SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

NAME

CG **INDEX NO.**

PHYSICS 8866

Preliminary Examination **21st August 2014**
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

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.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about an hour on each section.

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

For Examiners' Use	
Q1	/ 6
Q2	/ 7
Q3	/ 7
Q4	/ 8
Q5	/ 12
Q6	/ 20
Q7	/ 20
Q8	/ 20
Total marks	/ 80

DATA AND FORMULAE

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}

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
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

For Examiner's Use

Section A

Answer **all** the questions in this section.

1 **(a)** A stone is thrown horizontally with a speed of 8.20 m s^{-1} from the top of a cliff into the sea. The path of the stone is shown in Fig 1.1.

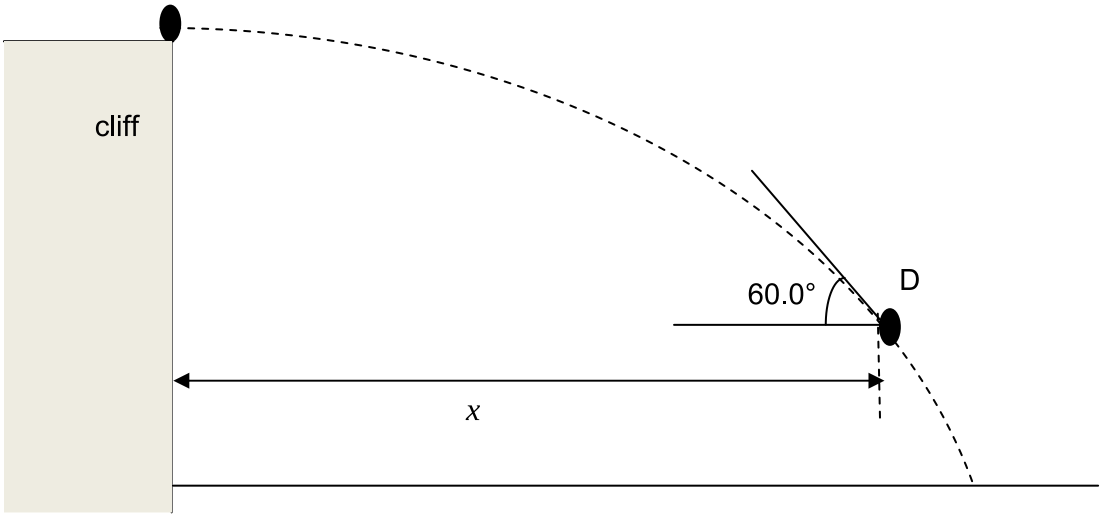


Fig. 1.1

At point D on the path of the stone, the stone is at a horizontal distance x from the cliff and is moving at an angle of 60.0° to the horizontal. Air resistance is negligible.

For the stone at point D,

(i) show that the vertical component of its velocity is 14.2 m s^{-1}. [1]

Horizontal component of velocity = 8.2 m s^{-1}

Vertical component of velocity = 8.2 tan 60° = 14.2 m s^{-1}

(ii) calculate the horizontal distance x.

Using v = u + at
Time of descent = 14.2 / 9.81 = 1.45 s

x = 1.45 x 8.2 = 11.9 m

x = ……..………..………. m [2]

(b) Another stone is thrown vertically downwards into the sea such that it enters the sea at a high speed.

(i) Describe the motion of the stone as it falls in the sea.

The rate of the stone slowing down its speed will decrease till it finally attains terminal velocity.

[2]

(ii) State for a similar stone of a heavier mass whether it will reach the same, higher or lower terminal velocity if it enters the sea with the same speed as the lighter stone.

It will reach a higher terminal velocity.

[1]

2 **(a)** As shown in Fig. 2.1, Block A of mass 2.5 kg is resting on a rough table. The static frictional force acting on Block A by the table is 5.0 N. Block B of mass 4.0 kg is attached to block A via an inelastic string which passes over a smooth pulley. The other end of block A is held by an inelastic string attached to a wall while the other end of block B is attached to a spring that is being compressed by 2.0 cm. The spring constant is 1000 N m^{-1}.

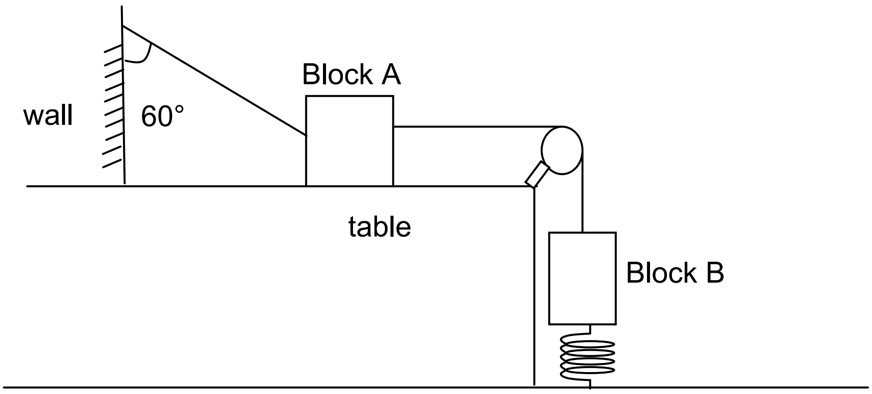
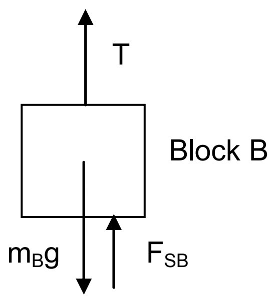


Fig 2.1

(i) Show that the tension in the string between block A and block B is 19.2 N. [1]



By considering the vertical forces acting on block B,

Since block B is in equilibrium,

$T + F_{SB} = m_B g$ (F_{SB} is the force by spring on block B)
$T = 4\ (9.81) – 1000\ (0.02) = 19.24$ N

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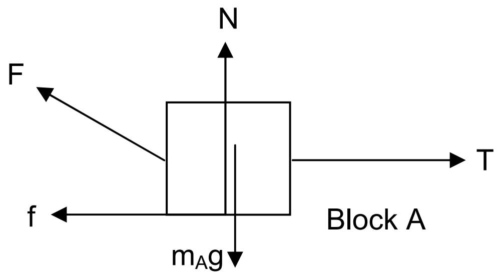
(ii) Hence or otherwise, calculate the normal contact force exerted by the table on block A.



By considering the horizontal forces acting on block A,

Since block A is in equilibrium,

Fcos30 + f = T
F = (19.24 – 5)/cos 30 = 16.44 N

By considering the vertical forces acting on block A,

Since block A is in equilibrium,

Fsin30 + N = m_Ag

N = 2.5 (9.81) – 16.44 sin30

= 16.3 N

normal force by table on block A = ……..…….….………N [3]

For Examiner's Use

(b) Object X of mass 8.0 kg is moving towards the right with a speed of 1.5 m s^{-1} while object Y of mass 10.0 kg is moving behind it in the same direction. The relative speed of approach between the objects is 1.0 m s^{-1}. At 1.5 s, object Y caught up with object X and both objects collide.

Fig 2.2 shows a graph of momentum against time for object X.

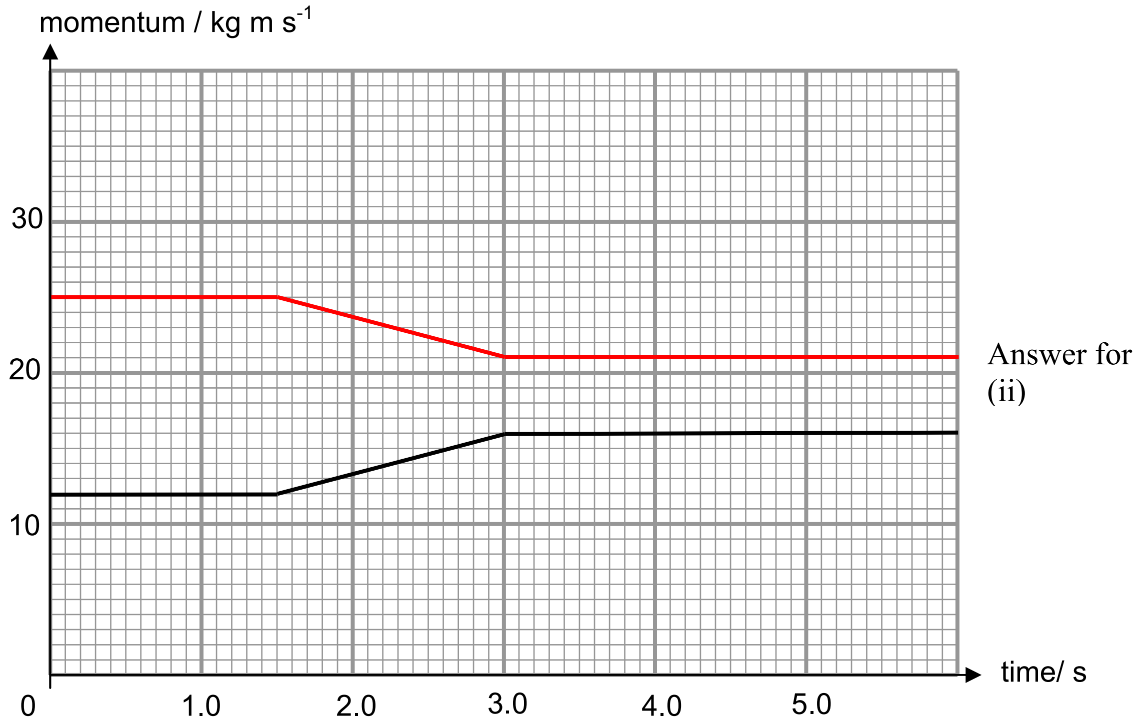


Fig 2.2

(i) Calculate the final momentum of object Y.

Since RSA = $u_1 - u_2$ = 1 m s^{-1} and that the speed of object Y must be more than X, the initial speed of Y is 2.5 m s^{-1}

By COLM,
$12 + (10)(2.5) = 16 + P_{fy}$
$P_{fy} = 21$ kg m s^{-1}

final momentum of object Y = ……..……….….……..kg m s^{-1} [2]

(ii) Draw the momentum against time graph for colliding object Y in Fig. 2.2. [1]

3 In Fig 3.1 below, a block of mass 2.0 kg is placed against a spring on a rough plane inclined at angle 35°. The block is held in position and it compresses the spring by x m. The spring has a spring constant of 1500 N m^{-1}.

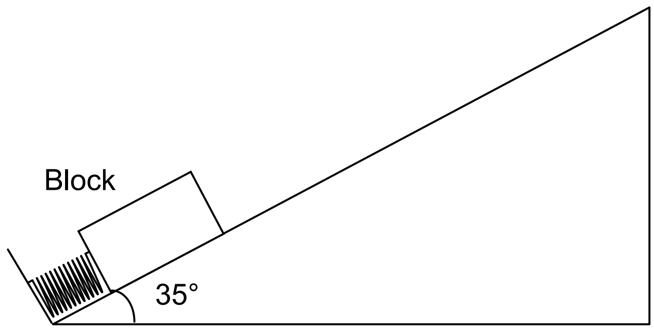


Fig 3.1

The block is then released. It moves upwards along the slope and after separating itself from the spring, it moves up by 0.50 m along the plane before coming to a momentary stop as shown in Fig. 3.2. The average frictional force experienced by the block as it moves up the plane is 2.0 N.

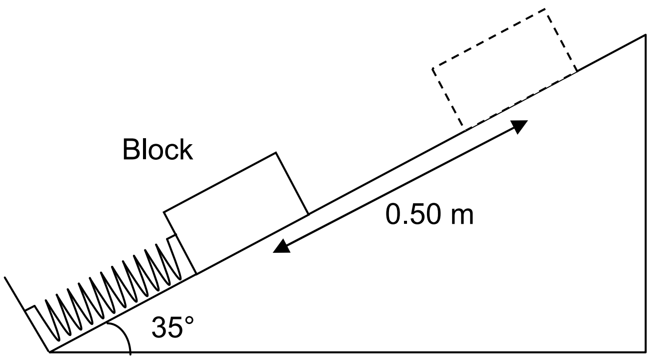


Fig 3.2

For Examiner's Use

(a) In terms of x, write down an expression for the work done by friction from the time the block is released until it comes to a momentary stop.

$WD_{by\ friction} = -2\ (x + 0.5) = -\ (2x + 1)$

work done by friction = ……..………..………J [1]

(b) Calculate the value of x.

By COE,

initial total energy = final total energy

$EPE = WD_{against\ friction} + GPE$

$\frac{1}{2}\ (1500)\ (x^2) = 2\ (x + 0.5) + 2\ (9.81)\ (x + 0.5) \sin 35°$
$750x^2 = 2x + 1 + 11.25\ x + 5.63$
$750x^2 = 13.25\ x + 6.63$

$x = 0.10$ or -0.09 (NA)

x = ……..……..………. m [2]

(c) In the graph below, sketch the following graphs from the time the block separates itself from the spring until it reaches a momentary stop.

The distance represents the distance along the plane.

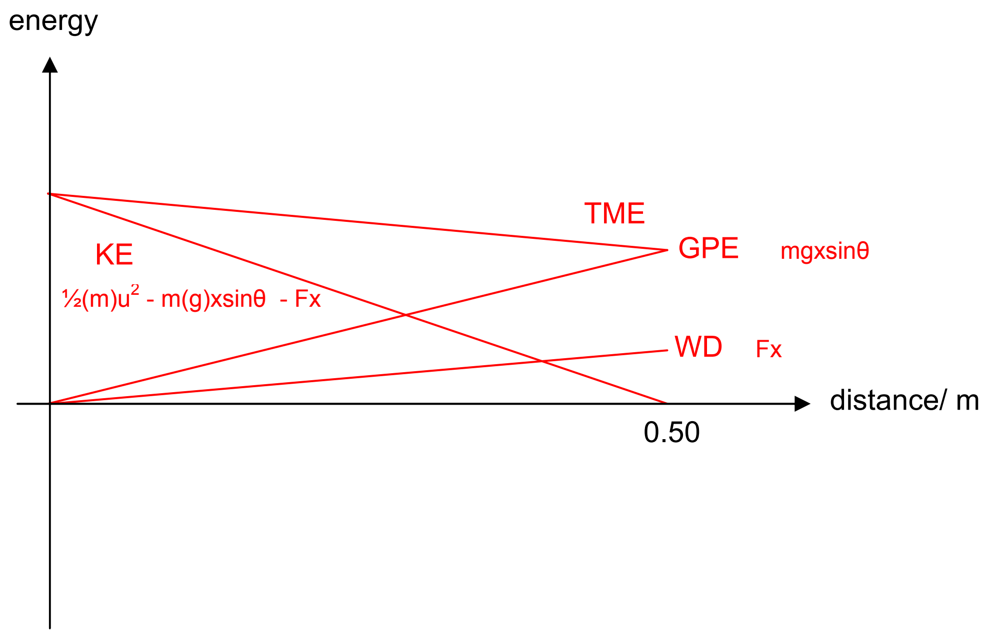
(i) work done against friction (WD) against distance [1]

(ii) total mechanical energy (TME) of block against distance [1]

(iii) gravitational potential energy (GPE) against distance [1]

(iv) kinetic energy (KE) against distance [1]

Label each of the graphs as WD, TME, GPE and KE respectively.



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4 Fig. 4.1 below shows a simple form of current balance. ABCD is a rectangular loop and all sides are made of copper loop except for section AD which is made of an insulator. ABCDEF all lie on the same horizontal plane.
When a current I flows through the solenoid and the loop, a rider of mass 10^{-4} kg has to be placed at the end of EF in order to restore equilibrium. The length of AB, BC and EF are 25 cm, 15 cm and 30 cm respectively.

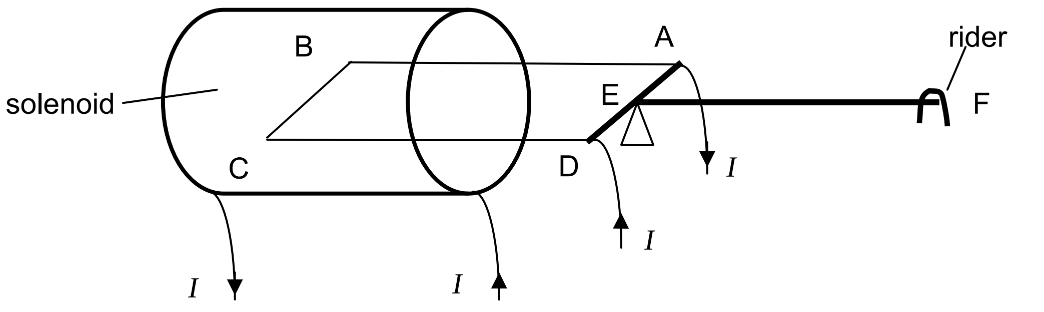


Fig. 4.1

(a) State the direction of magnetic field inside the solenoid.

.... In the direction of BA .... [1]

(b) **(i)** The magnetic flux density inside the solenoid is 3.0 x $10^{-3}\,I$. Write down, in terms of I, the force acting on arm BC.

$$F = B_{\perp}IL = (3.0\times10^{-3}I)(I)(0.15) = 4.50\times10^{-4}I^2$$

force = ... [1]

(ii) Hence, deduce the value of I.

Taking moments about AD,

$$(4.50\times10^{-4}I^2)(0.25) = (10^{-4})(9.81)(0.30)$$

$$I = 1.62\text{ A}$$

I = ... A [2]

(c) State and explain what will happen to equilibrium when the direction of current I is reversed.

As direction of the flow of current changes, both the direction of current in BC and direction of magnetic field inside the solenoid changes as well. Hence the force on BC will always be downwards.

[2]

(d) An ammeter was placed across wire BC as shown in Fig. 4.2 and a current was detected.

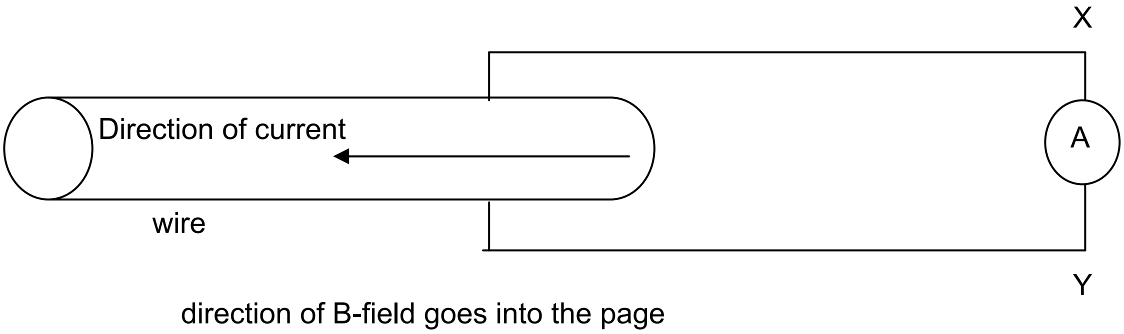


Fig. 4.2

(i) Explain why a current flow was detected by the ammeter.

The electrons experienced a magnetic force and was deflected downwards resulting in a current flow through the ammeter.

[1]

(ii) State the direction of the current flow through the ammeter.

From X to Y.

[1]

5 Wind power can be harnessed to generate electric power. Fig. 5.1 below shows a particular type of wind turbine. The wind causes the rotor blades to turn, and they drive a generator located inside the generator housing.

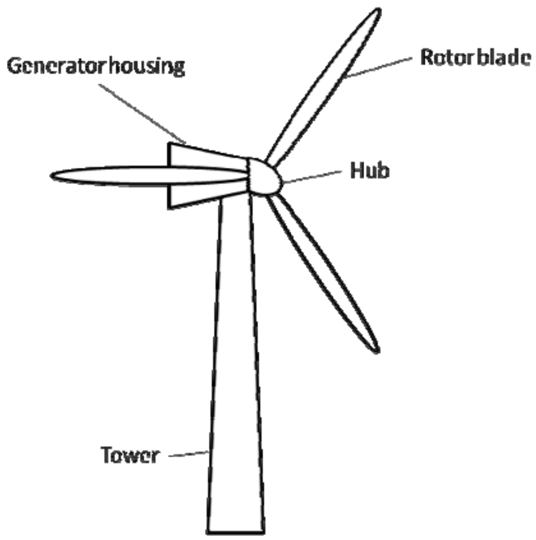


Fig. 5.1

Information about the performance of the wind turbine is provided by the manufacturer, as shown in Fig. 5.2.

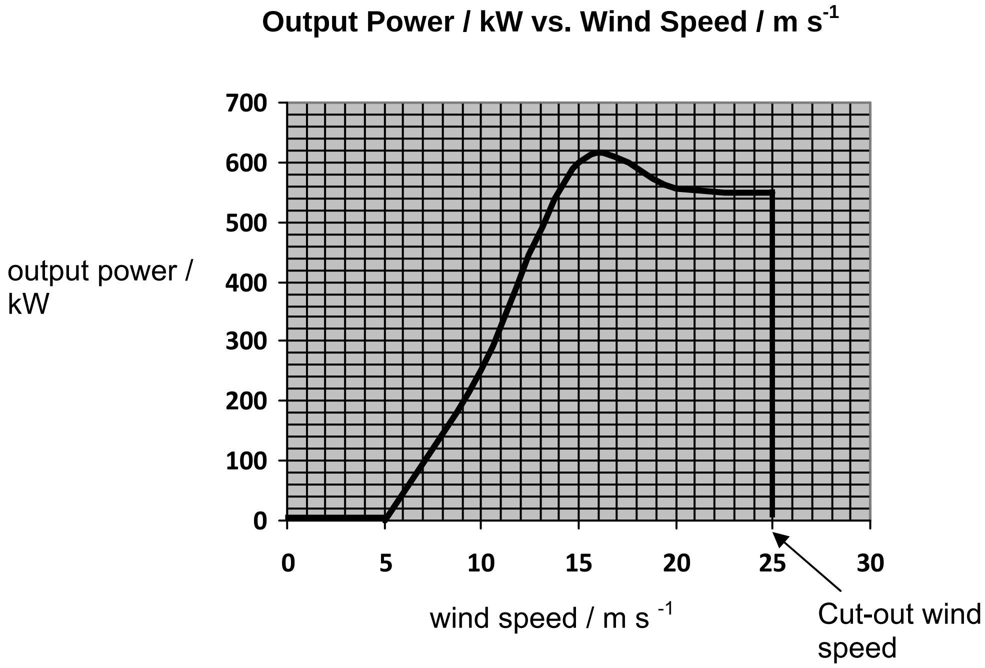


Fig. 5.2

For Examiner's Use

From the information provided by the manufacturer,

(a) Explain why there is no output power below a wind speed of 5.0 m s^{-1}.

A minimum wind speed is needed (for the force of the wind) to overcome (static) friction between the rotating and non-rotating parts of the blades and hub.

.... [1]

(b) Suggest why is there a need for a cut-off wind speed.

This is a safety braking feature to prevent damage to the rotor for wind speeds above a certain value.

.... [1]

(c) Air of density ρ and speed v is incident normally on a rotor of radius r at a rate of m_t , mass per unit time t.

(i) Determine the expression for m_t in terms of r, v and ρ.

m_t = mass of air per unit time

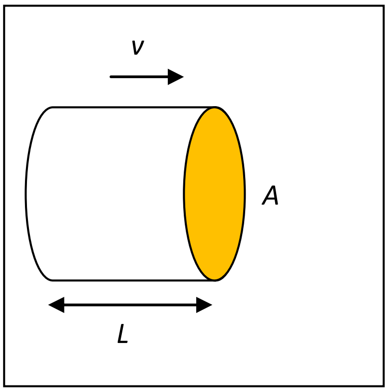
= (volume of air x density of air) / t

$= (A\,L\,\rho)/t$

$= (\pi r^2 L\,\rho)/t$

$= [\pi r^2 (v\,t)\,\rho]/t$

$= \pi r^2 v\,\rho$



m_t = ... [2]

(ii) Show that $E_t = ½\,\pi\,r^2 v^3\rho$, where E_t is the kinetic energy of the wind incident on the rotors per unit time. [2]

$E_t = ½\,m_t v^2$

$= ½\,(\pi r^2 v\,\rho)\,v^2$

$= ½\,\pi r^2 v^3 \rho$

For Examiner's Use

(d) When the wind turbine operates at maximum output power,

(i) determine the value of E_t. The air has density 1.25 kg m^{-3} and the rotor diameter is 40 m.

Using the values of r = (40/2), v = 16 m s^{-1} (for max. output power), ρ = 1.25 kg m^{-3}

$E_t = \frac{1}{2}\pi (40/2)^2 (16)^3 (1.25)$

$= 3.2 \times 10^6$ W

E_t = ………………………….. W [2]

(ii) calculate the overall efficiency of the generation of electric power.

Efficiency = (useful output power / input power) x 100%

= (620 x 10^3 W) / (3.2 x 10^6 W) x 100%

= 0.194 x 100%

= 19%

efficiency = …………………. % [2]

(e) Suggest two practical constraints in generating electricity using wind turbines in Singapore.

1) Lack of favourable and consistent wind conditions in Singapore.
2) Obstruction of wind due to many high-rise buildings.
3) Limitation of land space in Singapore for installation of wind turbines.

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

For Examiner's Use

Section B

Answer **two** questions from this section.

6 **(a)** State the *Principle of Superposition*.

The Principle of Superposition states that when two or more waves overlap, the resultant displacement at any point at any instant is the vector sum of the individual displacements that each wave would cause at that point.

[2]

(b) Monochromatic light illuminates a narrow slit which is 4.0 m away from a screen. Two very narrow parallel slits 0.50 mm apart are placed midway between the single slit and the screen so that interference fringes are obtained.

(i) Explain how diffraction and interference play a part in formation of the interference fringes.

The two small slits allow diffraction of the light reaching it so that the light from both slits will spread and meet each other. Interference occurs in the region between the two slits and the screen where the diffracted waves meet. (inferred when they say meet each other)

Where the two waves arrive in phase, constructive interference takes place and a bright fringe is formed. Where the two waves arrive in antiphase, destructive interference takes place and a dark fringe is formed.

[2]

(ii) The spacing of five bright fringes is 10 mm, calculate the wavelength of the light.

$x = \lambda D/a$

$(10/4) \times 10^{-3} = \lambda(2)/(0.5\times10^{-3})$

$\lambda = 6.25 \times 10^{-7}$ m

wavelength = ……………………….. m [2]

For Examiner's Use

(iii) State the changes in the fringes, if any, when the screen is moved closer to the double slit.

The spacing between the fringes will be reduced, but there is an increase in the intensity at the bright fringes only.

……[2]

(iv) The intensity of the bright fringe is I. A very thin paper is placed in front of one of the double slits such that the intensity of the light passing through the slit is now halved. Determine the intensity, in terms of I, of the new minima.

Assuming original amplitude of both waves is A.
For maxima, the resultant amplitude is 2A and the original I is proportional to $4A^2$.

When the intensity is now halved,
for minima, the resultant amplitude is now $(1-1/\sqrt{2})$ A .

Hence $I_1 / I = ((1-1/\sqrt{2})A)^2 / 4A^2$
Therefore $I_1 = 0.0214\ I$

Intensity = ………………….. [3]

(v) The monochromatic light source is now replaced by a light source producing red and blue light. State and explain what will be observed at the central fringe.

The red and blue light will overlap, resulting in a violet fringe, with a red tinge at the edges. The red tinge is due to the fact that the fringe separation, and hence fringe width of the red light is larger because of its larger wavelength.

……[2]

For Examiner's Use

(c) Suggest a reason for each of the scenarios below:

1. When the light beams from the two headlamps of a car overlap, explain why it is not possible to have an observable interference pattern.

Headlights are not coherent sources and therefore incapable of producing observable interference patterns.

....[1]

2. When a source producing sound waves of wavelength 5.0 m is connected to two loudspeakers which are placed 2.0 m apart facing each other, explain why is it not possible to locate a position along a straight line joining the two sources where there will be a minima.

Since the distance between the speakers (2 m) is less than half a wavelength (2.5 m), the path difference is always less than half wavelength and hence, it is not possible to find a position where destructive interference will take place and hence a minima.

....[2]

(d) A diffraction grating contains many closely spaced slits through which a beam of light can be split. The beams passing through the slits then interfere and produce a many-slit interference pattern. With a large number of slits, the intensity maxima are no longer evenly spaced and the position (or angle) of the nth order intensity maxima can be determined by :

$$d \sin \theta_n = n\lambda$$

where d is the separation between slits
n is the order of diffraction (an integer)
θ_n is the angle between the nth order intensity maxima and the normal to the grating
λ is the wavelength of the incident beam
as shown in Fig. 6.1

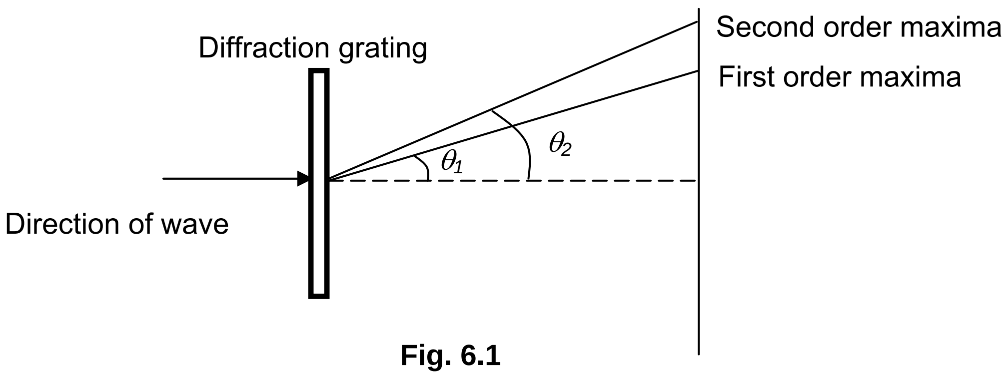


Fig. 6.1

A monochromatic light of wavelength 700 nm is incident on a diffraction grating that has a slit separation of 3.63 x 10^{-6} m. The second order spectrum appears at a distance of 3.0 cm away from the zeroth order spectrum as shown in Fig.6.2.

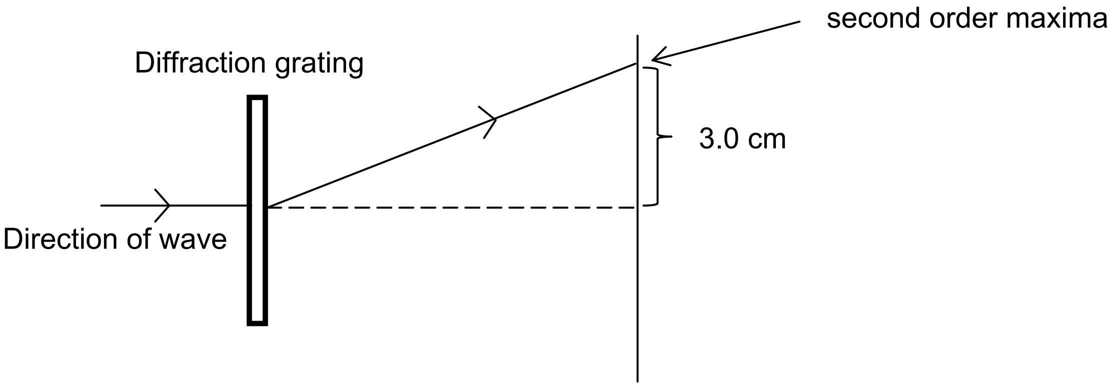


Fig. 6.2

(i) Determine how far the screen is away from the diffraction grating.

d sin θ = nλ
3.63 x 10^{-6} sin θ = 2 (700 x 10^{-9})
sin θ = 0.385
θ = 22.6°
tan θ = 3/L
L = 7.18 cm

distance = …………………….. cm [2]

(ii) When a patient receives a chest x-ray at the hospital, the x-rays pass through a series of parallel ribs in the patient's chest. Explain if the ribs act as a diffraction grating for x-rays.

The separation distance of the ribs is much larger than the wavelength of the x-rays, hence there are no observable effects and hence the ribs do not act as a diffraction grating.

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

7 A thermistor is often used in an electrical circuit to detect temperature changes.

(a) Describe and explain using the definition of potential difference why the potential difference across a thermistor connected directly to an e.m.f. source in a circuit with no other components does not change when temperature of the thermistor increases.

When temperature of thermistor increases, charged particles are released from the lattice ions of the thermistor, leading to an increase in the number of charged particles.
The increase in vibration of lattice ions also led to more work done in order to move the charges across the thermistor.
However, as the increase in number of charge carriers balances effect of the increase in work done, the work done per unit charge, which is the potential difference, remains the same.

[3]

(b) The setup shown in Fig. 7.1 was used to detect the variation in temperature of the environment through observing the brightness of a filament lamp in the setup.

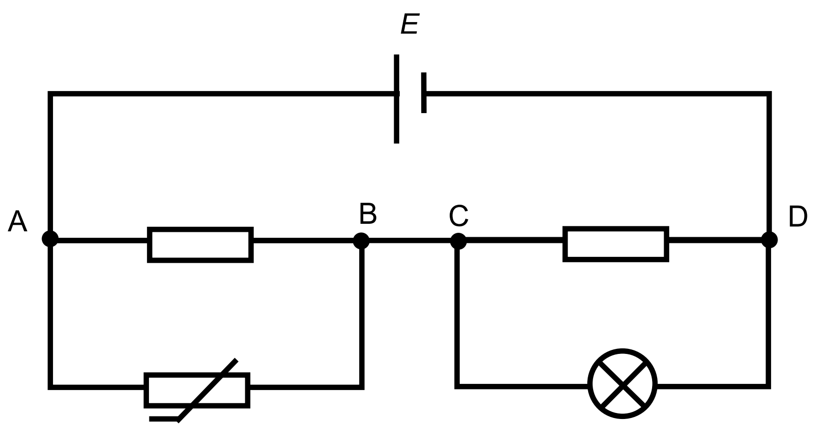


Fig. 7.1

Describe and explain the variation of the potential difference across the lamp over time when temperature of the environment and also the lamp increases.

As temperature increases, resistance of thermistor decreases. [inferred from part (a)]
This causes the effective resistance across AB to decrease.
As the filament lamp heats up, the resistance of the lamp increases as well.
Hence, effective resistance across CD increases.
By potential divider principle, the potential difference across the bulb increases.

……………………………………………………………………………………………………[4]

(c) The electrons within an electrical circuit is moving at a speed (also known as drift velocity) of 10^{-4} m s^{-1}.

(i) Explain how it is possible for a light bulb connected by metre long wires as shown in Fig. 7.2 to be lighted up almost immediately when the switch is closed.

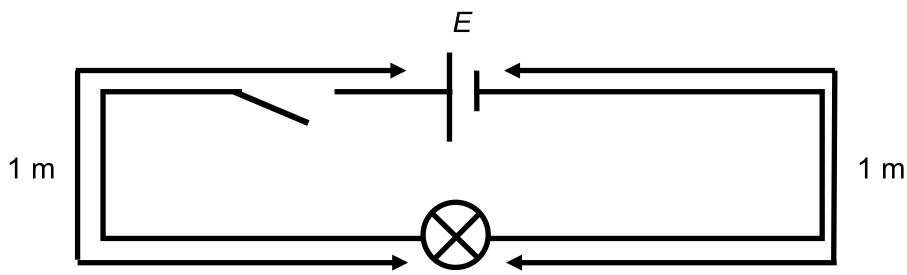


Fig. 7.2

When the switch is closed, all electrons start moving simultaneously at all points within the circuit almost immediately due to the electric field applied across the circuit due to the cell.
The electrons in the light bulb moves as well and this will cause the current necessary to light up the light bulb. It is not necessary for the electrons from the cell to reach the light bulb to light it up.

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

(ii) The cross-sectional area of the wire is 3.14 x 10^{-6} m s^{-1} and the average number of electrons per unit volume of the wire (also known as electron density) is 8.5 x 10^{28} electrons m^{-3}.

Determine the current in the wire.

$$I = \frac{Q}{t} = \frac{Q}{Vol}(Area)(\frac{length}{time}) = \frac{Q}{Vol}(Area)(\text{drift velocity})$$
$$= (8.5\times10^{28}\times1.6\times10^{-19})(3.14\times10^{-6})(10^{-4})$$
$$= 4.27 \text{ A}$$

current = ………………… A [2]

(d) Fig. 7.3a and Fig. 7.3b shows 2 similar fixed resistors of resistance *R* in two different connection setup, supplied by identical e.m.f. source *E*.

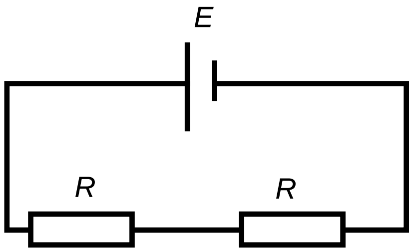


Fig. 7.3a

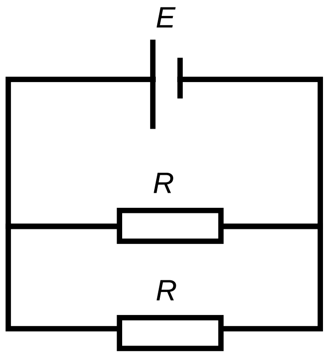


Fig. 7.3b

(i) State and explain whether the cell in Fig. 7.3a or Fig. 7.3b will last longer before it stops supplying power to the resistor.

In Fig. 7.3a, as the total resistance is larger, the power supplied is lower than that in Fig. 7.3b as the power supplied to the entire setup in Fig. 7.3a is $E^2/(2R)$ while that in Fig. 7.3b is $E^2/(R/2)$.

Therefore, with a larger power supplied and an equal amount of total energy it can supply, the cell in Fig. 7.3b will stop supplying power earlier.

…………………………………………………………………………………………………[4]

For Examiner's Use

(ii) The internal resistance of the e.m.f. source is 2*R*.

Determine the power supplied to the circuit when the connection in the setups in Fig. 7.3a and Fig. 7.3b in terms of *R* and *E*.

$$P_a = \frac{(\frac{2R}{4R} \times E)^2}{2R} = \frac{E^2}{8R}$$

$$P_b = \frac{(\frac{R/2}{2R + R/2} E)^2}{\frac{R}{2}} = \frac{2E^2}{25R}$$

power supplied in Fig. 7.3a = …………………………

power supplied in Fig. 7.3b = ………………………… [3]

(iii) The Maximum Power Theorem states that the power supplied to the circuit is maximum when the internal resistance is equal to the total external resistance of the circuit. State and explain whether your answer in **(d) (ii)** contradicts this theorem.

When the internal resistance is equal to the total external resistance of the setup in Fig. 7.3a, the power supplied to the circuit is higher than that of the setup in Fig. 7.3b which does not have a total external resistance equal to the internal resistance.
Hence, there is no contradiction.

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

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

8 **(a)** When electromagnetic radiation falls on a metal surface, electrons may be emitted. This is the photoelectric effect.

(i) Write down Einstein's photoelectric equation and state what each term represents.

$hf = \Phi + K_{max}$

hf: the energy of the incident photon

Φ: work function of the metal

K_{max}: maximum kinetic energy of the emitted photoelectron from surface of metal

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

(ii) Explain why, for a particular metal, electrons are emitted only when the frequency of the incident radiation is greater than a threshold frequency.

For photoelectrons to be emitted, the energy (*hf*) of each photon must be greater than the work function of the metal.
With *h* as a constant, this means that energy of photon is proportional to the frequency of the photon hence, frequency for emission must exceed a certain minimum value.

.......[2]

(b) In a photoelectric experiment, the stopping potential for electrons emitted from a metal illuminated by light of wavelength 501 nm is 0.850 V.

(i) Calculate the work function of the metal.

The work function is given by:

$$\Phi = hf - K_{max} = \frac{hc}{\lambda} - eV_s$$

$$= \frac{(6.63\times10^{-34})(3.0\times10^{8})}{501\times10^{-9}} - (1.6\times10^{-19})(0.850)$$

$$= 2.61\times10^{-19} \text{ J}$$

work function = …………………… J [2]

(iii) Calculate the threshold frequency for the surface.

The threshold frequency f_0 is given by:

$$\Phi = hf_0$$

$$f_0 = \frac{\Phi}{h} = \frac{2.61\times10^{-19}}{6.63\times10^{-34}}$$

$$= 3.94\times10^{14} \text{ Hz}$$

threshold frequency = ………………….. Hz [1]

(ii) Suggest a physical quantity of the metal that affects the work function.

The density of the metal. A metal of higher density has higher (mass and) proton number which gives rise to higher electrostatic attractive forces between the electron and lattice ions. This results in higher work function.

[2]

(c) In 1924, Louis-Victor de Broglie proposed a theory of wave-particle duality.

Name an experiment that gives evidence for the wave nature of particles. Explain how the observations of the experiment support the fact that particles have wave properties.

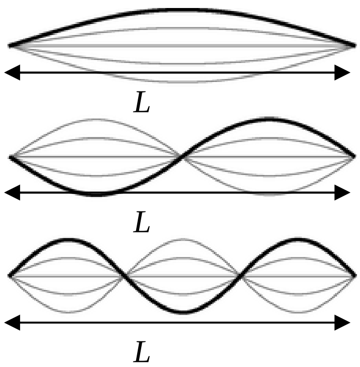
Electron diffraction experiment.
The observed interference pattern suggests that the electrons have been diffracted by the crystal (carbon film) and have interfered with each other exhibiting wave-like behaviour. This is evidence for the wave nature of particles.

[2]

(d) A particle of mass *m* is confined to a narrow tube of length *L*, the de Broglie waves of the particle can "resonate" in the tube. These waves can be taken to be stationary waves with nodes at both ends of the tube.

(i) When resonance occurs, show that the de Broglie wavelengths λ are quantized and can be expressed as

$$\lambda_n = \frac{2L}{n}, \text{ where } n = 1, 2, 3, \ldots$$ [2]



When resonance occurs, *L* must be equal to *n* multiples of half-wavelength:

$$L = n\left(\frac{\lambda_n}{2}\right)$$, where n = 1, 2, 3…

So, $\lambda_n = \frac{2L}{n}$, where *n* = 1, 2, 3, …
Since λ can only take on specific values, it is quantized.

(ii) State the relationship between the de Broglie wavelength λ and the speed of the particle *v*. [1]

The de Broglie wavelength λ is given by:

$$\lambda = \frac{h}{p} = \frac{h}{mv}, \text{ where v is the speed of the particle}$$

OR

$$v = \frac{h}{m\lambda}$$

(iii) Hence, show that the corresponding kinetic energies *K* of the particle can only have discrete values and can be expressed as

$$K_n = \frac{h^2 n^2}{8mL^2}$$, where *n* = 1, 2, 3, … [2]

The de Broglie wavelength λ is given by:

Kinetic energy K_n is given by:

$$K_n = \frac{1}{2}mv^2 = \frac{m}{2}\left(\frac{h}{m\lambda_n}\right)^2$$

$$= \frac{h^2}{2m}\left(\frac{n}{2L}\right)^2, \text{ subst. } \lambda \text{ from part (d)(i)}$$

$$= \frac{h^2 n^2}{8mL^2}, \text{ where n =1, 2, 3, ...}$$

(iv) The particle is an electron and *L* = 100 pm, determine the smallest amount of kinetic energy the electron can have.

The smallest KE is when $n = 1$,

$$= \frac{h^2 (1)^2}{8mL^2} = \frac{(6.63\times10^{-34})^2}{8(9.11\times10^{-31})(100\times10^{-12})^2}$$

$$= 6.03\times10^{-18} \text{ J}$$

smallest kinetic energy = …………………… J [2]

For Examiner's Use

(v) Suggest how the confined electron, which is described in **(d) (iii)**, can be excited to higher energy levels.

The electron can be excited by incoming photons.
However, in order for a photon to be absorbed, its energy must correspond exactly to the difference between two energy levels of the electron.

OR

Excitation is possible through collisions with other electrons which possess energies greater than the difference between the energy levels.

[2]

End of Paper