H

NANYANG JUNIOR COLLEGE
Science Department

JC 2 PRELIMINARY EXAMINATION

Higher 2

Candidate Name	
Class	
Tutor Name	

PHYSICS 9646/02

Paper 2 Structured Questions **24 September 2013**

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and tutor name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **20** printed pages

Nanyang Junior College

Data

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

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^2 - x^2\right)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	α	exp(-2kd)
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

For Examiner's Use

1 **(a)** State the relation between force and momentum.

Force is proportional (or equal) to the rate of change of momentum [B1]. [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 1.1.

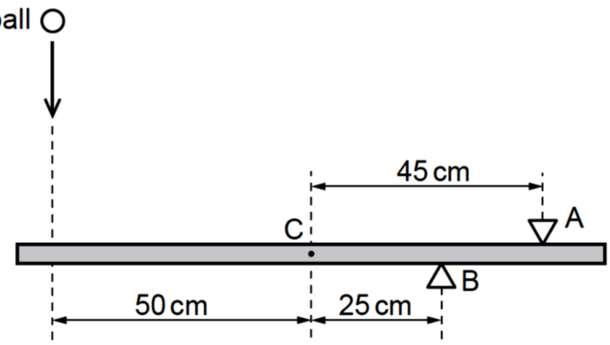

Fig. 1.1

The support A is 45 cm from the centre of gravity C of the bar and the support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 1.1. The variation with time of the velocity of the ball before, during and after hitting the bar is shown in Fig. 1.2.

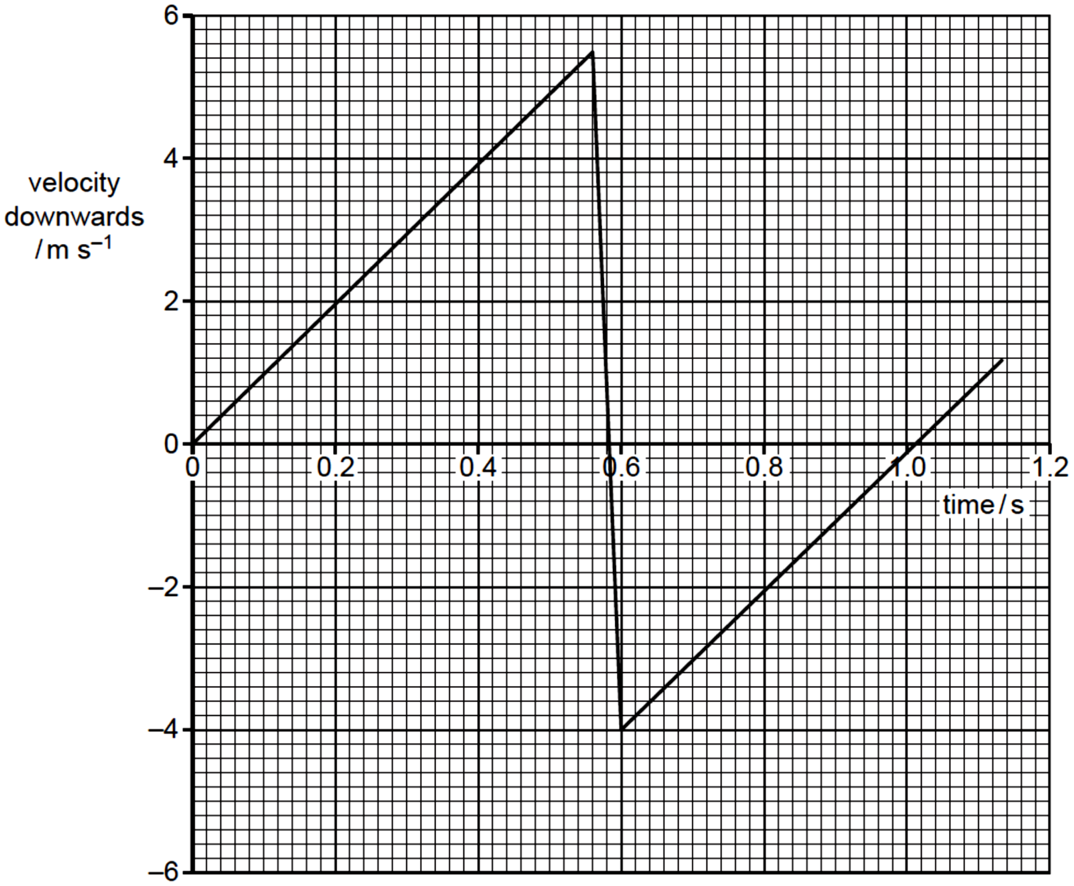

Fig. 1.2

For Examiner's Use

For the time that the ball is in contact with the bar, use Fig. 1.2 to determine

(i) the magnitude of the change in momentum of the ball,

$\Delta p = 140 \times 10^{-3} [5.4 - (-4.0)]$ [M1]
$= 1.32 \text{ kg m s}^{-1}$ [A1]

change in momentum = ... kg m s^{-1} [2]

(ii) the magnitude of the force exerted by the ball on the bar.

Resultant $F_{ball} = F_{bar\ on\ ball} - W_{Ball}$

$\frac{\Delta p_{ball}}{t} = F_{bar\ on\ ball} - W_{Ball}$ [B1]

$\frac{1.32}{0.04} = F_{bar\ on\ ball} - (140 \times 10^{-3})(9.81)$

$F_{bar\ on\ ball} = \frac{1.32}{0.04} + (140 \times 10^{-3})(9.81) = 34 \text{ N}$ [A1]

Examiner's Comments:
Most candidates failed to realise that the change in momentum of the ball is only due to the resultant force on the ball, which is not solely the $F_{bar\ on\ ball}$.

force by ball = ... N [2]

(c) Hence, calculate the magnitude of the force exerted on the bar by support A for the time that the ball is in contact with the bar.

Taking moments about B,

$34(0.50 + 0.25) + 0.450(9.81)(0.25) = F_A(0.45 - 0.25)$ [M1]

$F_A = 133 \text{ N}$ [A1]

Examiner's Comments:
Some candidates failed to calculate the weight of the bar, using only the mass of the bar instead.

force by support A = ... N [2]

For Examiner's Use

2 An unpowered artificial satellite of mass m has been placed in a stable orbit around the Sun in the same direction as that of the Earth. It is at a distance of $0.99R$ from the Sun, where R is the orbital radius of the Earth as shown in Fig. 2.1.

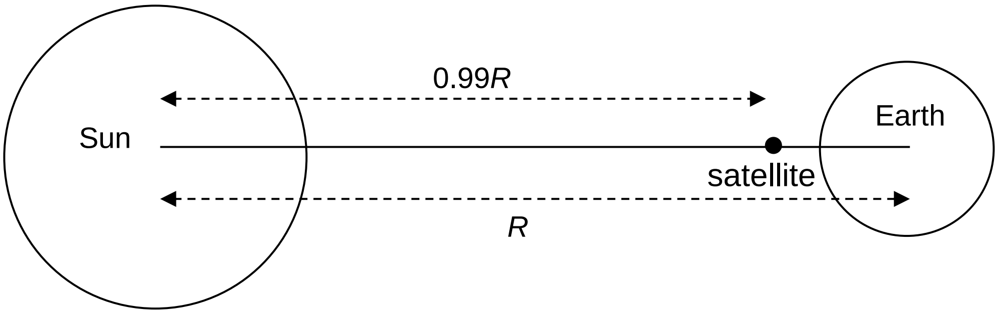

Fig. 2.1

(a) Ignore the very small force the satellite acts on the Earth. Show that the period of the Earth round the Sun T_E is given by

$$T_E = \sqrt{\frac{4\pi^2}{GM_S}}R^{3/2}$$

where M_S is the mass of the Sun.

The gravitational force of the Sun on the Earth accelerates it towards the centre of the circular motion.

$\Sigma F = ma$

$$\frac{GM_S M_E}{R^2} = M_E R\left(\frac{2\pi}{T_E}\right)^2$$

$$\frac{GM_S}{R^2} = R\left(\frac{2\pi}{T_E}\right)^2$$

$$T_E = \sqrt{\frac{4\pi^2}{GM_S}}R^{3/2}$$

Examiner's Comments:

Most candidates did the proof correctly. But the presentations show that many students learned the solution by heart from somewhere. The standard answer given started like this:

$F_g = F_c$

$mr\omega^2 = GM_sM_E/R^2$.

I suppose what they mean is the gravitational force provides the centripetal force. I would like to emphasise that there is no centripetal force. It is better to say the gravitational force accelerates the Earth towards the Sun. Then, by Newton's 2nd law,

$\Sigma F = ma$

$GM_sM_E/R^2 = mr\omega^2$

For Examiner's Use

Bear in mind that, it is a force that produces the acceleration, not an acceleration produces a force!

[2]

(b) Show that the resultant force on the satellite is given by $0.99\frac{GM_Sm}{R^2}$, given that the mass of the Sun is 3.33 x 10^5 times the mass of Earth.

$$\Sigma F = \frac{GM_Sm}{(0.99R)^2} - \frac{GM_Em}{(0.01R)^2} = 1.02\frac{GM_Sm}{R^2} - 10000\frac{G(\frac{M_S}{3.33x10^5})m}{R^2}$$

$$= 1.02\frac{GM_Sm}{R^2} - 0.03\frac{GM_Sm}{R^2} = 0.99\frac{GM_Sm}{R^2}$$

Examiner's Comments:

The steady and patient candidates got this one correct. Only a few messed up the working and still put in the final answer, tried to pass off fake products as genuine. A few of them put in ΣF = 0, and then equate the force on the satellite by the Sun and that by the Earth. That means they do not know the net force cannot not be zero because the satellite is doing a circular motion.

[2]

(c) Hence determine the period of the satellite round the Sun in terms of the period of the Earth T_E.

$$0.99\frac{GM_Sm}{R^2} = m(0.99R)(\frac{2\pi}{T})^2$$

$$\frac{GM_S}{R^2} = R(\frac{2\pi}{T})^2$$

$$T = \sqrt{\frac{4\pi^2}{GM_S}R^2} = T_E$$

Examiner's Comments:

More than half of the candidates got this one right. The rest used R as the radius of the circular motion instead of 0.99R for the satellite. A few were not aware that the resultant force on the satellite was already proved in part (b).

Period of satellite = ... [2]

For Examiner's Use

(d) 'Since the satellite is going round the Sun in a stable orbit, it is in stable equilibrium.' Comment on the statement.

The satellite is not in equilibrium because it has centripetal acceleration. Hence the resultant force is not zero. [1]

Examiner's Comments:

1. A few students thought that it is in equilibrium though they have proved that the net force in (c) which is not zero.
2. Many produced 'standard answer' from somewhere: 'there is still a gravitational force' from the Sun, but the key words 'resultant force or acceleration is not zero' did not occur.
3. Few said there is other celestial body around.
4. Many said it is in translational equilibrium and not in rotational equilibrium because it is in circular motion. They obviously not knowing that an object is in rotational equilibrium as far as it is not rotating faster and faster or slower and slower. i.e. no rotational acceleration.
5. Some said that it is not at rest, therefore it is not in equilibrium. They should bear in mind, an object is in translational equilibrium if it is not accelerating. If it is not accelerating and not moving, then it is in static equilibrium.
6. Some candidates focused on the word stable instead of equilibrium. Actually there are three types of equilibrium: unstable equilibrium, stable equilibrium and neutral equilibrium.

3 (a) State the *principle of superposition*.

When two or more waves meet at a point, the resultant displacement is the vector sum of the displacements of the separate waves. [1]

.... [1]

Examiner's Comments :

Common mistakes include using amplitude instead of displacement, stating the conditions to set up stationary waves (i.e. waves travelling in opposite directions).

(b) Figure 3.1 shows a double slit S_1 and S_2 emitting waves of amplitude *A* and of wavelength 590 nm. They are placed 0.800 mm apart and at a distance of 2.70 m from a line XY. Point O is in the center of the fringe pattern. Two polarizers P_1 and P_2 are placed in front of S_1 and S_2 respectively. The polarizers are rotated such that a fringe pattern is observed along the line XY.

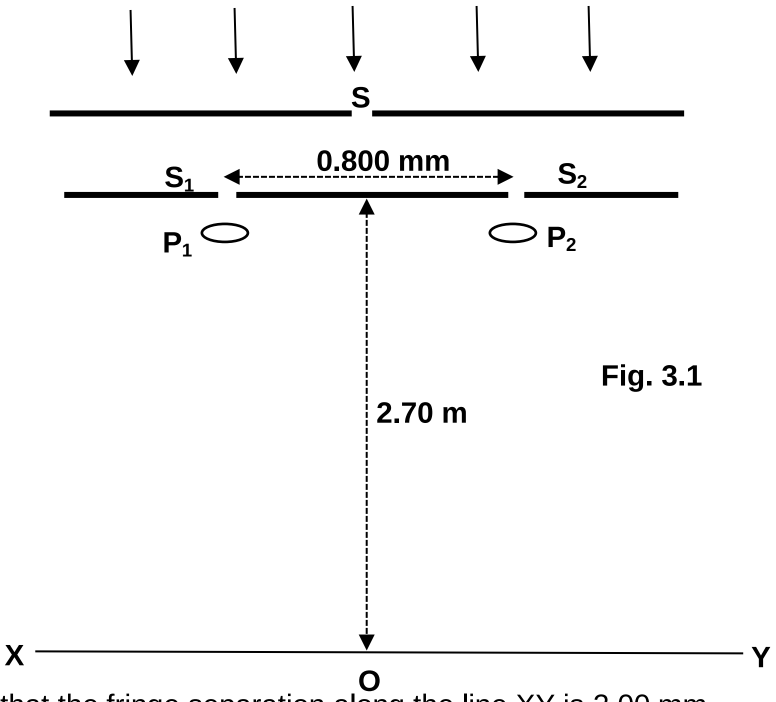

Fig. 3.1

(i) Show that the fringe separation along the line XY is 2.00 mm.

$\Delta x = \lambda D/a = 590 \times 10^{-9} \times 2.70 / 0.800 \times 10^{-3} = 2.00$ mm [1]

[1]

(ii) On Fig. 3.2, ignoring diffraction effects, sketch the variation of intensity along the line XY. Label your values clearly on the axes. [2]

intensity

Shape : square of sinusoidal with maximum centered at O mark [1]

Values : maxima occur at 2 mm & 4 mm/minimum occur at 1 mm & 3 mm. [1]

Intensity at corresponding maxima is the same; ie both n = 1 has same intensity. [1]

Max marks is 2 marks

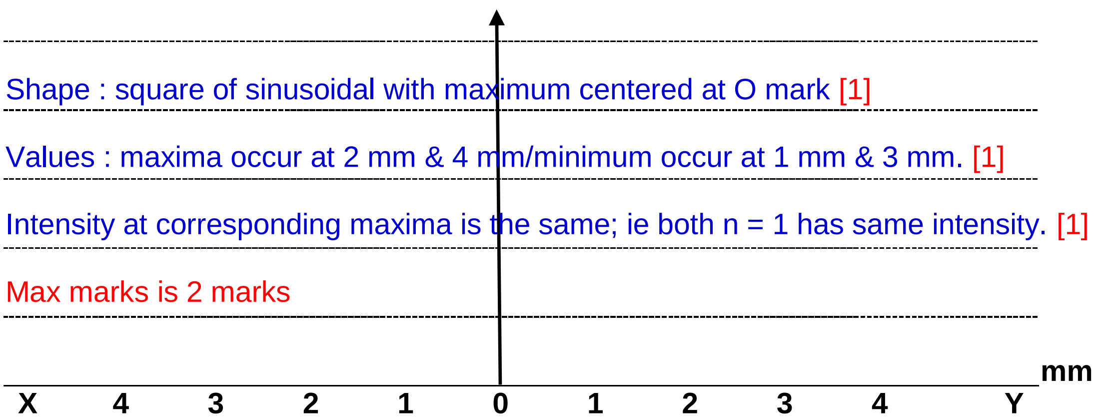

Fig. 3.2

For Examiner's Use

(c) The polarizer P_1 is rotated 90^o along its plane.

(i) Calculate the resultant amplitude at point O on the line XY in terms of *A*.

Point O is a where the waves meet in phase with vector addition of crest & creat perpendicular to one another.

Resultant amplitude = $\sqrt{2}$A [1]

amplitude = …………… [1]

(ii) Calculate the resultant amplitude at a point 1.00 mm from point O along the line XY in terms of *A*.

At 1 mm is where the waves meet out of phase with vector addition of crest & trough perpendicular to one another.

Resultant amplitude = $\sqrt{2}$A [1]

amplitude = …………… [1]

(iii) Describe the appearance of the fringe pattern.

The positions of CI & DI have the same intensity. [1]

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

4 An ideal transformer has 5000 turns on its primary coil. It is used to convert a main supply of root mean square value of 230 V to an alternating voltage having a peak value of 12.0 V.

(a) (i) Explain what is meant by *root mean square value of 230 V*.

The root mean square value of 230 V means that an equivalent value of 230 V of steady source of potential difference or e.m.f. dissipated the same amount of heat energy at the same rate as the alternating source for a given resistance. [2]

(ii) Calculate the number of turns on the secondary coil.

$$\frac{N_s}{N_p} = \frac{V'_{rms\,s}}{V_{rms\,p}}$$

$$\frac{N_s}{5000} = \frac{12/\sqrt{2}}{230}$$

$$N_s = 184$$

number of turns = ……………….. [2]

For Examiner's Use

(b) The secondary coil is connected in series with a resistor R. The variation with time *t*, in seconds, of the potential difference at the secondary coil is given by the expression

$$V = 12.0 \sin(380t)$$

(i) Determine the frequency of the supply.

$V = 12.0 \sin \omega t$

$\omega = 2\pi f = 380$

$f = 60.5$ Hz

frequency = ... Hz [1]

(ii) To prevent overheating, the mean power dissipated in R must not exceed 300W. Calculate the minimum resistance of R.

$$P_{max} = 300W = \frac{V_{rms}^2}{R} = \frac{V_o^2}{2R}$$

$$R = \frac{V_o^2}{2P_{max}}$$

$$R = \frac{12^2}{2 \times 300} = 0.24\Omega$$

resistance = ... Ω [2]

5 **(a)** A uniform magnetic field has constant flux density *B*. A straight wire of fixed length carries a current I at an angle θ to the magnetic field as shown in Fig. 5.1.

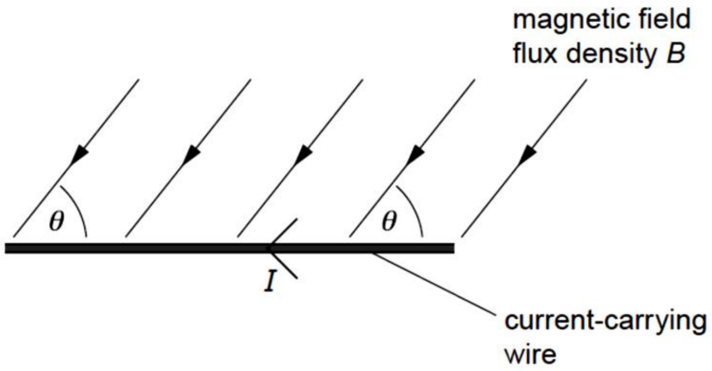

Fig. 5.1

(i) Define the term *magnetic flux density*.

It is the force per unit length experienced by a straight conductor carrying unit current when the conductor is placed at right angles to the magnetic field [B1] [1]

For Examiner's Use

(ii) The current I in the wire is changed, keeping the angle θ constant.

On Fig. 5.2, sketch a graph to show the variation with the current I of the force F on the wire. [1]

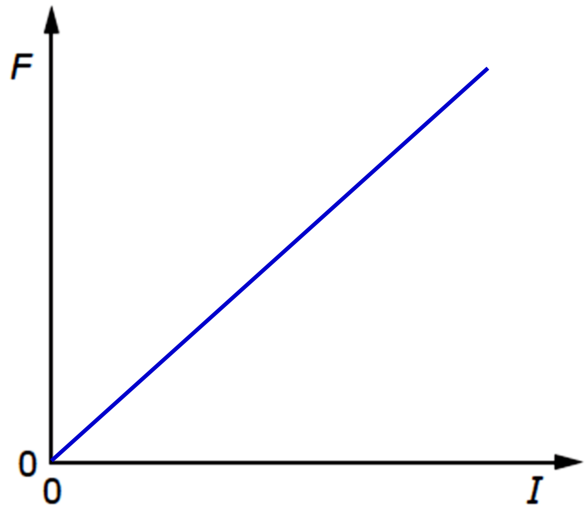

Fig. 5.2

(iii) The angle θ between the wire and the magnetic field is now varied. The current I is kept constant.

On Fig. 5.3, sketch a graph to show the variation with angle θ of the force F on the wire. [1]

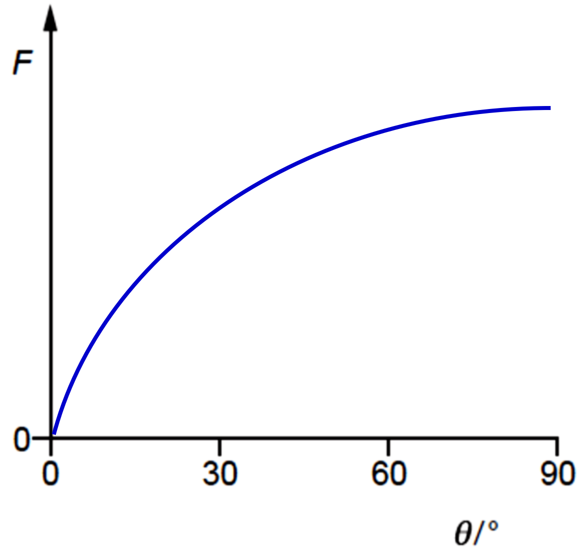

Fig. 5.3

For Examiner's Use

(b) Negative ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field of flux density B and are deflected in a semi-circular arc, as shown in Fig. 5.4.

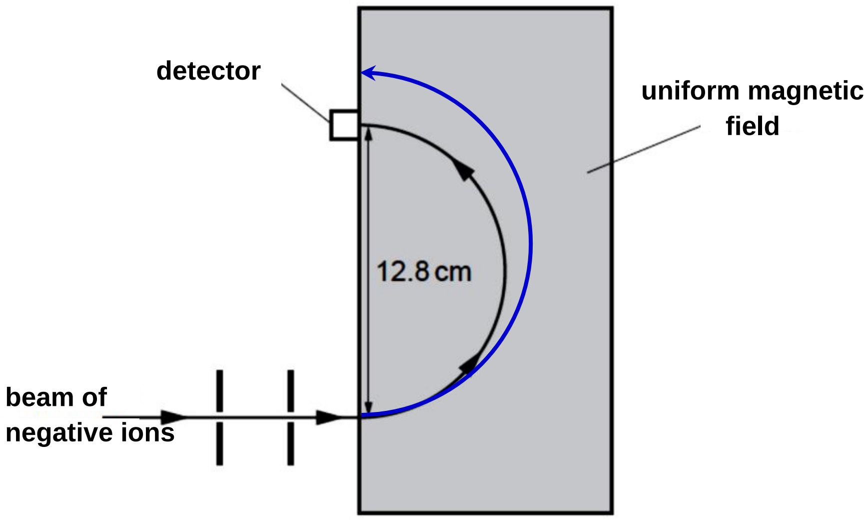

Fig. 5.4

The ions, travelling with speed 1.40×10^5 m s^{-1}, are detected at a fixed detector when the diameter of the arc in the magnetic field is 12.8 cm.

(i) By reference to Fig. 5.4, state the direction of the magnetic field.

Out of the plane of the paper [B1]. .... [1]

(ii) The ions have mass 20*u* and charge – 1.6 × 10^{-19} C. Show that the magnetic flux density is 0.454 T. Explain your working.

Since the magnetic force on the ions provide for its centripetal force [B1],

$$Bqv = \frac{mv^2}{r}$$

$$B = \frac{mv}{qr}$$

$$= \frac{(20 \times 1.66 \times 10^{-27})(1.40 \times 10^5)}{(1.6 \times 10^{-19})\left(\frac{12.8 \times 10^{-2}}{2}\right)}$$

$$= 0.454 \text{ T}$$

[2]

(iii) Ions of a larger mass with the same charge and speed as those in **(b)(ii)** are also present in the beam. On Fig. 5.4, sketch the path of these ions in the magnetic field of magnetic flux density 0.454 T. [1]

6 Fig. 6.1 shows a simple circuit. The resistance of the lamp is 20 Ω and it requires a minimum of 60 V to light up.

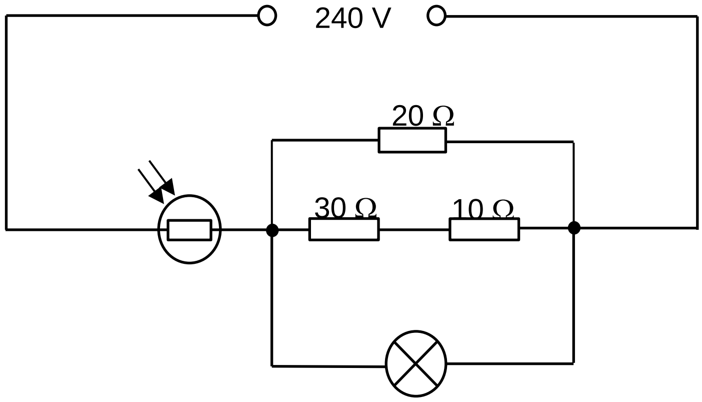

Fig. 6.1

Fig. 6.2 shows how the current I through the light dependent resistor varies with the potential difference V across it when different intensities of light fall onto it.

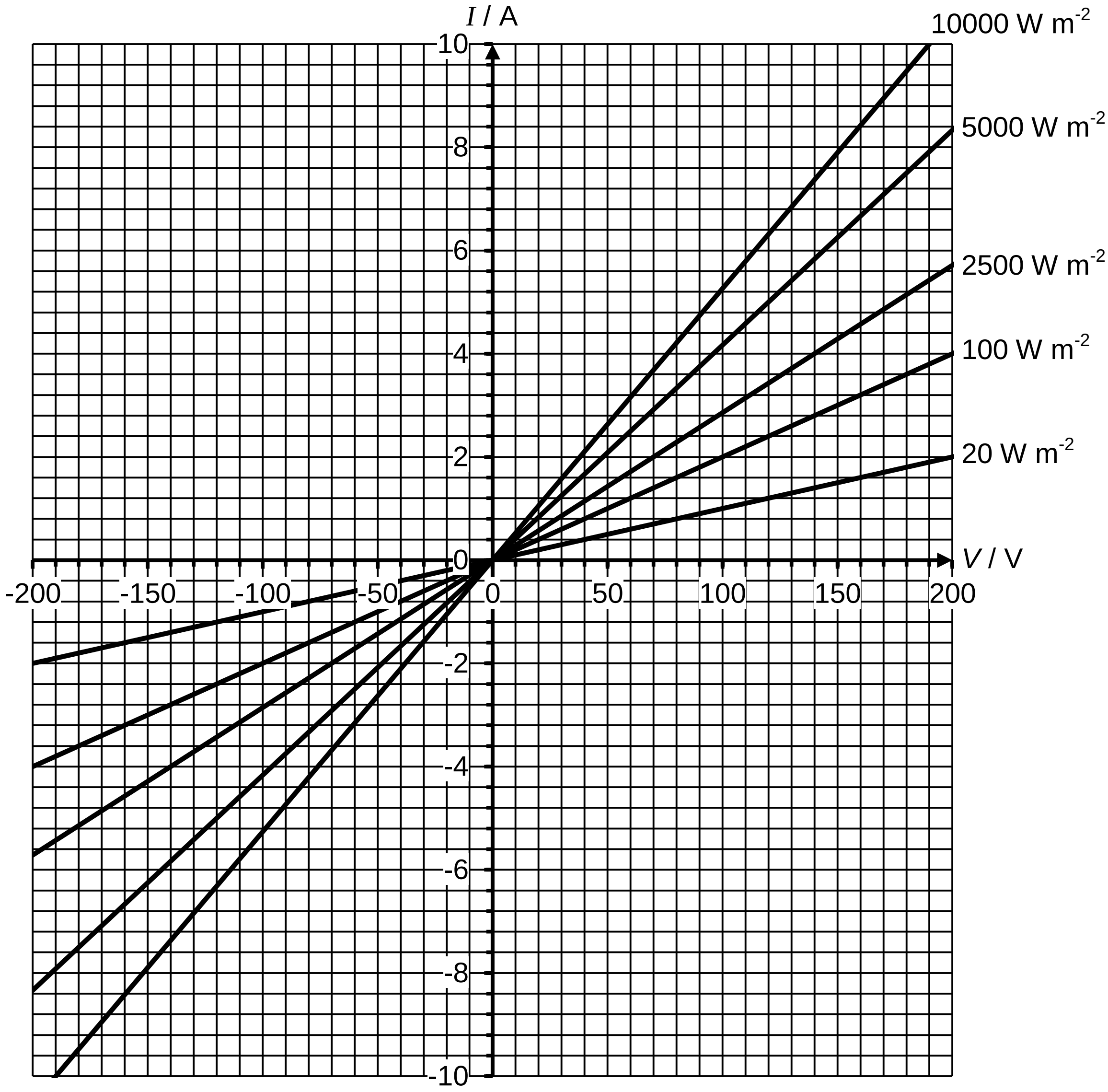

Fig. 6.2

For Examiner's Use

For Examiner's Use

(a) Calculate the current through the 30 Ω resistor when the potential difference across the lamp is 40 V.

$$I = \frac{V}{R}$$

$$= \frac{40}{30+10}$$

$$= 1.0 \text{ A}$$

[1] – using 40 Ω

[1] – correct numerical answer

current = ... A [2]

(b) Explain how the above circuit can be used as a warning system for an environment which requires low intensity light.

If the intensity of the light in the environment is high, the resistance of the light dependent resistor will be low. This will cause the potential difference across the lamp to be more than 50 V [1], causing the lamp to light up [1], indicating that the intensity of the light in the environment is high. [2]

For Examiner's Use

(c) Using Fig. 6.2, determine the intensity of light which will produce a potential difference of 60 V across the lamp.

$$\text{Total resistance of parallel arrangement } = (\frac{1}{40} + \frac{1}{20} + \frac{1}{20})^{-1}$$
$$= 8\ \Omega \quad [1]$$

$$\text{Resistance of L.D.R: } \frac{8}{8+R} \times 240 = 60$$
$$R = 24\ \Omega \quad [1]$$

From the graph, the graph which shows a resistance of 24 □ is the one with an intensity of 5000 W m^{-2}. [1]

OR

If the p.d across the lamp is 60 V, the p.d. across the L.D.R will be 240 – 60 = 180 V. If we have the current flowing through the L.D.R when its p.d. is 180 V, we can look for the point on Fig. 6.2 and determine which graph and which ntensity.

$$\text{Total resistance of parallel arrangement } = (\frac{1}{40} + \frac{1}{20} + \frac{1}{20})^{-1}$$
$$= 8\ \Omega \quad [1]$$

$$\text{Current flowing through the L.D.R: } I = \frac{60}{8} = 7.5 \text{ A} \quad [1]$$

From the graph, the graph which shows a current of 7.5 A at 180 V is the one with an intensity of 5000 W m^{-2}. [1]

intensity = ……………………….. W m^{-2} [3]

For Examiner's Use

7 Wind power can be used for the generation of electric power. Fig 7.1 and Fig 7.2 illustrate a particular type of wind turbine.

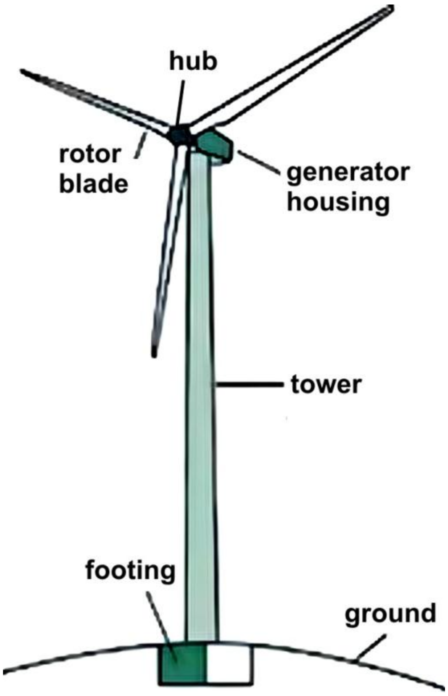

Fig 7.1

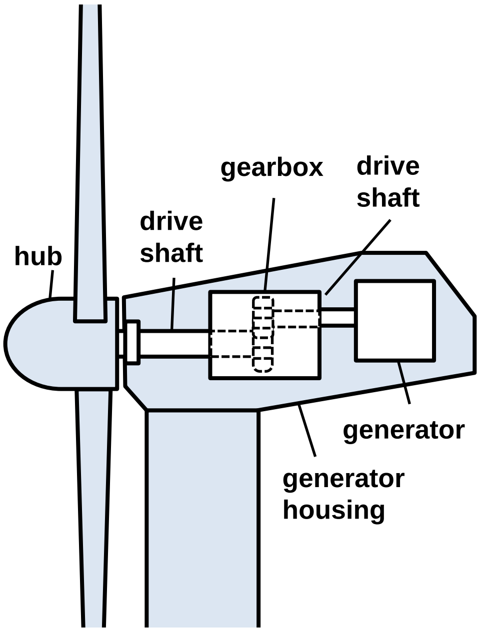

Fig 7.2

Table 7.3 shows some information provided by the manufacturer.

Table 7.3

Height of tower (ground to hub)	80	m
Blade length	45	m
Number of blades	3	
Rated power	3	MW
Voltage	650	V
Frequency	50	Hz

Fig 7.4 shows the wind turbine power curve provided by the manufacturer.

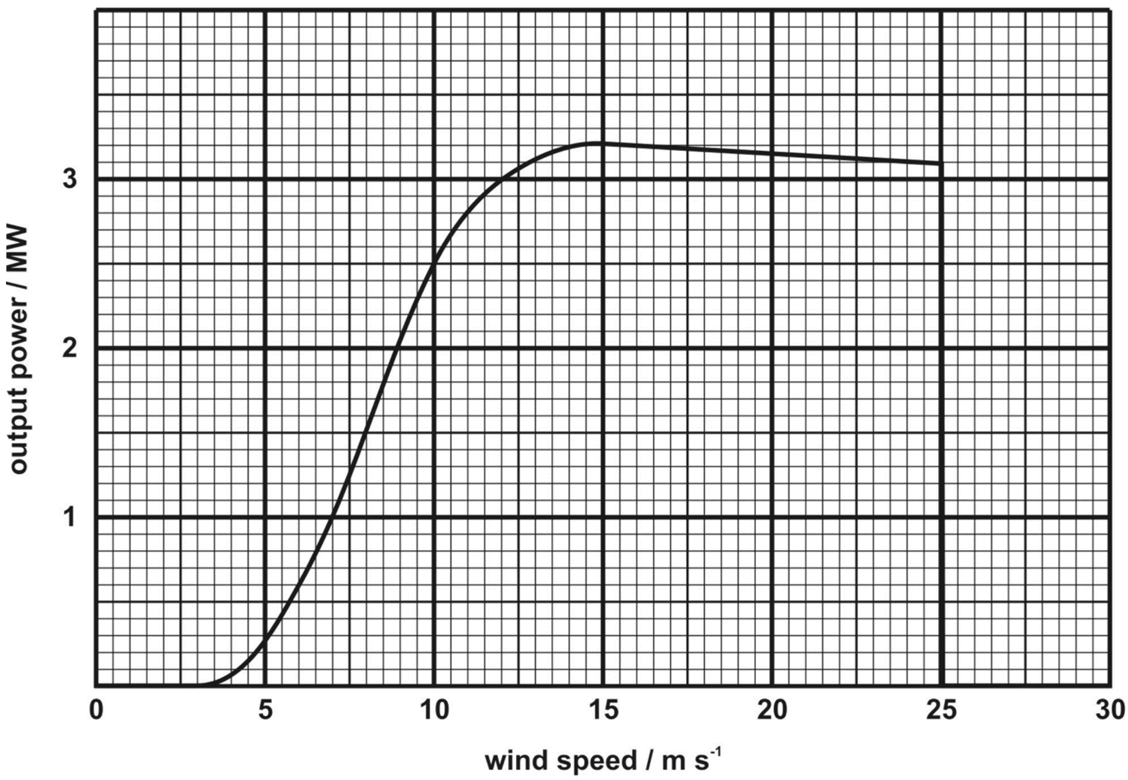

Fig 7.4

(a) Using the information provided in Table 7.3, calculate

(i) the height of the lowest point of the rotor above the ground,

Height = 80 – 45 = 35 m

height = …………………… m [1]

(ii) the area swept by the rotor blades

Sweep area = $\pi \times 45^2 = 6.36\times10^3$ m^2

area = …………………… m^2 [1]

(iii) the period of revolution of the rotor when the wind speed is 10 m s^{-1}, given that the ratio of the speed of the blade tip to the wind speed is 7.

Blade tip speed = 7 × 10 = 70 m s^{-1}

Period = $\pi \times (2 \times 45) / 70 = 4.0$ s

period = …………………… s [2]

For Examiner's Use

(b) (i) Discuss, with reasons, if the rated power of 3 MW is a fair value.

The turbine is able to produce more than the rated power for wind speeds between 12 m s^{-1} and 25 m s^{-1}.

For sites with wind speeds averaging above 12 m s^{-1}, the rated power will be a fair value.

.... [2]

(ii) The average monthly electrical energy consumption per household in Singapore is 470 kW h. Calculate the number of homes one wind turbine can serve when operating at the rated power.

Power consumption per household = 470 ÷ (30 × 24)

= 0.65 kW

No of homes = 3000 ÷ 0.65 = 4600

number of homes = ... [2]

(c) (i) Using the information provided in Fig 7.4, obtain values for

1. the maximum power output,

maximum power = 3.2 MW [1]

2. the wind speed for this power.

wind speed = 15 m s^{-1} [1]

(ii) The incident wind power *E*, which is the kinetic energy of the air incident on the rotor to turn the blades per unit time, is given by

$$E = k L^2 v^3$$

where *L* is the blade length of the turbine,
v is the incident wind speed, and
k is a constant of value 1.96 kg m^{-3}

Calculate, for the turbine operating at maximum output power, the incident wind power.

$E = 1.96 \times 45^2 \times 15^3$

$= 1.34 \times 10^7$ J s^{-1}

incident wind power = ... W [1]

For Examiner's Use

(iii) According to Betz' Law, which is derived from the principles of conservation of mass and momentum, the maximum amount of the incident wind kinetic energy that can be captured by a wind turbine is 59.3%.

Suggest one evidence that not all of the incident wind energy can be captured.

The wind will still be moving, albeit at a lower speed, after passing through the rotor. Thus it could not have lost all of its kinetic energy. ..... [1]

(iv) Calculate the efficiency of the wind turbine in converting the accessible kinetic energy to electrical energy when operating under the conditions stated in **(i)**.

Accessible wind power = $0.593 \times 1.34\times10^{7}$

$= 7.94\times10^{6}$ W

Efficiency = $3.2\times10^{6} / 7.94\times10^{6}$

= 40%

efficiency = ... % [2]

(d) The wind turbine, like most others, has a cut-out speed. This means that at high wind speeds, the gearbox disengages the generator from the rotor and the generator is no longer turned by the rotor.

(i) Use Fig 7.4 to determine the cut-out speed.

cut-out speed = ...25........ m s^{-1} [1]

(ii) Suggest one reason why it is necessary to have a cut-out speed.

To prevent the generator circuit from being overloaded / producing too much waste heat. ..... [1]

(e) Wind turbines are usually erected in wide open spaces. As such, they are vulnerable to (i) strong winds which may cause the rotor to rotate too fast and be damaged, and (ii) lightning which may strike the rotor, causing damage.

For each of the hazards mentioned, suggest how the risk of damage to the rotor may be minimized.

(i) Strong winds

✓ Install brakes to resist rotation.

✓ Turn the blades to face away from the wind. ..... [1]

(ii) Lightning

✓ Use poor electrical conductor such as fiberglass for blades.

✓ Install lightning rods taller than the turbine nearby. ..... [1]

For Examiner's Use

8. Fig. 8.1 shows a coil (coil X).

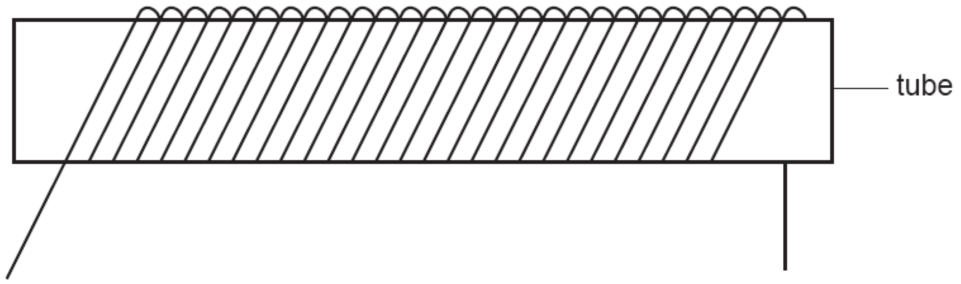

Fig. 8.1

A student winds another coil (coil Y) tightly around coil X.

A changing e.m.f. in coil X induces an e.m.f. in coil Y.

The student wishes to investigate how the e.m.f. *V* in coil Y depends on the frequency *f* of the current in coil X.

It is suggested that *V* is directly proportional to *f*.

Design a laboratory experiment to investigate the suggested relationship. You should draw a diagram, in the space provided below, showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,
(b) the measurements to be taken,
(c) the control of variables,
(d) the analysis of the data,
(e) the safety precautions to be taken.

For Examiner's Use

Method of data collection [5]
Methods/instruments to measure I.V. • Use c.r.o. to determine period/frequency or read off signal generator. **Methods/instruments to measure D.V.** • Coil Y connected to voltmeter/c.r.o. in a workable circuit. **Method to vary the I.V** • Method to keep current constant in coil X: adjust signal generator/use of rheostat. **Method to create the condition in order to measure the I.V. / D.V. may be required.** • Alternating power supply/signal generator connected to coil X in a workable circuit. **Correct positioning or connection of apparatus** • Two independent coils labelled X and Y.
Method of analysis [2]
• Plot a graph of V against f. • Relationship is valid if the graph is a <u>straight line passing through the origin</u>.
Additional detail (max 4)
Correct method to ensure C.V. constant/monitor C.V. 1) Keep the current in coil X constant and keep the number of turns on coil (Y)/area of coil Y constant **A list of specific steps taken to taken to further improve accuracy of results or good experimental practice.** 2) Use large current in coil X/large number of coils on coil Y (to increase emf). 3) Use iron core (to increase emf). 4) Detail on measuring emf e.g. height × y-gain. 5) Avoid other alternating magnetic fields. 6) Detail on measuring frequency from c.r.o. to determine period and hence f. 7) Use of ammeter/c.r.o. and resistor to check current is constant 8) Use insulated wire for coils. 9) Keep coil Y and coil X in the same relative positions.
Safety precautions [1]
• Reference to hot coils – switch off when not in use/use gloves/do not touch coils. Must refer to hot coils.