may find the following equation useful: $\sin 2x = 2\sin x \cos x$

angle above horizontal = ... ° **[4]**

Solution:

M1



M1

Let θ be the angle above horizontal that the archer is aiming as shown above (angle shown is exaggerated). **M1**
Consider the horizontal direction only, taking right as positive,

$$s_x = u_x t$$

$$t = \frac{65.0}{90\cos\theta} \quad (1)$$ **A1**

Consider the vertical direction only, taking up as positive,

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

$$0 = 90\sin\theta t - 4.905t^2$$

$$t = \frac{90\sin\theta}{4.905} \quad (2)$$

Sub (1) in (2),

$$\frac{65.0}{90\cos\theta} = \frac{90\sin\theta}{4.905}$$

$$4050\,(2\sin\theta\cos\theta) = 65.0 \times 4.905$$

$$\sin 2\theta = \frac{65.0 \times 4.905}{4050}$$

$$\theta = 2.26°$$

(b) The target board and its stand are resting on a frictionless ground. When the arrow strikes the target board, the arrow, target boards and stand move together as one body along the ground.

(i) Explain why the total momentum of 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 the system in the vertical direction is not conserved.

[1]

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

(ii) The target board and the stand have 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,

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

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

$$v = \frac{(0.880)(90\cos 2.26) + (12.2)(0)}{0.880 + 12.2}$$ **M1**

$$v = 6.05\,\text{m s}^{-1}$$ **A1**

(iii) State the momentum of the archer along the frictionless ground immediately after the arrow is shot off from the archer. Explain your answer.

[2]

Solution: **B1**
By principle of conservation of linear momentum, **considering the system of archer,**

Therefore, the momentum of the archer must be numerically equal to the final momentum of the arrow and target, which is $p = (0.880 + 12.2)(6.05) = 79.1\,kg\,m\,s^{-1}$, **towards the left.** B1

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

At a particular instant of time,

Fig. 3.1 shows the graph of displacement, *s*, against distance, *x*, of the air particles.
Fig. 3.2 shows the regions of rarefaction and compression.
Fig. 3.3 shows the pressure variation with position along the wave at an instant of time.

Fig. 3.1

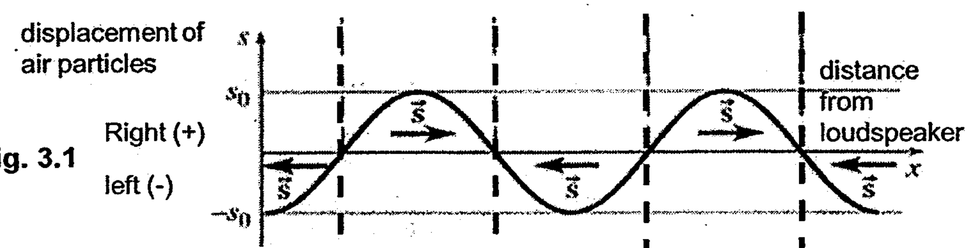


Fig. 3.2

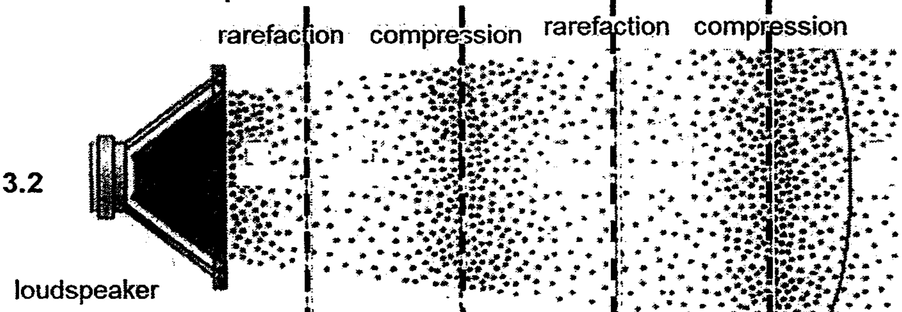
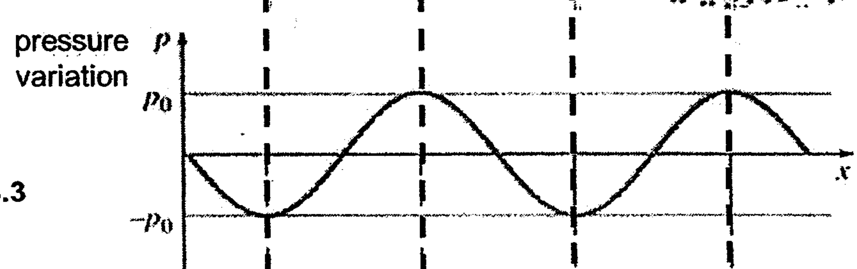


Fig. 3.3



(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 and explain how you would deduce the velocity of the rarefaction and compression.

[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. 3.2. 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/wavelength nature and speed.** **B1** **B1**

2. Determine the distance between any two consecutive nodes in the stationary wave formed.

[2]

distance = ... m

Solution:
Inter-nodal distance $= \frac{\lambda}{2}$ **M1**
$= \frac{4}{2} = 2\text{m}$ **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**

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

[1]

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

OR

(b) The circuit shown in Fig. 4.1 is used to compare potential differences of cells.

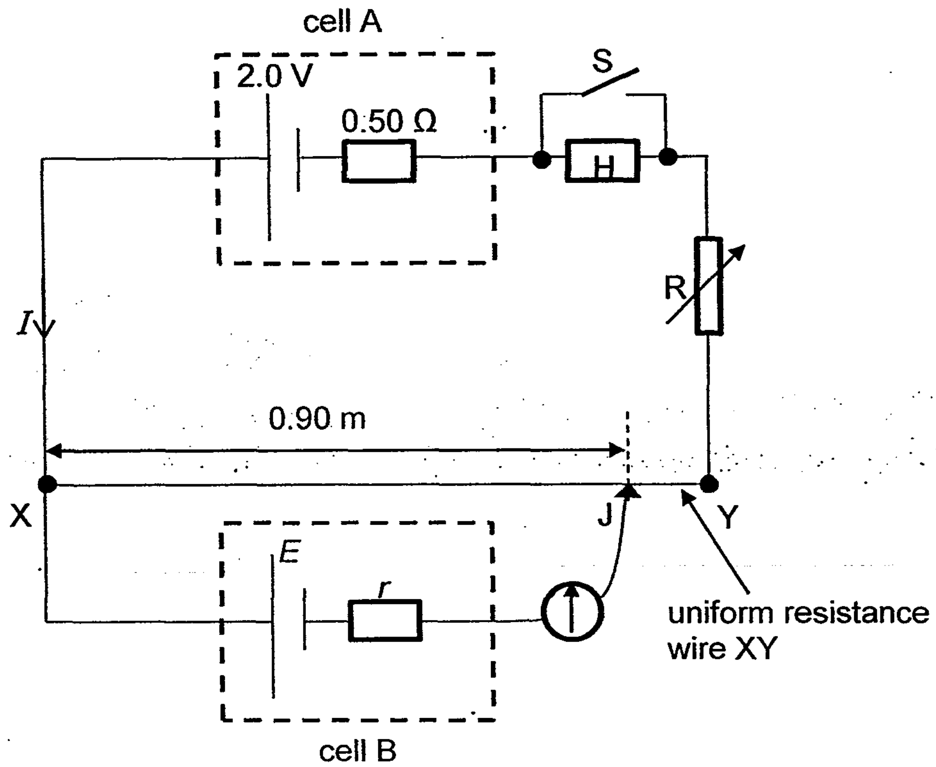


Fig. 4.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. When switch S is closed, the current through cell A is *I*. Cell B has e.m.f. *E* and internal resistance *r*.

The current through cell B is made zero when the movable connection J is adjusted such that the length of XJ is 0.90 m. The variable resistor R has resistance 1.5 Ω while the fixed resistor H has resistance 1.0 Ω

(i) Determine the value of *E*.

E = ... V **[3]**

Solution

$2.0 = I \times (4.0 + 1.5 + 0.5)$ C1

$I = 0.333$ A (allow 2 s.f.)

$R = \frac{0.9}{1.0} \times 4 \; (= 3.6)$ M1

$E = IR = 0.333 \times 3.6 = 1.20$ V A1

(If factor of 0.9 not used, then 2/3 marks)

(ii) When switch S is opened, determine quantitatively if the balance length XJ exists for this setup no change in the values of cell B. **[2]**

With switch S opened, the potential difference across XY is now

$$V_{XY} = \frac{4.0}{4.0 + 0.5 + 1.5 + 1.0} \times 2 = 1.14 \text{ V}.$$

However the e.m.f. of cell B is 1.20 V (remains constant) which is larger than the potential difference across XY.

B1

Thus it would not be possible to determine the balance length XJ.

5 Fig. 5.1 shows a simplified circuit diagram of the apparatus used in an experiment involving a photocell and a copper resistance wire XY to demonstrate the photoelectric effect. Scientists were particularly interested in 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.

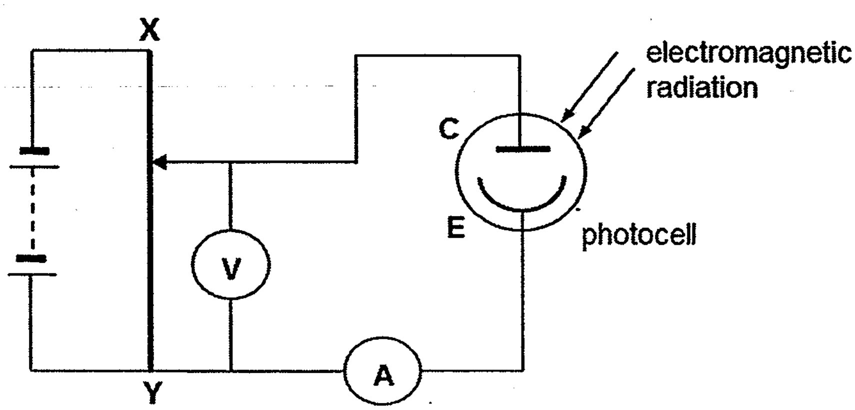


Fig. 5.1

(a) State what is meant by the *photoelectric effect*. **[1]**

Solution

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. **B1**

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

$$E = \Phi + E_K$$

State the quantity represented 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**

(c) 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. 5.2.

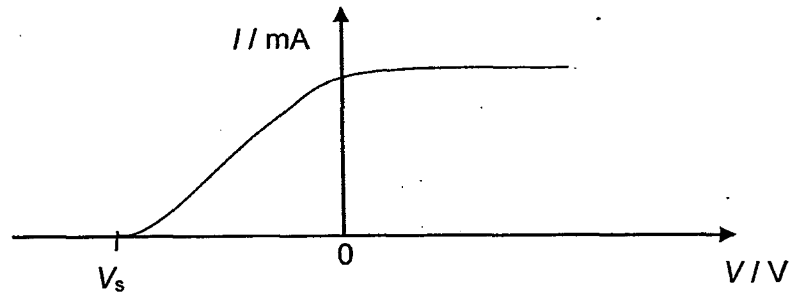


Fig. 5.2

(i) Explain

1. why there is a current registered in the ammeter even though the applied voltage across plates E and C 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 in the current despite an increasing positive applied voltage when 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. 5.2 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 Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 6.1 have been used since 1870, particularly for pumping water on farms.

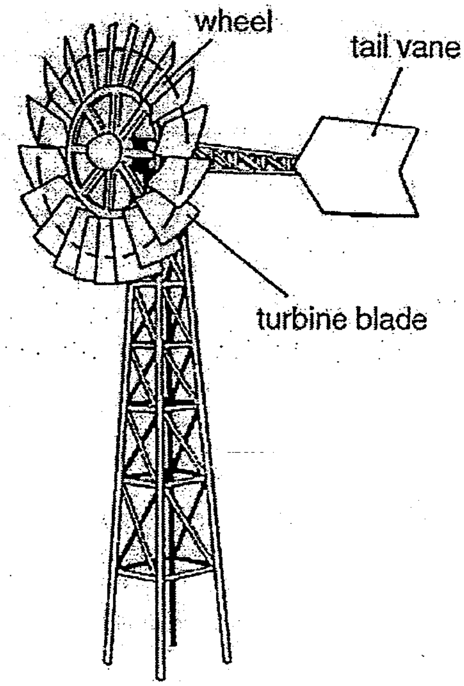


Fig. 6.1

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. 6.2 shows the variation of P, the output power of windmills similar to that shown in Fig. 6.1 with the diameter of the wheel for different wind speeds, v.

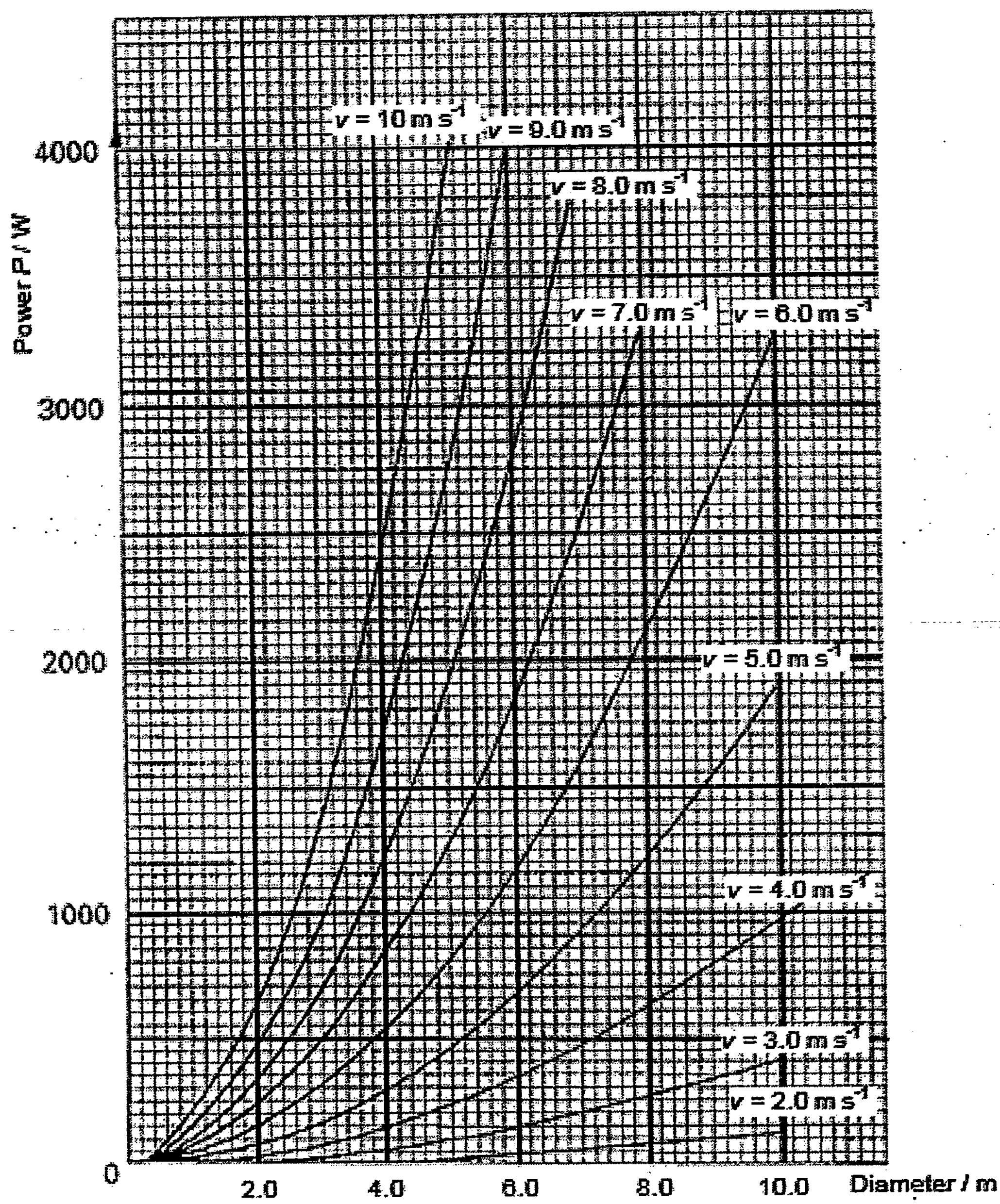


Fig. 6.2

(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. 6.2 to determine lg (P / W) 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. 6.3.

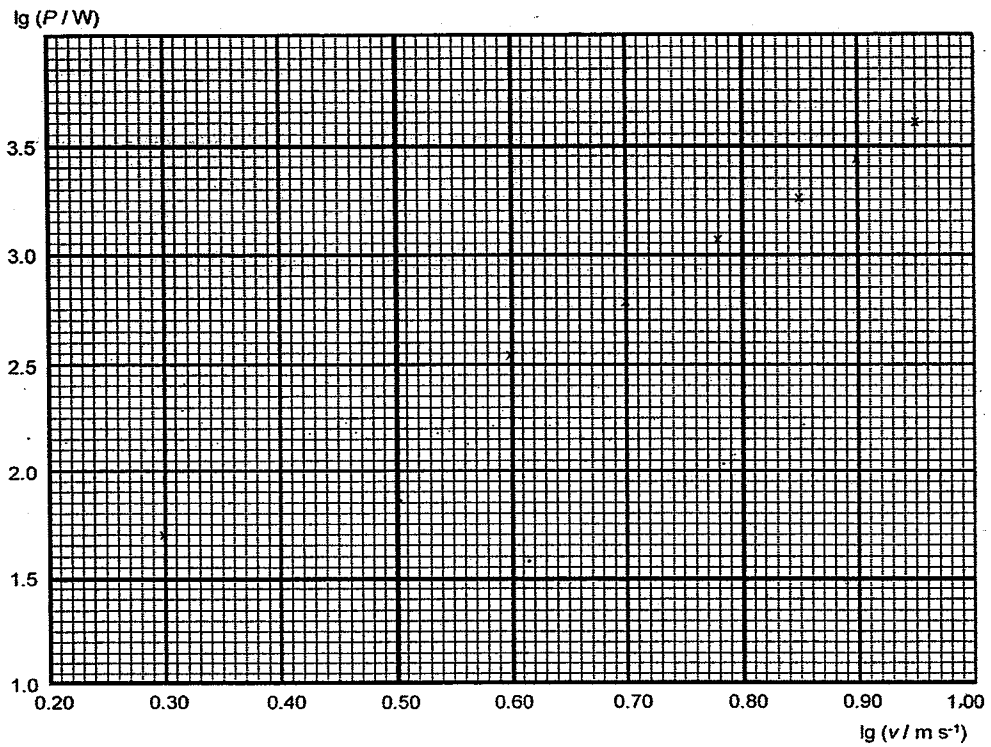


Fig 6.3

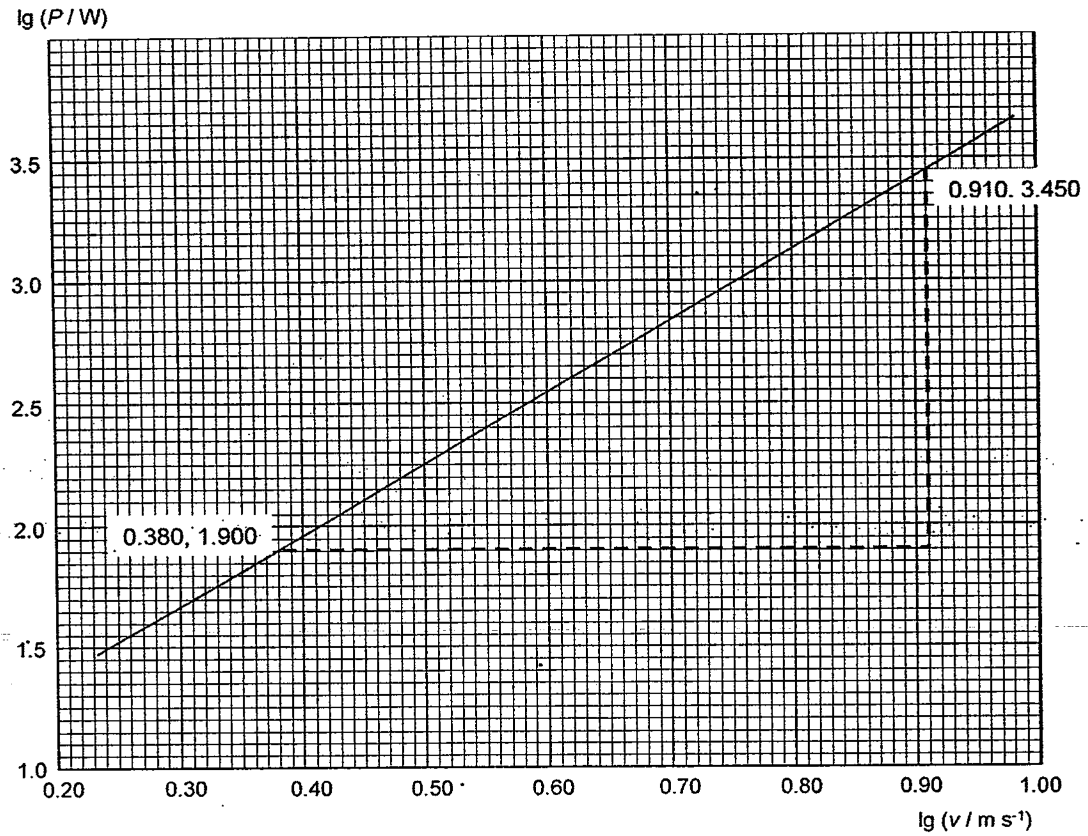
On Fig. 6.3,

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 a cylindrical volume, **M1**

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

$$\frac{\text{volume}}{\text{time}} = \pi r^2 v$$ **A1**

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

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

(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**

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

$$= 9409.92 = 9400 \text{ J}$$ **A1**

(iii) Use Fig. 6.2 to find the fraction of the power from the moving air in **(b)(ii)** that is converted into useful power.

fraction of power = ... **[2]**

Solution:

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. 6.2, at v = 8.0 m s^{-1}, diameter = 6.0 m,
Actual useful power output, P = 2750 W **M1**

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.

- Surface area of the blade.
- Friction between the wheel and the axle.

7 Gamma ray (γ-ray) is a type of ionising radiation. The absorption of γ-ray as it passes through a metallic material increases as the thickness of the material increases. The count rate of the γ-ray, *C*, penetrating through a material depends on the thickness *d* of the material.

You are provided with a Cobalt-60 source, a Geiger-Müller Tube connected to a datalogger that measures the total number of counts in a fixed time period and a number of lead slabs of standard business card size to act as absorbers of γ-rays. Cobalt-60 is a radioactive source that emits both β rays and γ-rays at the same time. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between *C* and *d*.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay special attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the relationship between *C* and *d* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment. **[12]**

Solution:

1. Defining the Problem

Criteria:

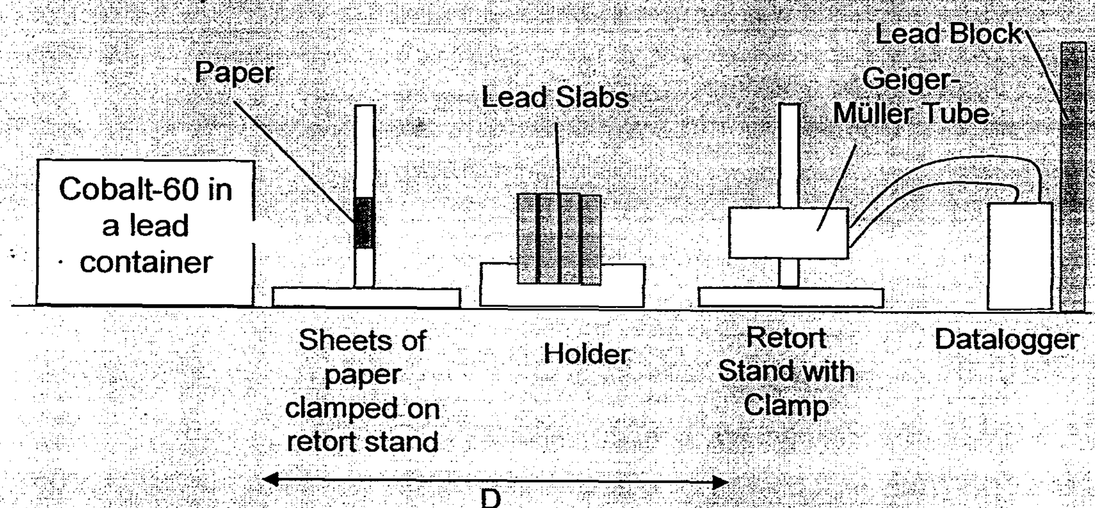
a) Identification of 1 IV, 1 DV and at least 2 CVs.
b) All IV, DV and CVs are physical quantities
c) Variables are specific and clear

IV: Thickness of lead slabs, *d*

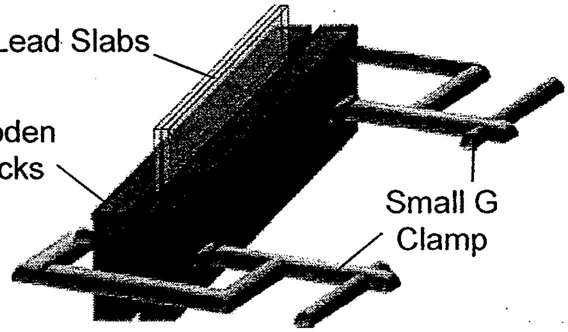
DV: Count rate of γ-rays after passing through the leab slabs, *C*

CVs: Distance between source and Geiger-Müller Tube, initial Activity / Count Rate of Cobalt-60 source

2. Diagram



More detail on the lead slab with holder,



3. Procedures

1. Set up the apparatus as shown in the diagram, first without the lead slabs. Measure the length between the Cobalt-60 source and the Geiger-Müller (GM) tube with a metre rule D = 30 cm. Secure the GM tube on a retort stand so as to keep D constant throughout the experiment.
2. The **count rate at the GM tube location can be determined by using the GM tube connected to the datalogger**. Switch on the GM tube connected to a datalogger for **1 min** to measure the number of counts shown on the datalogger. **Use a stopwatch to measure the time taken**. Reset the number of count and measure the counts for 1 min again**. Calculate the average counts and take the average total number of counts divided by 60 s to get the average count rate as measured by the GM tube.**
3. Perform step 2 with the Cobalt-60 source in the lead container. Record the count rate as C_{Cobalt}. **Place a few sheets of paper** in between the Cobalt-60 source and the GM tube and repeat step 2. There should be a decrease in the count rate as the β-ray is blocked by the sheets of paper. **Increase the number of sheet of paper until the point where an additional sheet of paper does not decrease the count rate.** At this point, only γ-rays from the source reaches the GM tube.
4. Remove the Cobalt-60 source from the lead container and repeat step 2. Record this count rate as the **background count rate**, $C_{background}$.
5. Insert the Cobalt-60 source and repeat step 2 to measure the initial count rate of the Cobalt-60 γ-rays together with the background count rate. Minus the $C_{Background}$ from the count rate obtained to get the initial count rate of the Cobalt-60 γ-rays $C_{initial}$. The paper is still placed after the source to block out the β rays.
6. Measure the **thickness of 5 lead slabs using a Vernier Caliper/micrometer screw gauge**. Measure the thickness at least 3 times at different parts of the lead slab and take the **average thickness of the 5 slabs**. Record the thickness of the lead slabs as *d*.
7. Place the 5 lead slabs in between the Cobalt-60 source and the GM tube. Perform step 2. Minus the count rate obtained in this way with the background count rate, $C_{background}$ to obtain *C*.
8. Repeat step 7 to obtain a second reading for 5 lead slabs so as to get an average reading for *C*.
9. Repeat step 6 to 7 by **increasing the number of lead slabs**, 2 at each time, until **at least 6 sets of readings** for thickness *d* and count rate *C* are obtained.
10. Assume that the relationship between *C* and *d* is given by,

$$C = C_{initial} e^{-kd}$$

where *k* is a constant. Therefore,

$$\ln C = \ln C_{initial} - kd$$

11. **Plot a graph of ln *C* against *d*. A straight line graph with negative gradient −*k* and vertical intercept ln $C_{initial}$ is expected**

4. Additional Details

- Account for background radiation count rate using the method described in step 2 of

- Conduct a preliminary experiment to determine a suitable range of values. It is to ascertain whether a distance of 30 cm would be able to get sensible reading. Furthermore, using 5 lead slabs at the start is arbitrary. A preliminary experiment can determine the range for the number of lead slabs used so that at least 6 sets of readings can be obtained.
- Use the same Cobalt-60 source for all sets of readings so as to keep constant the initial activity/count rate.
- After step 9, remove the lead slabs and perform step 2, to check that the initial count rate remains constant. Change to a new source if it is not at the same count rate and repeat the whole experiment.
- Before the start of the experiment, use a laser to align the apparatus first before using Cobalt-60 as the source.

5. Safety

Any action plan to account for the safety of the experimenter and the people around during the experiment. Any one, but not limited to, the following:

a) Handle the radioactive Cobalt-60 source with tweezers and gloves to prevent direct contact with the radioactive source and prevent it from entering the body.
b) Place the Cobalt-60 source in a lead container at all times to prevent unnecessary exposure to ionizing radiation.
c) Have warning signs around the experiment set up to prevent anyone from coming in contact with the radioactive source or coming into the path of the β-rays and γ-rays radiation.
d) Place a large thick lead slab after the GM tube to absorb the stray β-rays and γ-rays in the direction such that there is no leaking of radiation out of the set up.

(The above plan is a sample plan. The marking criteria is shown on the column on the right.)