ARANMORE CATHOLIC COLLEGE

YEAR 12 PHYSICS 3A3B - 2010

TEST 3: - ELECTROMAGNETISM

NAME: SOLUTIONS

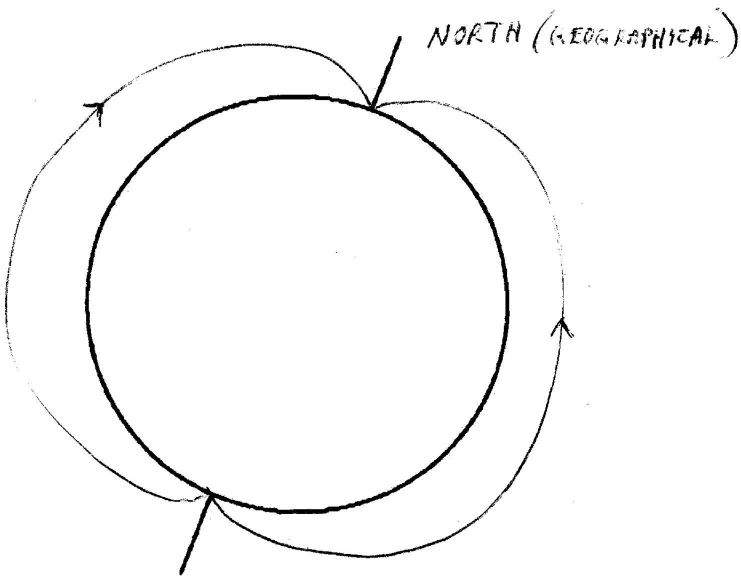
MARK: /50

Instructions:

1. Answer all questions in the spaces provided.
2. Show all working out to get full marks as shown in brackets after each question.
3. Answers should be in decimal form and show correct use of significant figures.
4. Graphic and scientific calculators as per Curriculum Council guidelines are permitted.
5. Where practical, answers must be in blue or black ink.

QUESTIONS:

1. On the diagram of the earth below, draw the Earth's magnetic field. (3 marks)



1 MARK FOR LINES (MIN 2)

1 MARK FOR ARROW DIRECTION

1 MARK INDICATION OF ORIENTATION OF EARTH.

2. Estimate the magnitude of the force acting on the 10 A wires in your place of residence, if they are perpendicular to the field of the earth ($B_e = 6.0 \times 10^{-5}$ T). How will the force on the actual wires in your residence differ from this value and give two reasons why they will differ?

(4 marks)

$I = 10A$ (MAX)
$B = 6.0 \times 10^{-5} T$
$\theta = 90°$

$F = BIl\sin\theta$ (1)

$\frac{F}{l} = 6 \times 10^{-5} \times 10 \times 1$
$= 6 \times 10^{-4} Nm^{-1}$. (1)

(1) ACTUAL FORCE WILL BE LESS DUE TO:
(a) NOT ALL WIRES PERPENDICULAR TO B ($\sin\theta \neq 1$ (i.e. <1)).
(1) OR (b) I WILL NOT BE AT MAXIMUM ($I < 10A$).

3. (a) A magnetized needle is placed on a piece of polystyrene and floated in the middle of a container of water. Describe the motion of the needle until it comes to rest and explain your answer.

(3 marks)

(1) - NEEDLE WILL ROTATE TOWARDS A NORTH/SOUTH ALIGNMENT, GO A LITTLE PAST THIS ORIENTATION, THEN MOVE BACK AND FORTH PAST THIS ORIENTATION UNTIL IT STOPS ALIGNED IN NORTH/SOUTH DIRECTION.
(1) - MAGNETIC FORCE ON EACH END OF NEEDLE DUE TO EARTH'S MAGNETIC FIELD
(1) - PRODUCES A TORQUE WHICH ATTEMPTS TO ROTATE THE NEEDLE.
(MOMENTUM CAUSES IT TO GO PAST NORTH AND COME BACK AGAIN)

(b) Explain why the needle of a cheap compass in Perth is not quite in the horizontal plane. In which way does it dip – does the north or south end of the compass dip downwards? Is there anywhere on the earth that the needle of this compass would be horizontal?

(3 marks)

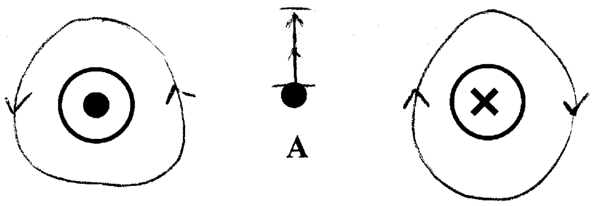
(1) - SOUTH END DIPS DOWN
(1) - EARTH'S MAGNETIC FIELD IS NORTH AND ALSO POINTS A LITTLE UPWARDS IN SOUTHERN HEMISPHERE (PERTH) DUE TO EARTH'S CURVATURE.
(1) - ON EQUATOR.

4. Determine the direction of the resultant magnetic field due to the following identical bar magnets or the current-carrying conductors, at each of the points A, B, C and D.

(4 marks)

CONDUCTORS:

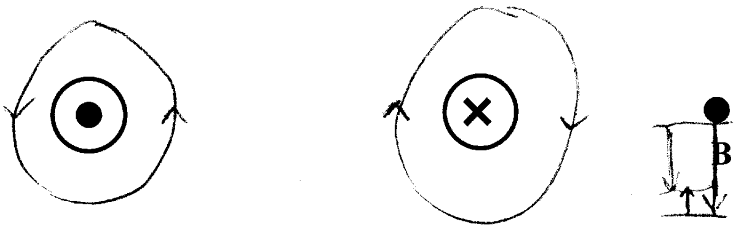
(a)



DUE NORTH (IF N)
(OR UPWARDS)

(1)

(b)



DUE SOUTH.

(1)

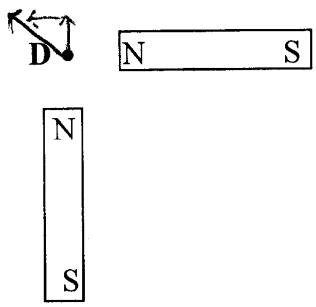
BAR MAGNETS:

(c)

DUE EAST.

(1)

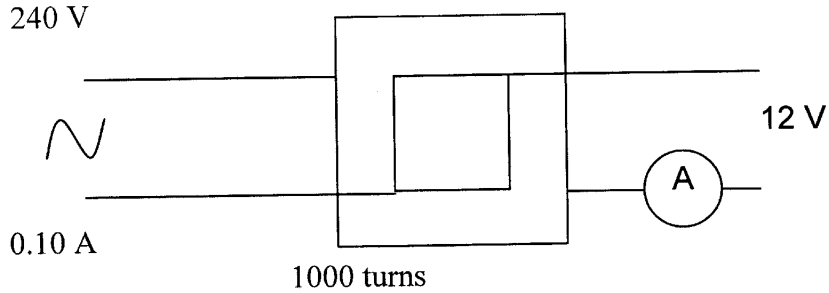
(d)



NORTH-WEST.

(1)

5. A simple transformer is illustrated below:



(a) Determine the reading on the ammeter and the number of secondary coils, assuming 100% efficiency.

(4 marks)

PRIMARY

$V_p = 240V$

$I_p = 0.10 A$

$N_p = 1000$ TURNS

SECONDARY

$V_s = 12V$

$V_p I_p = V_s I_s$ (1)

$I_s = \frac{V_p I_p}{V_s} = \frac{240 \times 0.10}{12} = 2.0\ A.$ (1)

$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ (1)

$N_s = \frac{V_s N_p}{V_p} = \frac{12 \times 1000}{240} = 50$ TURNS. (1)

(b) What are eddy currents? Explain their effect on a transformer.

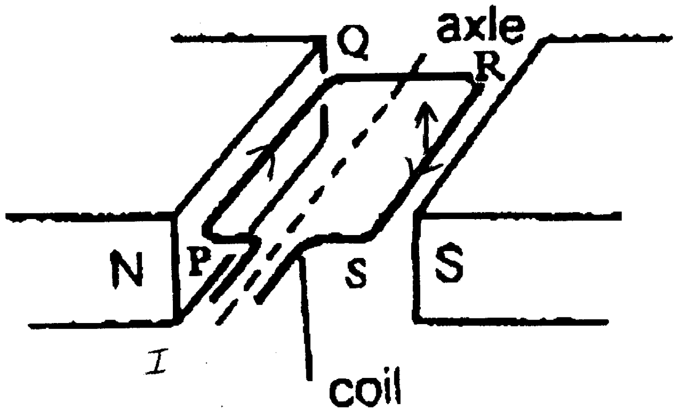
(3 marks)

(1) – EDDY CURRENTS ARE (CIRCULAR) CURRENTS INDUCED IN A CONDUCTING PLATE DUE TO CHANGING MAGNETIC FLUX IN THE PLATE.

(1) – IF EDDY CURRENTS OCCUR IN THE IRON CORE OF A TRANSFORMER, ENERGY (OR POWER) LOSS OCCURS DUE TO RESISTANCE OF CORE ($P = I^2R$).

(1) – THIS ENERGY LOSS OCCURS IN FORM OF HEAT AND REDUCES THE EFFICIENCY OF A TRANSFORMER (IT CAN ALSO BE A FIRE HAZARD IF OVERLOADED).

6. Peter was required to build a simple DC motor as part of a laboratory investigation. He wound a rectangular coil of 20 turns to make a coil with a length of 0.05 m and a width of 0.04 m. The coil was pivoted in the centre so that it could rotate around the axis as shown by the dotted line in the diagram below. A current of 2.00 A (from P to S through the coil) was used and the field in the region of the coil had a uniform strength of 6.00×10^{-1} T.



F IS UPWARDS. (1)

(a) On the side marked RS of the coil, indicate the direction of the force by drawing an arrow on the diagram. Calculate the magnitude of the force. (Show all working.)

(4 marks)

$B = 0.600$ T
$I = 2.00$ A
$\ell = 0.05$ m
$N = 20$ TURNS
$\theta = 90°$

$F = N B I \ell \sin\theta$ (1)
$= 20 \times 0.6 \times 2 \times 0.05$ (1)
$= 1.2$ N UPWARDS. (1)

(b) The coil is stationary in the position shown on the diagram, but begins to rotate when the current is turned on. Explain how this happens when the total force acting on the coil is 0 N.

(3 marks)

(1) F(PQ) IS DOWNWARDS
SO F(PQ) = − F(RS) HENCE $F_{TOTAL} = 0$ N.

(1) – HOWEVER, SINCE COIL IS PIVOTED IN CENTRE AND THE TWO OPPOSING FORCES ARE AT EITHER SIDE OF THE COIL, A TORQUE IS PRODUCED.

(1) – THE TORQUE CAUSES COIL TO ROTATE.

(c) Explain three ways that the speed of the coil could be increased.

(3 marks)

NEED TO INCREASE THE TORQUE:

$$\tau = NBIA$$

(ANY 3)

SO INCREASE:

N - NO. OF TURNS

I - CURRENT

B - STRENGTH OF MAGNETIC FIELD

A - AREA OF COIL (OR l OR r)

(d) Explain how this arrangement could be modified to make a generator.

(3 marks)

(1) - NO CURRENT SUPPLIED

(1) - COIL ARMATURE CONNECTED TO A DRIVE PULLEY

(1) - COIL IS MECHANICALLY TURNED IN THE MAGNETIC FIELD AND INDUCES A CURRENT.

(e) Explain the role of Faraday's law and Lenz's law in the generator.

(4 marks)

(1) FARADAY - $\varepsilon = -\frac{\Delta \Phi}{\Delta t} = BA\omega \sin(\omega t)$

(1) - RATE OF ROTATION OF COIL IN MAGNETIC FIELD INDUCES AN EMF IN THE COIL DUE TO THE CHANGING FLUX.

(1) LENZ - THE MAGNETIC FIELD DUE TO THE INDUCED CURRENT WILL ALWAYS OPPOSE THE CHANGE IN THE EXTERNAL FIELD, WHICH PRODUCED THE INDUCED CURRENT.

(1) - THIS RESULTS IN THE ENERGY REQUIRED TO ROTATE THE COIL IN THE FIELD BEING TRANSFORMED INTO ELECTRICAL ENERGY.

7. An electrical power station produces electricity at 16 kV, but steps up the voltage to 330 kV before transmitting it to a small city 120 km away. The station uses a 200 MW generator to provide the city's power supply.

(a) Calculate the percentage power loss from the power station to the city if the average resistance in the transmission cables is $1.2 \times 10^{-4}\ \Omega\ m^{-1}$.

(4 marks)

(1) $R_{TOTAL} = 1.2 \times 10^{-4} \times 120000 = 14.4\ \Omega.$

$P_{TOTAL} = VI$

(1) $I = \frac{200 \times 10^6}{330 \times 10^3} = 606\ A$

(1) $P_{LOSS} = I^2 R = 606^2 \times 14.4 = 5.29 \times 10^6\ W$

(1) $\%\ LOSS = \frac{P_{LOSS}}{P_{TOTAL}} \times 100\% = \frac{5.29 \times 10^6}{200 \times 10^6} \times 100\%$

$= 2.6\%.$

(b) Explain why the power station steps up the voltage to 330 kV before transmitting electricity to the city.

(2 marks)

(1) - TO REDUCE THE POWER LOSS IN TRANSMISSION.

(1) - INCREASING V, DECREASES I, WHEN $P(=VI)$ IS CONSTANT. WITH LOWER I, POWER LOSS DECREASES $(P_{LOSS} = I^2 R)$.

(c) Why do the transmission cables from the power station have a much larger diameter than the cables which supply electric power direct to our homes?

(3 marks)

(1) - TO REDUCE THEIR RESISTANCE $\left(R = \frac{\rho l}{A}\right)$

(1) - TRANSMISSION LINES ARE VERY LONG AND SO R MUST BE MINIMISED IN ORDER TO DECREASE THE POWER LOSS. THE ONLY WAY TO DO THIS IS TO INCREASE THE CROSS-SECTIONAL AREA (i.e. DIAMETER).

(1) - THERE IS LESS POWER IN CABLES TO HOUSES AND SO CURRENT IS LOW AND POWER LOSS IS LESS OF A PROBLEM.

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END OF TEST