Semester One Examination 2016

Question/Answer Booklet

CORPUS CHRISTI COLLEGE

SEQUERE DOMINUM

PHYSICS

12 ATAR

Student Number:	In Figures	☐☐ ☐☐☐ ☐☐☐
	In words	Soln.

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: 180 minutes

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet Formulae and Data Booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction tape/fluid, eraser, ruler and highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor

Important note to candidates

No other items may be taken into the examination room. It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor before reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short answers	14	14	60	64	30
Section Two: Problem-solving	5	5	80	77	50
Section Three: Comprehension	14	14	40	39	20
				Total	100

Instructions to candidates

a) Write your answers in this Question/Answer Booklet.

b) When calculating numerical answers, show your working or reasoning clearly. Give final answers to three significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

c) You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

d) The Formulae and Data Booklet is **not** handed in with your Question/Answer Booklet.

Section One. Short responses. **64 Marks Allocated**

Attempt **ALL FOURTEEN** (14) questions in this section. Marks for each question are clearly identified.

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1. Sound waves are very different from electromagnetic waves. List **three** differences between sound waves and electromagnetic waves. **[3 marks]**

1st difference SPEED: $(3\times10^{8} ms^{-1})$ v $(330 ms^{-1})$.

2nd difference TRANSVERSE (v) LONGITUDINAL.

3rd difference EM DOESN'T REQ A MEDIUM.

3

2. Experimental analysis identifies a wave with a period of 1.32×10^{-15} seconds and having a wavelength of 3.95×10^{-7} metres.

a) Calculate the speed of this wave. **[3 marks]**

$$f = \frac{1}{T} = \frac{1}{(1.32\times10^{-15})} = 7.6\times10^{14} Hz$$

3

$$v = f\lambda = (7.6\times10^{14})(3.95\times10^{-7}) = 3\times10^{8} ms^{-1}$$

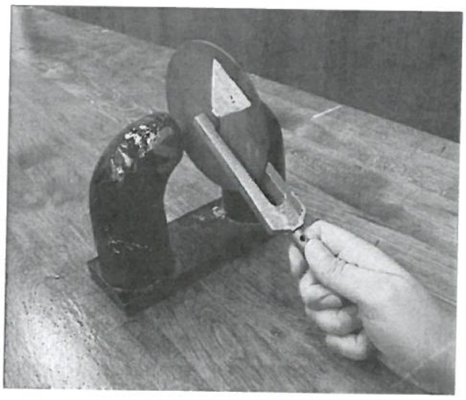
b) What is this wave most likely to be? Explain your answer. **[2 marks]**

THIS WAVE IS EM RADIATION OR LIGHT. DUE THE FACT THAT IT HAS A SPEED of 3×10^{8} ms^{-1}.

2

8

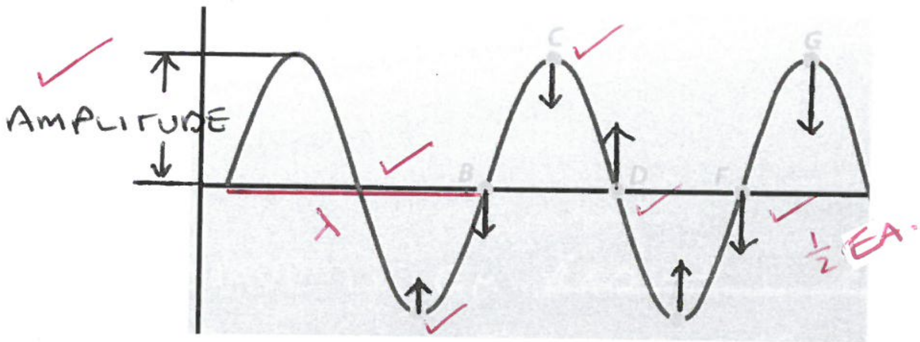
3. The picture shows a rotating copper disc being moved into the magnetic field region between the north and south poles of a strong horseshoe permanent magnet. Explain what, if anything, will happen to the rotating disc as it is held between the poles. **[5 marks]**



CHGING FLUX IS RELATIVE, EVEN THOUGH THE B FIELD IS CONST, THE DISC WILL EXPERIENCE A CHGING FLUX. LENZ'S LAW STATES THAT THE DISC WILL INDUCE AN OPPOSING FIELD THROUGH THE CREATION OF EDDY CURRENTS. THIS WILL CAUSE THE DISC TO SLOW DOWN.

5

4. Consider the diagram below showing a simple wave profile moving towards the right hand side of this page.



4

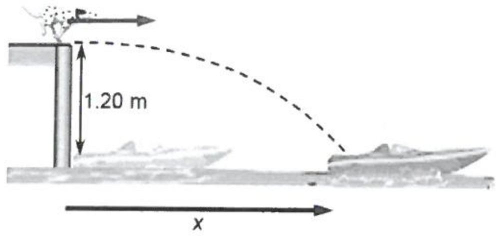
a) **On the diagram,** draw arrows representing the motion of points A, C, D and F. ½ EA **[2 marks]**

b) **On the diagram,** show the amplitude and wavelength of this wave. 1 EA. **[2 marks]**

SEE NEXT PAGE

9

5. The family dog runs horizontally off the end of the dock at a speed of 6.70ms^{-1} with the intention of landing in the boat that is 1.20 meters below the end of the dock.



Find the maximum horizontal displacement x that the boat can be from the end of the dock without us winding up with a wet dog. **[4 marks]**

$s = 1.2m.$

$a = g.$

$t = ?$

$u = 0 ms^{-1}$

$v = ?$

$s = ut + \frac{1}{2}gt^2 \quad (u = 0)$

$\therefore t^2 = \frac{2s}{g} = \frac{2(1.2)}{9.8} = 0.25s.$

$\therefore t = 0.50$ secs.

$s = vt = (6.7)(0.5) = \underline{3.35 \text{ metres}}.$

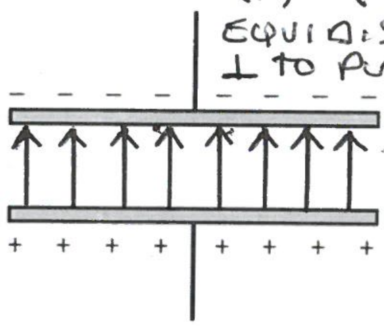
(4)

6. Consider the parallel plates arrangement shown here.

a) Using **at least eight field lines**, sketch the field that exists between the plates. **[2 marks]**

b) Given that the plates are 1.00cm apart and that a potential difference of 500V exists between them. Calculate the work done in moving a proton from the lower to the upper plate. Give your answer in eV. **[3 marks]**

$(+) \rightarrow (-)$. (1)
EQUIDIST. (½)
⊥ TO PLATES (½)



$\mathcal{E} = \frac{V}{d} = \frac{F}{q}$

$\therefore Fd = Vq = (500)(1.6 \times 10^{-19})$

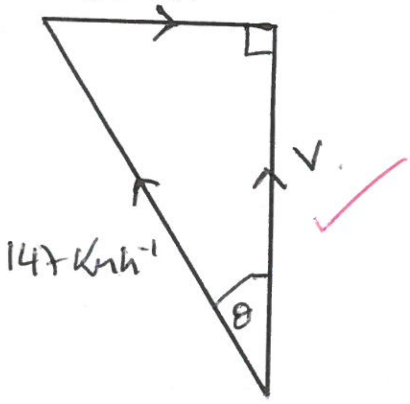
$= 8 \times 10^{-17}$ m.

$\therefore Wd(eV) = \frac{8 \times 10^{-17}}{1.6 \times 10^{-19}} = \underline{500 eV}.$

(5)

(9)

7. An aircraft attempts to land along a north-south aligned landing strip. It approaches from the south and has an air speed of 147kmhr $^{-1}$. The wind is blowing from the west at 37.0kmhr $^{-1}$. Draw a vector diagram to show the direction the aircraft needs to head and calculate its actual velocity, <u>in ms^{-1}</u>, relative to the runway. **Show all working**. **[5 marks]**



$V^2 = (147)^2 + (37)^2 = 20,240$

$\therefore V = 142 \text{ Kmh}^{-1} = 39.5 \text{ ms}^{-1}$

$\sin\theta = \frac{37}{147} = 0.25$

$\therefore \theta = 14.6°$

$V = 39.5 \text{ ms}^{-1}, \text{ N } 14.6° \text{ S}$

5

8. Use the information given in the Formulae and Data Booklet to calculate the orbital period, **<u>in seconds</u>**, of the Moon around the Earth. **[5 marks]**

FROM DATA SHEET:

$T^2 = \frac{4\pi^2}{GM} r^3$

$G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ Kg}^{-2}$

$M_e = 5.97 \times 10^{24} \text{ Kg}$

$r_{me} = 3.84 \times 10^8 \text{ m}$

$\therefore T^2 = \frac{4(3.14)^2(3.84 \times 10^8)^3}{(6.67 \times 10^{-11})(5.97 \times 10^{24})}$

$= \frac{2.23 \times 10^{27}}{3.98 \times 10^{14}}$

$\therefore T^2 = 5.60 \times 10^{12}$

$\text{So } T = 2.38 \times 10^6 \text{ secs}$

5

SEE NEXT PAGE

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9. A student is swinging a yo-yo of mass 125g in a vertical circle of radius 0.95m at a speed of $4.50ms^{-1}$. Calculate the tension in the string when the yo-yo is at the lowest point of its path.

[4 marks]

AT BOTTOM:

$$T = F_c + mg = \frac{mv^2}{r} + mg.$$

$$= \frac{(125\times10^{-3})(4.5)^2}{(0.95)} + (125\times10^{-3})(9.8).$$

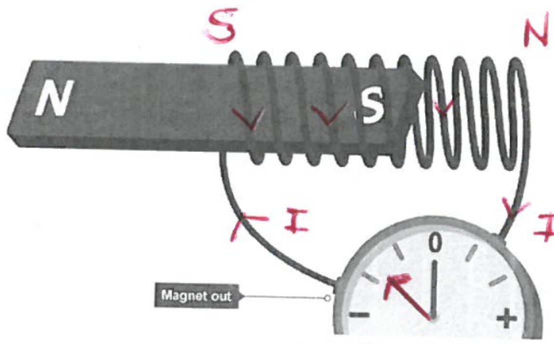
$$\therefore T = (2.67) + (1.23) = \underline{\underline{3.9N.}}$$

4

10. The diagram shows a permanent magnet being pushed (moving to the right) into copper solenoid coil. The coil is connected to an ammeter.

a) **On the diagram**, draw the direction of the induced current and the deflection of the ammeter.

[2 marks]



DEFLECTION ACW

5

2

b) List at least **<u>two</u>** ways that the induced current in the coil could be increased.

[2 marks]

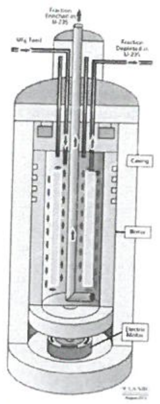
(i) MOVE MAGNETIC FASTER (OR)
(ii) ADD MORE TURNS TO THE COIL (OR)
(iii) USE STRONGER MAG.

(1 MARK EA, ANY TWO).

2

8

11. Enrichment of nuclear fuel uses the gas centrifuge process. Many rotating cylinders (centrifuges) that are connected in long lines. UF_6 gas is placed in the cylinder, which spins at high speed, creating a strong centrifugal force. Heavier U-238 gas molecules move to the cylinder wall, while lighter U-235 collects near the center.



Schematic of a centrifuge

How fast (**in rpm**) must a centrifuge rotate if a UF_6 gas molecule, located 10.0cm from the centre of rotation, is to experience an acceleration of $(1.00\text{x}10^5)$g? **[5 marks]**

$$a_c = \frac{v^2}{r} \quad \therefore v^2 = a_c r = (100{,}000)(9.8)(10\times10^{-2})$$

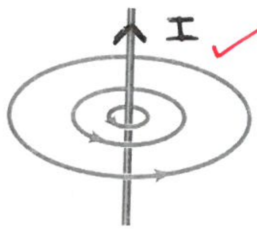
$$\therefore v = 313\ ms^{-1}$$

5

$$v = \frac{2\pi r}{T} = 2\pi r f$$

$$\therefore f = \frac{v}{2\pi r} = \frac{313}{(6.28)(10\times10^{-2})} = 49.8\ Hz = \underline{29.9\ rpm}$$

12. The picture shows the circular magnetic field created due to the movement of current in the vertical wire.



a) On the diagram show the direction of the current. **[1 mark]**

1

b) Given that the current flowing in the wire is 5.00A. Calculate the magnetic field strength at a point 7.00cm from the wire. **[3 marks]**

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(1.26\times10^{-6})(5)}{(6.28)(7\times10^{-2})}$$

3

$$B = \frac{6.3\times10^{-6}}{0.4396} = \underline{1.43\times10^{-5}\ T}$$

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13. Aircraft flying through the earth's magnetic field are subject to an induced EMF across the wings.

a) At which places on the earth will the aircraft experience the maximum induced EMF? Explain your answer. **[2 mark]**

THE AIRCRAFT WILL EXPERIENCE MAX IND EMF WHEN FLUX LINES ARE CLOSEST TOGETHER. AT THE POLES.

2

b) If the maximum magnitude of the earth's magnetic field is 5.00x10^{-5} T, calculate the magnitude of the EMF that would be induced across the wings of an Airbus A380 flying at 900kmh^{-1}. The wingspan of an A380 is 60 metres. **[3 marks]**

$B = 50 \times 10^{-6}$ T.

$l = 60$ m.

$V = 900$ Kmh^{-1}

$= 250$ ms^{-1}.

EMF = Bvl

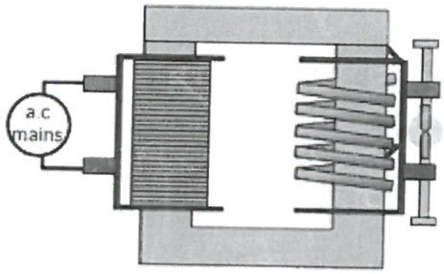
$= (5 \times 10^{-5})(250)(60)$.

$= 0.75$ VOLTS.

3

14. The transformer arrangement shown here is used to weld two iron nails together.

a) Explain how this arrangement can produce a large enough current to fuse the nails together. State any assumptions you have made. **[3 marks]**



Welding two nails together

STEP DOWN TRANSFORMER ∴ V↓ BUT SINCE P=IV, I↑.

ASSUME IDEAL TRANSFORMER (100%)

3

b) **Estimate** the secondary voltage of this transformer. **[3 marks]**

$V_p = 240$V.

OK! 15-25 $N_p = 20$ (EST)

$V_s = ?$

OK! 4-6 $N_s = 5$. (EST)

CORRECT EST 1

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$ ∴ $V_s = \frac{V_p N_s}{N_p}$.

$V_s = \frac{(240)(5)}{20} = 60$V.

3

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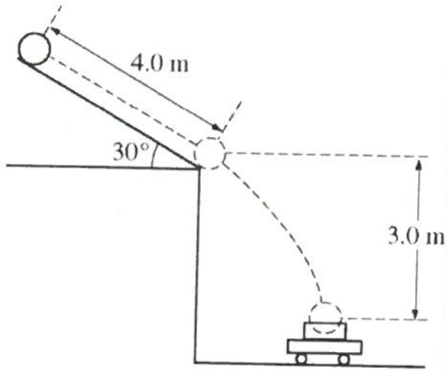
11

Section Two. Problem solving. **77 Marks Allocated**

Attempt **ALL FIVE** (5) questions in this section. Marks for each question are clearly identified.

1. During a snow storm, a large snowball rolls from the roof of a house, hitting a car parked in the driveway as shown here.



a) If the snowball rolls from rest, calculate the initial **velocity** of the snowball as it starts to fall. **[5 marks]**

5

$a = g\sin\theta = (9.8)\sin 30° = \underline{4.9\,ms^{-2}}$

$v = ?$

$u = 0\,ms^{-1}$

$s = 4\,m$

$a = 4.9\,ms^{-2}$

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

$v^2 = 0 + (2)(4.9)(4)$

$= 39.2$

$\therefore v = 6.26\,ms^{-1}$

(30° BELOW HORZ).

5

b) How long does it take for the snowball to hit the parked car? **[6 marks]**

$V_v = V\sin\theta = (6.26)\sin 30° = 3.13\ ms^{-1}$

$V^2 = u^2 + 2gs = (3.13)^2 + 2(9.8)(3)$

$\therefore\ V = 8.28\ ms^{-1}$

6

$t = \frac{V-u}{g} = \frac{8.28 - 3.13}{9.8}$ $\therefore\ t = 0.53\ s$

c) How close is the car parked to the front of the house? **[3 marks]**

$V_H = V\cos\theta = (6.26)\cos 30° = 5.42\ ms^{-1}$

$S_H = V_H t = (5.42)(0.53)$

$= 2.87\ m$

3

d) List **two** assumptions you have made when answering this question.
[2 marks]

1st assumption: NO FRICTION ON RAMP.

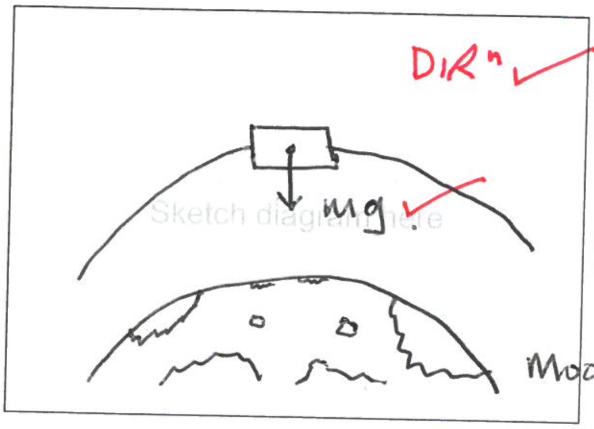
2nd assumption: NO AIR FOR PROJECTILE.

2

11

2. NASA has decided to place a satellite in orbit around the moon to determine if any traces of water exist on, or just below the surface.

a) Show, by sketching a diagram, the force exerted on the satellite by the moon as it orbits. **[2 marks]**



2

b) What is the acceleration due to the moon's gravity at a height of 2500km above the surface of the moon? **[4 marks]**

$$F = m_1 a = \frac{G m_1 m_2}{r^2} \quad \therefore \quad a = \frac{Gm}{r^2}$$

$$a = \frac{(6.67 \times 10^{-11})(7.35 \times 10^{22})}{((1.74 \times 10^{6}) + (2500 \times 10^{3}))^2}$$

$$= \frac{4.90 \times 10^{12}}{(4240000)^2} = \frac{4.90 \times 10^{12}}{1.80 \times 10^{13}}$$

4

$$\therefore \quad a = 0.29 \text{ ms}^{-1}$$

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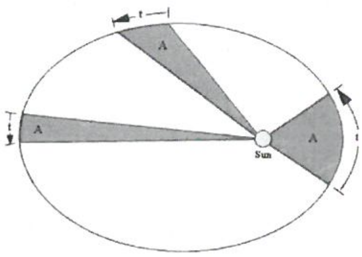
6

c) Kepler's second law states, "*An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time*". This is also known as the Law of Equal Areas. Show, by using the equations learned in class, that this is true. **[4 marks]**



$$F_c = F_g \quad \therefore \quad \frac{\cancel{m_1} v^2}{\cancel{r}} = \frac{G\cancel{m_1} m_2}{r^{\cancel{2}}}$$

$$v^2 = \left(\frac{2\pi r}{T}\right)^2 = \frac{Gm}{r}$$

4

$$\therefore \frac{4\pi^2 r^2}{T^2} = \frac{Gm}{r}$$

$$\therefore \frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

d) If the satellite is to have an orbital period of 24 hours, determine the height of the orbit above the moon's surface. **[5 marks]**

$$r^3 = \frac{T^2 Gm}{4\pi^2} = \frac{(24 \times 3600)^2 (6.67 \times 10^{-11})(7.35 \times 10^{22})}{4(3.14)^2}$$

$$r^3 = \frac{3.66 \times 10^{22}}{39.4} = 9.29 \times 10^{20}$$

5

$$\therefore r = 9.76 \times 10^6 \text{ m}$$

$$\text{So HEIGHT} = (9.76 \times 10^6) - (1.74 \times 10^6)$$

$$= \underline{8.02 \times 10^6 \text{ m}} \quad \underline{\text{ABOVE SURFACE}}$$

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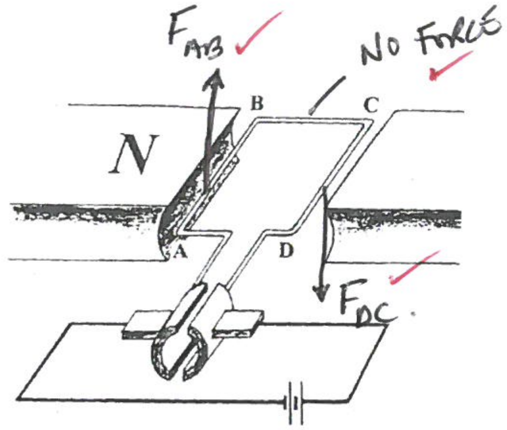
3. The diagram below shows a single rectangular loop of wire free to rotate in a uniform magnetic field of 0.06 T. The loop is carrying a current of 2.50 A and is 8.0 cm long and 3.0 cm wide.



a) **On the diagram**, identify the brushes and split ring commutator. **[1 mark]**

BRUSHES & COMMUTATOR (Y2 EA).

1

b) Explain the function of the brushes and the split ring commutator, what materials are they usually made from? **[2 marks]**

- BRUSHES ARE USUALLY MADE OF GRAPHITE AND ARE USED TO TRANSFER CURRENT FROM OUTSIDE CIRCUIT TO LOOP.

(Y2 EA).

2

- SPLIT RING COMMUTATOR IS USUALLY MADE OF COPPER AND CHANGES THE DIRECTION OF CURRENT EVERY 180° ROTATION OF LOOP.

c) **On the diagram**, clearly show the force acting on elements AB, BC and CD. **[3 marks]**

AB ↑, BC (NO FORCE), CD ↓

3

d) Calculate the magnitude of the force acting element AB. **[2 marks]**

$$F = IlB = (2.50)(8 \times 10^{-2})(0.06)$$

$$= \underline{0.012\,N}$$

2

8

e) Consider the rectangular loop in its present position, what torque will be acting on the loop at present? **[3 marks]**

$\tau = Fr = (0.012)(1.5 \times 10^{-2})$

$= (1.8 \times 10^{-4}) \times 2$

$= \underline{\underline{3.6 \times 10^{-4}\ Nm}}.$

3

f) The rectangular loop now rotates 90° from its present position in a clockwise direction. What torque now acts on the loop? Explain your answer. **[3 marks]**

AT THIS POSITION $\tau = 0\,Nm$. THIS IS DUE TO THE FACT THAT THE FORCE ACTS PARALLEL TO THE LEVER ARM.

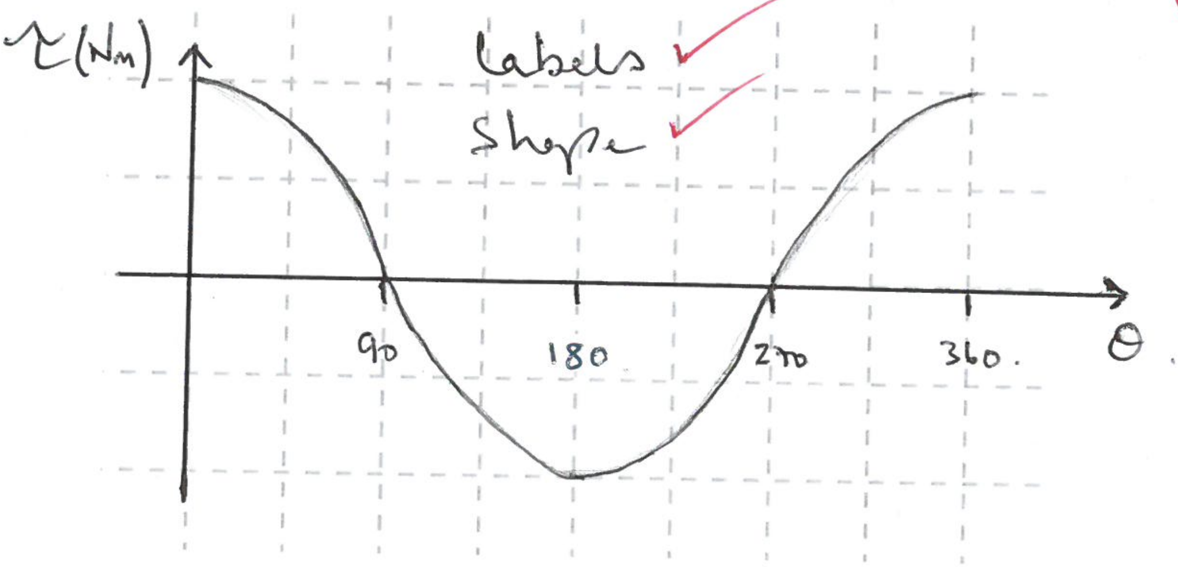
$\tau = Fr\sin\theta$, $\theta = 180°$

$\therefore \sin\theta = 0$.

3

g) Using the graph paper shown below, sketch the torque on the coil as it is rotated through 360°. **[2 marks]**

2



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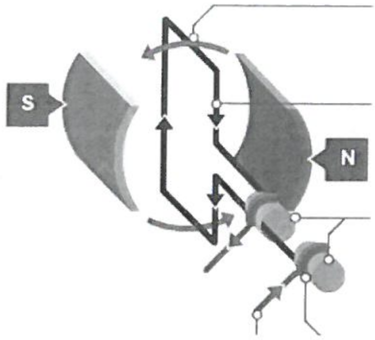
8

4. The diagram shown here represents an AC generator consisting of a rectangular coil with sides of 15cm x 20cm and 1200 turns, rotating in a uniform magnetic field. The magnetic flux through the coil in the present position is 2.50×10^{-4} Wb.



a) Calculate the magnitude of the magnetic field strength. **[3 marks]**

$\Phi_B = BA \quad \therefore \quad B = \dfrac{\Phi_B}{A} = \dfrac{(2.5\times10^{-4})}{(0.15\times0.2)}$ 3

$\therefore \underline{\underline{B = 8.33\times10^{-3}\ T}}$

b) If the coil rotates half a revolution from the position shown, in 0.03 seconds. Calculate the magnitude of the **maximum** induced EMF in the coil in this time. **[4 marks]**

$EMF = -2\pi NBAf$ (DATA SHEET).

$T = 0.06\,s, \quad \therefore f = \dfrac{1}{0.06} = \underline{16.7\,Hz}$ 4

$\therefore EMF = -(6.28)(1500)(8.33\times10^{-3})(0.15\times0.2)(16.7)$

$= \underline{\underline{39.3\ V}}$.

7

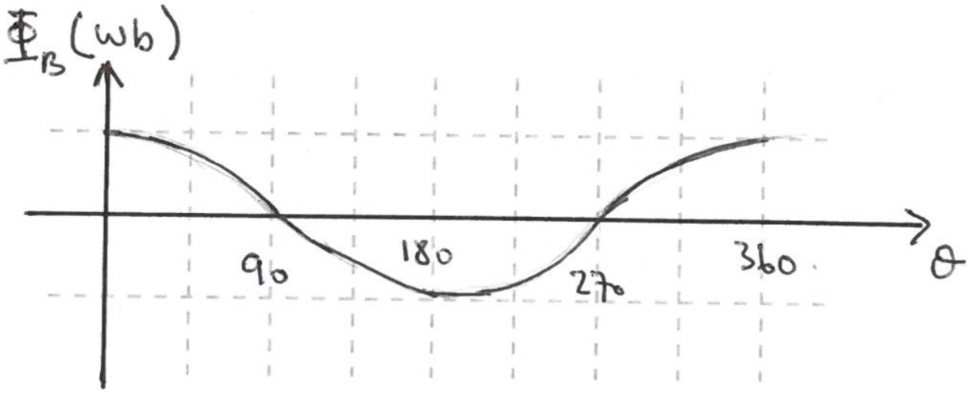
c) Explain how the EMF calculated in part (b) is produced. **[4 marks]**

FARADAY'S LAW STATES, A CONDUCTOR EXPERIENCING A CHANGING FLUX WILL INDUCE AN EMF SO AS TO OPPOSE (LENZ) THE CHANGE. AS THE CONDUCTING LOOP CUTS THE FLUX LINES BETWEEN THE MAGNETIC POLES, AN EMF IS INDUCED TO OPPOSE THE ROTATION IN ACCORDANCE WITH FARADAY'S LAW.

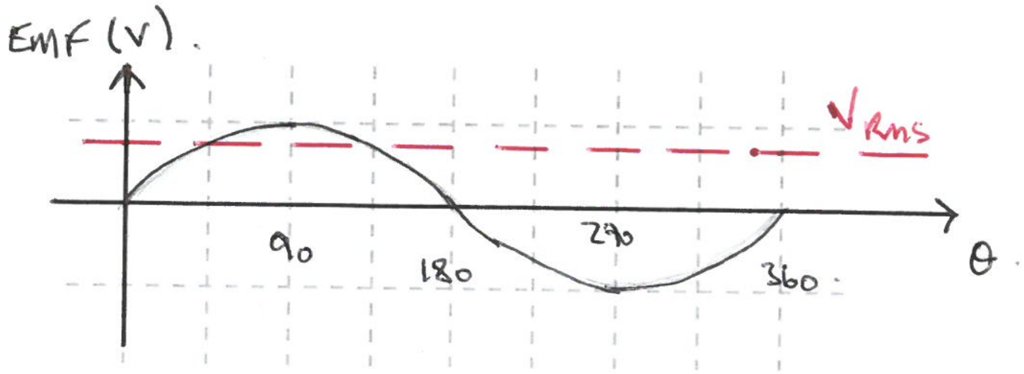
4

d) Using the graph paper shown below, sketch the flux and induced EMF on the coil as it is rotated through 360°. **[4 marks]**

4



- Labels.
- Max flux.
- Min emf.
- 90° out of phase



e) **Accurately draw** V_{RMS} on your graph (above). **[2 marks]**

2

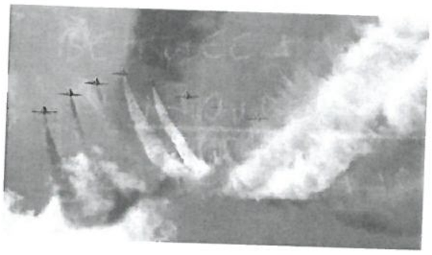
$$V_{RMS} = \frac{V_{MAX}}{\sqrt{2}} = \frac{39.3}{\sqrt{2}} = \underline{\underline{27.8V}}$$

DRAWN

SEE NEXT PAGE

10

5. The Royal Air Force Aerobatic Team, the Red Arrows, is one of the world's premier aerobatic display teams. A typical display will involve high speed loops, as well as high g banked turns.



a) The aerobatic team drop in formation from a height of 500 metres, forming a colourful loop. At the bottom of the loop, they are 100 metres from the ground and feel 3 times their normal weight. What speed are they traveling at when they reach the bottom of the loop? **[4 marks]**

$$\text{RADIUS} = \frac{(500-100)}{2} = 200\,m.$$

$$N = F_c + mg = 3mg$$

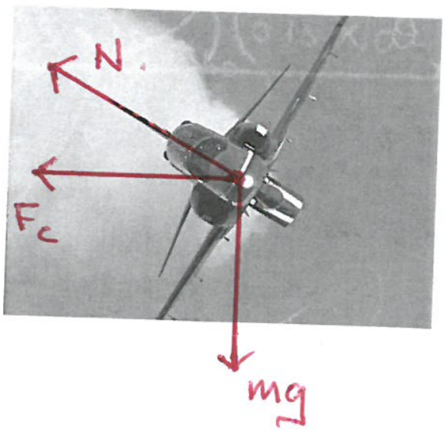
$$\therefore v^2 = 2gr = 2(9.8)(200)$$

$$= 3920$$

$$\therefore \underline{\underline{V = 62.6\,ms^{-1}}}.$$

4

b) Two planes break off and, using a high g banked turn, cross each others path just in front of the spectators. **On the diagram**, draw **ACCURATELY**, all the forces acting on this jet as it banks. **[3 marks]**



3

- FORCES NOT ACTING FM COG (−1)
- FORCES NOT STRAIGHT LINES (−1).

SEE NEXT PAGE

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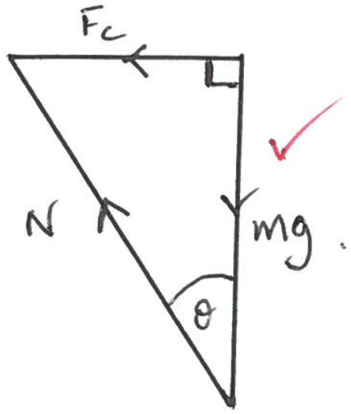
c) In which direction is this plane banking? **[1 mark]**

THE PLANE IS BANKING TO THE LEFT

1

d) Given that the banking turn has a diameter of 1.00km, **ESTIMATE** the speed of the jet as it makes the banked turn. **[5 marks]**

(EST θ = 55° to 65°)



$F_c = \frac{mv^2}{r} = mg\tan\theta$

5

$\therefore v^2 = rg\tan\theta$

FOR 55° (or) FOR 60° (or) FOR 65°

$v^2 = (500)(9.8)\tan 55°$ $= (500)(9.8)\tan 60°$ $= (500)(9.8)\tan 65°$

$\therefore v = 84\ ms^{-1}$ $= 92\ ms^{-1}$ $= 103\ ms^{-1}$

6

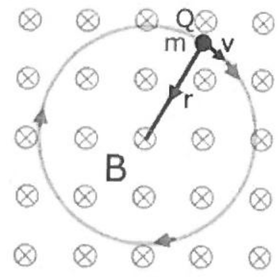
Section Three. Comprehension. **39 Marks Allocated**

Attempt **ALL FOURTEEN** (14) questions in this comprehension section. Marks for each question are clearly identified.

Charged particles and magnetic fields

A charged particle moving in a magnetic field experiences a perpendicular force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is known as the Lorentz force.



The Lorentz force is always perpendicular to both the velocity of the particle and the magnetic field that created it. When a charged particle moves in a static magnetic field it will trace out a helical path in which the helix axis is parallel to the magnetic field and in which the speed of the particle will remain constant.

Since the Lorentz force is always perpendicular to the motion of the particle, the magnetic field cannot do work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

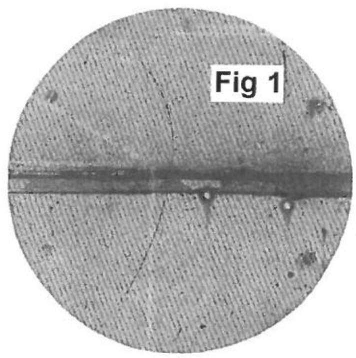
This phenomenon can be used in a number of useful ways:

1. To identify elementary particles.
2. To identify or categorise unknown elements.
3. As a tool to position elements precisely when building minute structures.

Identifying elementary particles

Elementary particle detectors utilise the fact that charged particles move in circular paths when they enter a magnetic field region.

The photo shows a cloud chamber photograph of the first positron ever identified. A 6 mm lead plate separates the upper half of the chamber from the lower half. The positron must have come from below since the upper track is bent more strongly in the magnetic field.

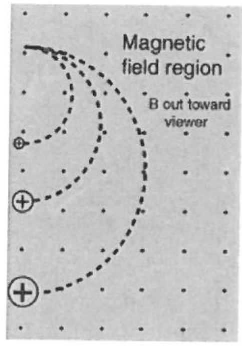


Cloud chambers are used to photograph elementary particles as they pass through the detector. This allows physicists to identify particles created through high energy collision events such as the LHC in CERN, Geneva. This picture shows the curving track of charged particles in a magnetic field cloud chamber.

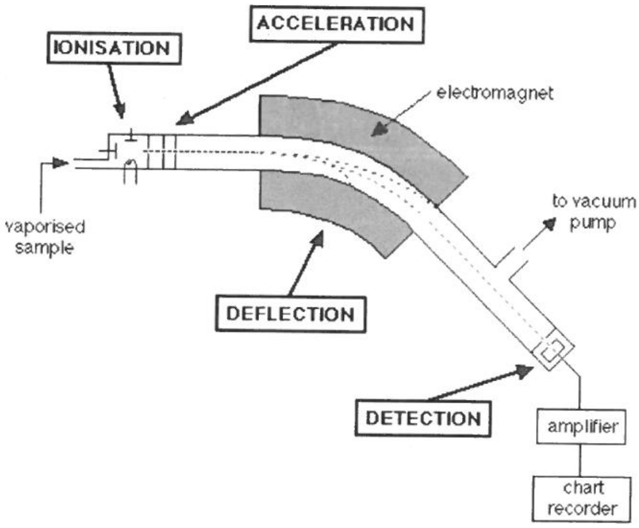
Identifying or categorizing unknown elements

Mass spectrometers are sensitive detectors of elements and isotopes based on their masses. They utilise and analytical technique that measures the mass-to-charge ratio of charged particles, making use of the Lorentz force that acts on charged particles moving in a magnetic field.

Ions are accelerated through a series of parallel plates inside a vacuum tube arrangement.



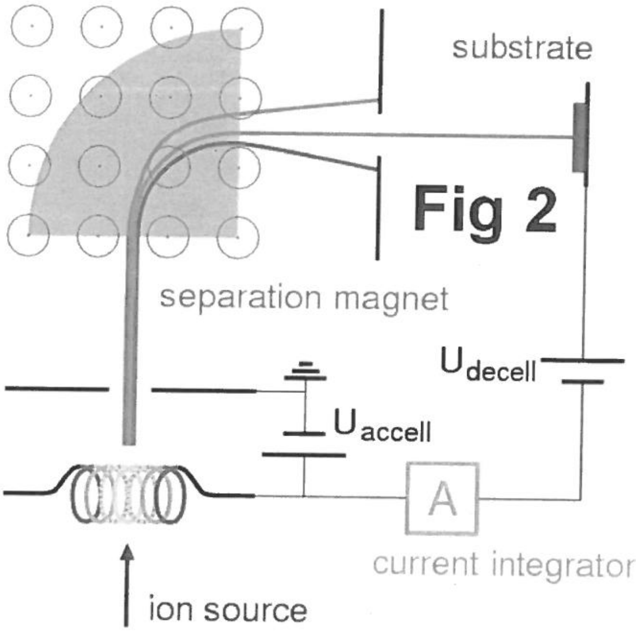
When the ions reach the electromagnet they are deflected from their straight line path through the action of the Lorentz force. Depending on their mass, charge, velocity and the applied magnetic field, they can be made to move in circular paths of varying radii. This allows identification by a trained technician.



Positioning elements precisely when building minute structures

Ion implantation is an engineering process where ions of a particular type are accelerated in an electrical field, deviated and targeted by a magnetic field and impacted into a solid. This process is used to change the electrical properties of the materials and is widely used in the semiconductor device fabrication of computer chips.

The introduction of dopants in a semiconductor is the most common application of ion implantation.



Dopant ions such as boron, phosphorus or arsenic are generally created from a gas source, so that the purity of the source can be very high. These gases tend to be very hazardous. When implanted in a semiconductor, each dopant atom can create a charge carrier in the semiconductor. A hole can be created for a p-type dopant, and an electron for an n-type dopant. This modifies the conductivity of the semiconductor in the implant area. This is what makes a semiconductor conduct.

The energy of the ions, as well as the ion species and the composition of the target determine the depth of penetration of the ions in the substrate. Typical ion energies are in the range of 10 to 500 keV. Energies in the range 1 to 10 keV can be used, but result in a penetration of only a few nanometers or less.

Typical dopants for semiconductors:

	Symbol	Mass (amu)	Charge
Boron	B	10.8117	3+
Phosphorus	P	30.9738	3-
Arsenic	As	74.9216	3-

Questions

1. Explain why the Lorentz force cannot do work on a isolated charged particle inside a magnetic field **B**. Use mathematical formulae to help explain your answer.

(3 marks)

$W_d = Fs\cos\theta$, SINCE F & S ARE PERPENDICULAR $\theta = 90°$ $\cos 90 = 0$ WHICH GIVES $W_d = 0. = (F)(s) \times 0.$

3

$\therefore$ NO WORK DONE !

2. Show that the radius of a charged particle inside a magnetic field **B** is given by the mathematical relationship:

(3 marks)

r = mv/qB

$F_c = F_B$ (SINCE CIRC MOTION).

$\therefore \frac{mv^{\cancel{2}}}{r} = q\cancel{v}B$. SO $mv = qBr$

3

$\therefore r = \frac{mv}{qB}$.

3. Refer to figure 1. Explain the statement, '*the positron must have come from below since the upper track is bent more strongly in the magnetic field*'.

(4 marks)

SINCE $r = \frac{mv}{qB}$; $r \propto v$ (m, q, B = CONST). 4

AS THE POSITRON TRAVELED THROUGH THE LEAD SHIELD IT LOST E_K AND SLOWED DOWN. SINCE $r \propto v$ THIS RESULTS IN A SMALLER RADIUS AND GREATER BENDING OF THE TRACK.

10

Questions

1. Explain why the Lorentz force cannot do work on a isolated charged particle inside a magnetic field **B**. Use mathematical formulae to help explain your answer.

[3 marks]

2. Show that the radius of a charged particle inside a magnetic field **B** is given by the mathematical relationship:

[3 marks]

$$r = mv/qB$$

3. Refer to figure 1. Explain the statement, '*the positron must have come from below since the upper track is bent more strongly in the magnetic field*'.

[4 marks]

4. Determine the direction of the magnetic field in Figure1. **(1mark)**

The direction of the **B** field in Figure 1 is: INTO THE PAGE. ✓ 1

5. Why is it necessary to have a very good vacuum in a mass spectrometer? **(3 marks)**

IF AIR WAS ALLOWED INTO THE SYSTEM THE AIR PARTICLES WOULD SCATTER THE IONS ✓ THROUGH COLLISIONS. THIS WOULD CHG THE SPEED AND DIRECTION ($r \propto v$, $r\downarrow$ IF $v\downarrow$) ✓ OF THE IONS CAUSING THEM TO MISS THE TARGET SUBSTRATE. ✓ 3

6. Refer to figure 2. What is the charge of the particle that hits the target substrate? **(1 mark)**

The charge of the particle that hits the substrate is: (+VE). 1

7. Calculate the velocity of a boron ion that is fired into the substrate with the maximum typical energy. **(4 marks)**

BORON MASS $= (10.8117)(1.6606 \times 10^{-27})$

$= 1.80 \times 10^{-27}$ Kg. ✓

MAX ENERGY = 500 KeV $= 8 \times 10^{-14}$ J. ✓

4

$$E_K = \frac{1}{2} m v^2$$

$$\therefore v^2 = \frac{2E}{m} = \frac{2(8 \times 10^{-14})}{1.80 \times 10^{-27}}$$ ✓

✓

$$\therefore v = 9.43 \times 10^6 \; ms^{-1}.$$

9

4. Determine the direction of the magnetic field in Figure1. **[1mark]**

The direction of the **B** field in Figure 1 is: ______________________

5. Why is it necessary to have a very good vacuum in a mass spectrometer? **[3 marks]**

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6. Refer to figure 2. What is the charge of the particle that hits the target substrate? **[1 mark]**

The charge of the particle that hits the substrate is: ______________________

7. Calculate the velocity of a boron ion that is fired into the substrate with the maximum typical energy. **[4 marks]**

8. The ion implanter is now reconfigured to deliver As ions into the substrate and the ion energy is reduced to produce a velocity of 8,50x10^4 ms^{-1}. If the internal magnetic field is set to be 5.00 mT, what radius of curvature should the machine now be set to? **(4 marks)**

CHARGE :

$q = (3)(1.6 \times 10^{-19})$

$= \underline{4.8 \times 10^{-19} C}$. ✓

MASS :

$m = (74.9216)(1.6606 \times 10^{-27})$

$= \underline{1.24 \times 10^{-25} kg}$ ✓

$$r = \frac{mv}{qB}$$

(4)

$$= \frac{(1.24 \times 10^{-25})(8.50 \times 10^{4})}{(4.8 \times 10^{-19})(5 \times 10^{-3})}$$ ✓

$= \underline{\underline{4.39 \text{ m}}}$. ✓

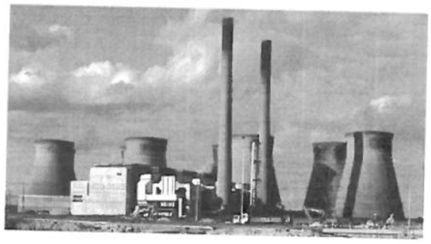
(4)

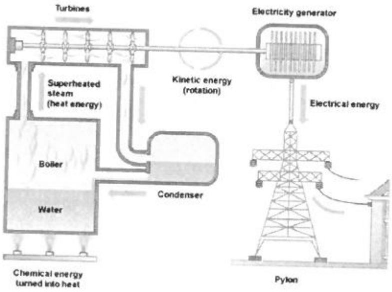
8. The ion implanter is now reconfigured to deliver As ions into the substrate and the ion energy is reduced to produce a velocity of $8{,}50 \times 10^{4}$ ms^{-1}. If the internal magnetic field is set to be 5.00 mT, what radius of curvature should the machine now be set to?

[4 marks]

Generation and Transmission of Electricity

Approximately 30% of the energy used in Australia is generated by power stations. The largest power station in Western Australia is Muja, which is situated close to the coalmining town of Collie.



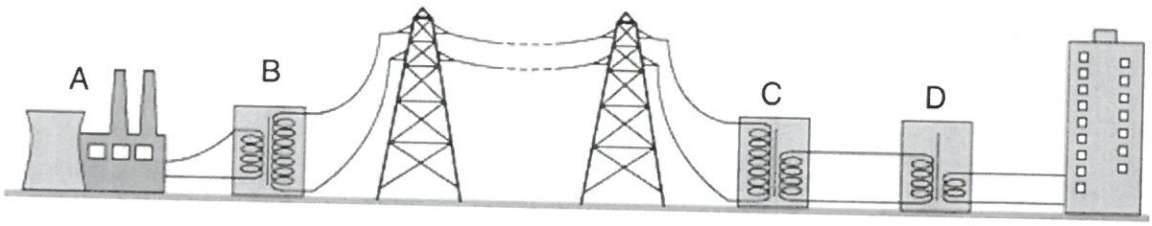


At Muja coal is ground to the consistency of powder and then burned to heat water until it turns into steam. Steam at 540°C and pressure of 16MPa (megaPascals) is used to drive turbines at a rate of 3000 rpm.

Muja power station generates at a total of 1040MW from it's 8 generators. There are 4 60MW generators and 4 200MW generators. The 60MW generators produce power at 11.8kV and the 200MW generators produce power at 16kV. Generators feed the electricity produced into transformers where the voltage can be stepped up or stepped down.

Before the electricity is distributed, transformers are used to step up the voltage to 330kV. High voltage transmission has advantages in reducing energy lost due to the resistance of the transmission lines. On the outskirts of Perth there is a substation that reduces the voltage to 11kV and in the local park is a further small transformer that reduces the voltage to 240 volts for household use.

Questions



9. Using the diagram shown above identify components A, B, C and D and describe the function they provide. **[4 marks]**

A	COAL FIRED POWER STATION, EITHER (60MW @ 11.8KV) or (200MW @ 16KV)
B	STEP-UP TRANS: (11.8KV to 330KV) or (16KV to 330KV).
C	STEP-DOWN TRANS: (330KV to 11KV).
D	STEP-DOWN TRANS: (11KV to 240V) DOMESTIC USE.

4

(½ PER TICK)

10. Explain why the generator is designed to produce (AC) alternating current and not (DC) direct current **[2 marks]**

TRANSFORMERS CAN ONLY STEP-UP OR STEP-DOWN AC CURRENT TO INCREASE (OR DECREASE) VOLTAGE, AS CHANGING FLUX IS REQUIRED.

2

11. Explain why the voltage is stepped up to 330kV before it is distributed to users on the grid. **[2 marks]**

SINCE $P = IV$, WHEN $V\uparrow$ (STEP-UP), $I\downarrow$. POWER LOSS IS GIVEN BY $P = I^2R$, SO WHEN $I\downarrow$, POWER LOSS IS REDUCED.

2

8

12. Calculate the current generated in one of the 60MW generators. **[2 marks]**

$$P = IV \quad \therefore \quad I = \frac{P}{V} = \frac{60 \times 10^6}{11.8 \times 10^3}$$

$$= \underline{\underline{5.09 \times 10^3\ A}}.$$

(2)

13. Calculate the turns ratio of a transformer used to step-up the voltage from a 60MW generator to 330kV. **[2 marks]**

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{330 \times 10^3}{11.8 \times 10^3} = 28.$$

$$\therefore \underline{\underline{\text{RATIO} = 28:1}}.$$

(2).

14. Assume that power station A is a 60MW power station and that the distance BC is 1.20km. If the resistance in the transmission lines is 0.002Ωm^{-1}, calculate the power lost in this section of the electrical distribution network. **[4 marks]**

$$AC \quad \therefore \quad R(\times 2) = (1200)(0.002)(2)$$

$$= 4.8\,\Omega.$$

(4).

$$I_s = \frac{I_p V_p}{V_s} = \frac{(5.09 \times 10^3)(11.8 \times 10^3)}{(330 \times 10^3)} = 182\,A$$

$$P = I^2 R = (182)^2 (4.8)$$

$$= \underline{\underline{1.59 \times 10^5\ W}}.$$

SEE NEXT PAGE

(6).

Extra page for additional working

SEE NEXT PAGE

Extra page for additional working

End of examination

SEE NEXT PAGE