

CARLETON UNIVERSITY

Regular Final
EXAMINATION
December 2015

Duration: 3 hour

Department name and course number:

Electronics: ELEC 3105 A / PLT 3003 A

Course Instructor(s): **R. Gauthier**

Number of students: 100+

AUTHORIZED MEMORANDA:

University approved CALCULATOR. No other electronic device permitted.
Students may bring a cube, cylinder and sphere with them.

Students MUST count the number of pages in this examination paper **before** beginning to write and report any discrepancies immediately. This question paper has 18 pages including equation pages.

This exam consists of 5 sections. Carefully read the instructions in each section and only answer the stated number of questions. No bonus marks are given for extra answers. The exam is graded out of 60 points and is worth 60% of your final grade.

Invigilators are not to answer any questions or inquiries related to the exam questions. The solution must be clearly indicated. Multiple solutions or solutions that are not clearly identified will be marked incorrect. In the answers you provide, if the wording is vague, or subject to the corrector's interpretation, it will be marked incorrect. Clearly state and justify all assumptions made. In the event that a question seems to be missing information proceed to the next question, returning to the offending question time permitting. Unless otherwise indicated use free space for the magnetic and electric properties. **Clearly mark the units for all final answers. Clearly indicate axis/units for any graphs.** Simply stating a final answer from memory gives no points. **SHOW YOUR WORK!**

Do not write answers in the exam questionnaire. All writings in the exam questionnaire are not graded and not considered part of your answers. All exam questionnaires must be handed in with your answers.

Exam booklets required → YES

Section 1: General Knowledge Based Questions

Answer all questions in this section

Each question is worth 1 point


1.1: If the distance between two negatively charged ions is doubled, the force on one of them due to the other will:

- a) increase by a factor of 2
- b) remain the same
- c) decrease by a factor of 2
- d) decrease by a factor of 4

$$\frac{kq_1q_2}{r^2} \Rightarrow \frac{kq_1q_2}{4r^2}$$

1.2: When placed a distance d from a positive point charge, a positively charged particle has a potential energy U due to the electric field created by the point charge. If the charged particle is moved to a distance $2d$, which of the following represents its potential energy?

- a) $U/2$ ← difference
- b) $U/4$
- c) $U/2$
- d) $2U$

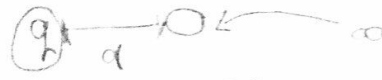


$$V = \frac{kq}{R} = \frac{kq}{d}$$

$$\Rightarrow \frac{kq}{2d}$$

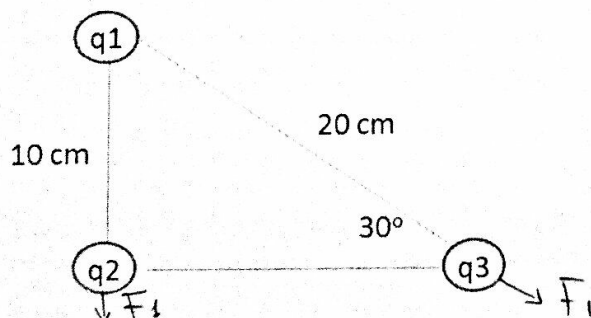
1.3: A charged particle is moved from a great distance to a distance d from a point charge. At distance d , the electric field has a strength E and a potential V . Which of the following represents the work done per unit charge q ?

- a) V
- b) Eqd
- c) Vq
- d) Eq/d



$$Vq$$

1.4: Three point charges are separated by the distances shown. If all charges are equal, which of the following is true?



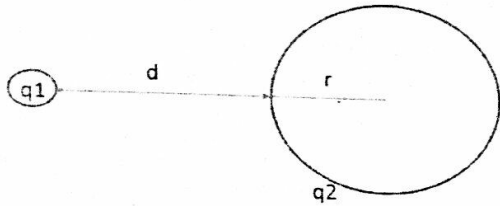
$$kq_1q_2(100)$$

$$kq_1q_3(25)$$

- a) The electrostatic force on q_2 due to q_1 is half as great as the electrostatic force on q_3 due to q_1
- b) The electrostatic force on q_2 due to q_1 is equal to the electrostatic force on q_3 due to q_1
- c) The electrostatic force on q_2 due to q_1 is twice as great as the electrostatic force on q_3 due to q_1
- d) The electrostatic force on q_2 due to q_1 is four times as great as the electrostatic force on q_3 due to q_1

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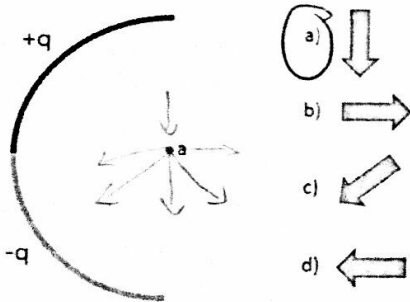
1.5: Inside a vacuum chamber, a point charge q_1 is separated by a distance d from the surface of a hollow sphere with a radius r and made of a conducting material. The sphere has a charge q_2 . Note k is the Coulomb's law constant. What is the electric field strength a distance $r/2$ from the center of the sphere?



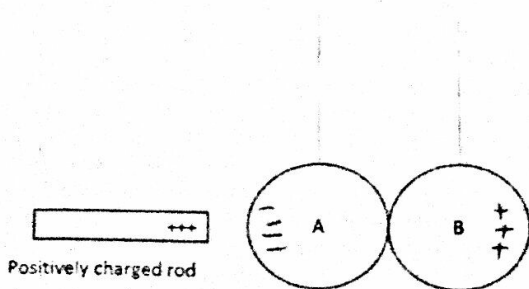
- a) zero
- b) kq_1/r^2
- c) $2kq_1/r$
- d) $kq_1/(4r^2)$

$$\frac{kq_1}{(d + \frac{r}{2})^2}$$

1.6: The curve shown is made from a nonconducting material. It holds a positive charge on its top half and a negative charge on its bottom half. Which of the following represents the direction of the net electric field at point a?



1.7: A and B below are neutral conductors hanging from a string that do not conduct electricity. If a positively charged rod is placed near A as shown, and B is then separated from A:

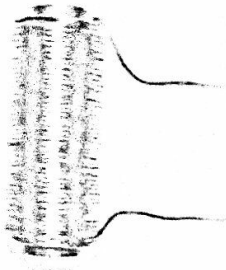


- a) Both A and B will be positively charged
- b) Both A and B will be negatively charged
- c) A will be positively charged and B will be negatively charged
- d) B will be positively charged and A will be negatively charged

1.8: Which of the following is true for any circuit?

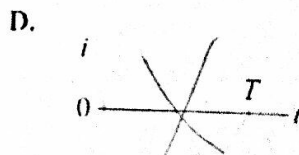
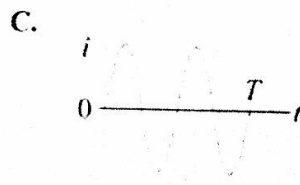
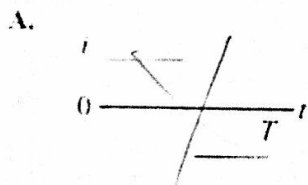
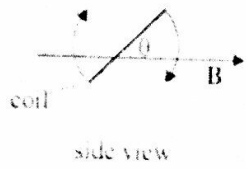
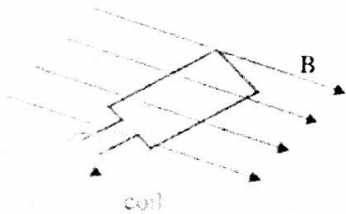
- a) The rate of flow of electrons is the same at any point in the circuit ~~X~~
- b) The voltage drop in one complete trip around the circuit from any point is equal to the voltage of the battery
- c) Any two resistors placed across the same voltage will have the same current ~~X~~
- d) The voltage between two points in a circuit is independent of the path chosen to measure it ✓

* 1.9: A piece of iron is wrapped by copper wire as shown. Which of the following is correct?



- a) A current in the wire will turn the iron into a bar magnet ~~X~~
- b) If the iron is magnetized, a current will be produced in the wire during magnetization
- c) Both a) and b) are true
- d) Neither a) or b) is true

* 1.10: A conducting coil is rotated at a constant speed in an external magnetic field as shown. A current is generated within the loop. T represents the time required for the loop to make one full rotation. Which of the following most likely represents the current i generated within the coil as a function of time.

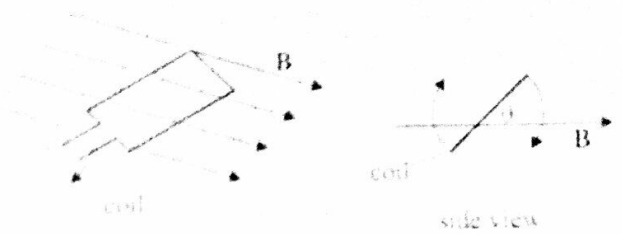


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1.11: Which of the following would increase the current generated in the coil?

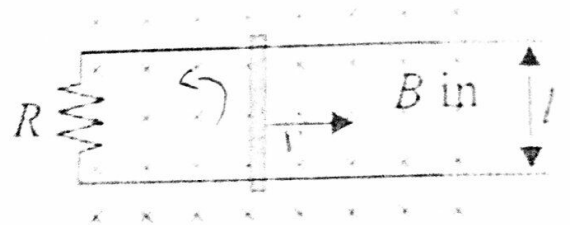
- i) increase the speed of rotation of the wire loop
- ii) increase the size of the coil
- iii) increase the strength of the magnetic field

- a) i) only
- b) ii) only
- c) i) and ii) only
- d) i), ii) and iii)



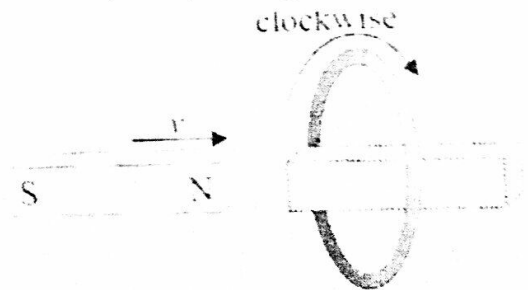
1.12: A conducting bar is slid at a constant velocity v along two conducting rods. The rods are separated by a distance l and connected across a resistor R . The entire apparatus is placed in an external magnetic field B directed into the page. How will the current in the apparatus be generated?

- a) sinusoidally
- b) clockwise (up through the resistor)
- c) counter clockwise (Down through the resistor)
- d) There is not enough information to determine the direction of the current

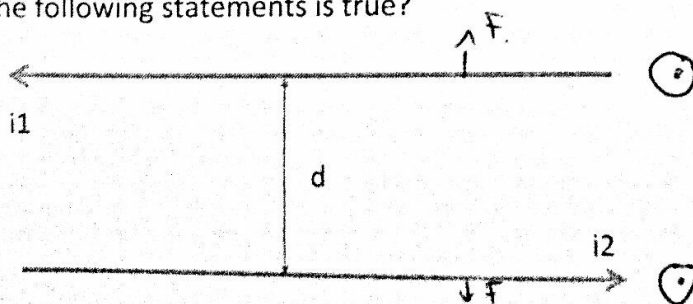


1.13: A magnet is pulled through a stationary, conducting ring at a constant velocity. In which direction will the current in the ring be generated when the magnet moves completely through the ring?

- a) clockwise then counter clockwise
- b) counter clockwise then clockwise
- c) clockwise only
- d) counter clockwise only

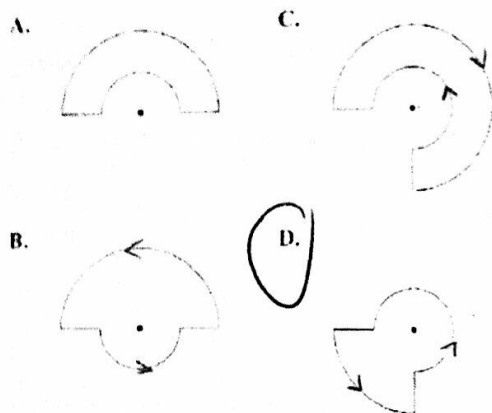


1.14: Two long wires 1 and 2 separated by a distance d conduct current in opposite directions. Which of the following statements is true?



- a) The magnetic field created by i_1 creates a net force on both wires
- b) The magnetic field created by i_1 creates a net force on wire 1 only
- c) The magnetic field created by i_1 creates a force on wire 2 only

d) The magnetic field created by i_1 does not create a net force on either wire.
 1.15: A clockwise current of the same magnitude exists in each of the rings shown. At which points shown is the magnetic field strength the greatest?

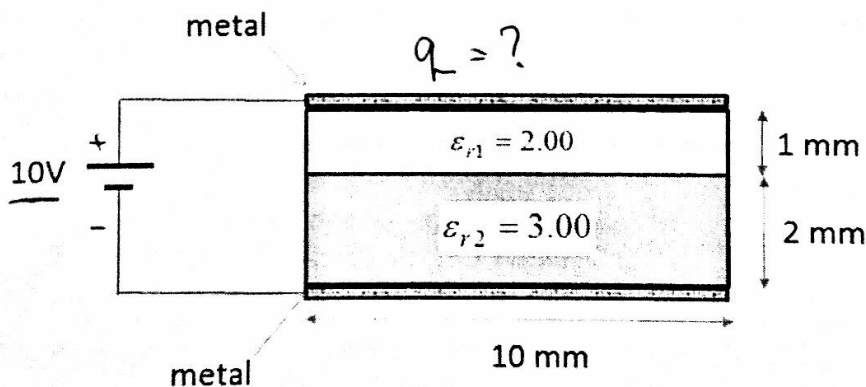


Section 2: Electrostatics

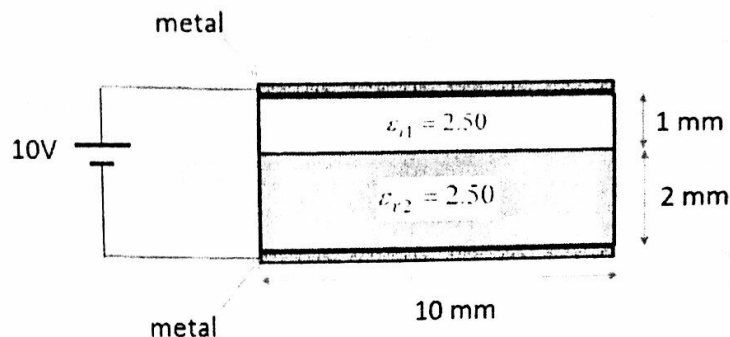
Answer only 3 of the 4 questions in this section

Each question is worth 3 point

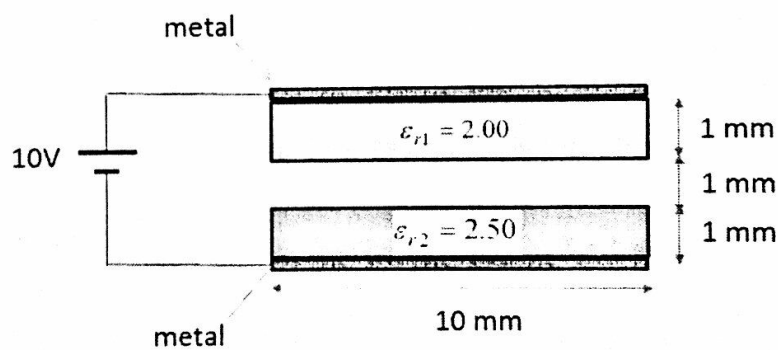
2.1: If the voltage difference between the upper and lower metal plates is 10 V, with the upper plate at the higher potential, determine the total positive charge on the plate connected to the positive terminal of the battery. Assume that the electric field is uniform and confined inside the "capacitor" plates. Also take the depth of the plates to be 10 mm.



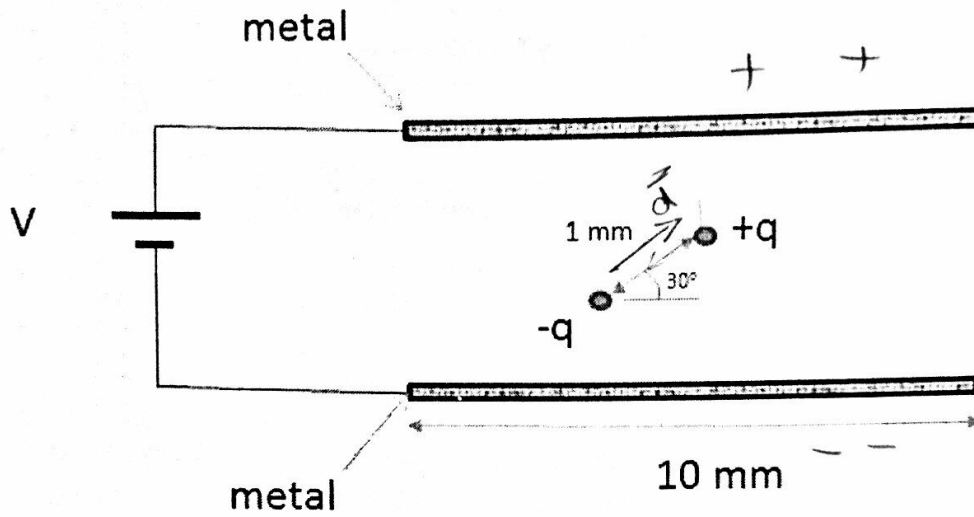
2.2: If the voltage difference between the upper and lower plates is 10 V, with the upper plate at the higher potential, use either Poisson's or Laplace's equation to obtain an expression for the potential as a function of position between the plates. Assume that the electric field is uniform and confined inside the "capacitor" plates. Take $\epsilon_{r1} = \epsilon_{r2} = 2.50$. Also take the depth of the plates to be 10 mm.



2.3: A small 1 mm gap is introduced between the two dielectric materials. Use the principle of virtual work to determine an expression for the electrostatic force trying to bring the dielectric media together. Assume that the electric field is uniform and confined inside the "capacitor" plates. Also take the depth of the plates to be 10 mm. Take the electric field value in the dielectric medium with $\epsilon_{r1} = 2.00$ as 1V/m.



2.4: An air filled parallel plate capacitor is shown in the figure. The voltage is adjusted such that the electric field between the plates is exactly 10 V/m (down). A rigid dipole is placed inside the capacitor in the orientation shown. Take q to be 1 C and the charge separation to be 1 mm . What is the net force on the dipole? What is the net torque on the dipole (indicate CW or CCW as well)? Assume the dipole does not alter the electric field between the capacitor plates.



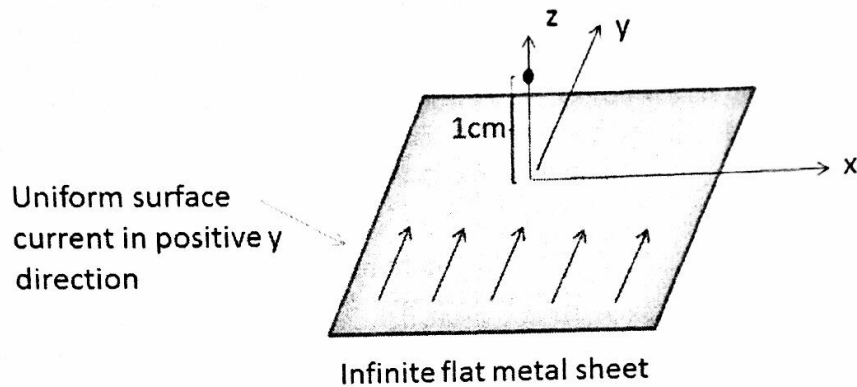
Section 3: Magnetostatics

Answer only 3 of the 4 questions in this section

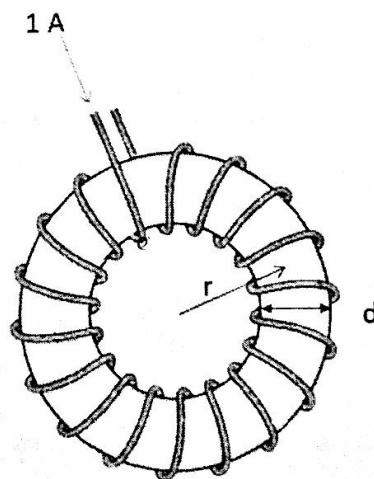
Each question is worth 3 point

3.1: Define paramagnetic, diamagnetic and ferromagnetic. Indicate at least one interesting magnetostatic property of each. Indicate what property of the electrons in the atoms is responsible for the magnetic behaviour.

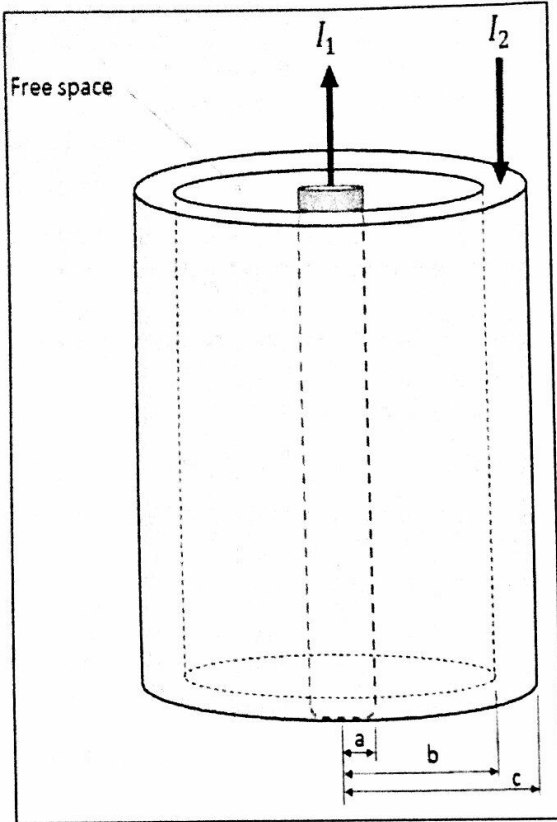
3.2: An infinite flat metal plate carries a uniform surface current of 1 A/m in the direction shown. Determine the magnetic flux density vector at a point 1 cm above the plate.



3.3: A toroid is shown in the figure. The radius of the toroid $r = 5 \text{ cm}$ and has a circular core cross-section with a diameter $d = 10 \text{ mm}$. A current $I = 1 \text{ A}$ flows in the windings. If the core has a relative permeability of 20.0 , determine H , M and B inside the toroid. Assume the magnetic field is uniform over the cross-sectional area of the toroid.



$$\frac{\mu_0 N^2 A}{l}$$



A section of an infinitely long and perfectly straight coax cable is shown in the figure. The inner conductor has a radius $a = 1$ mm and carries a current I_1 in the \hat{z} direction. The inner conductor has a relative permeability, $\mu_{r1} = 1.00$. The outer conductor region is in the shape of metallic cylindrical shell of inner radius $b = 5$ mm and outer radius $c = 6$ mm. The outer metallic shell carries a total current of I_2 in the $-\hat{z}$ direction. The outer metallic shell conductor has a relative permeability, $\mu_{r2} = 2.00$. Assume the current is uniformly distributed over the cross-section of the conductors.

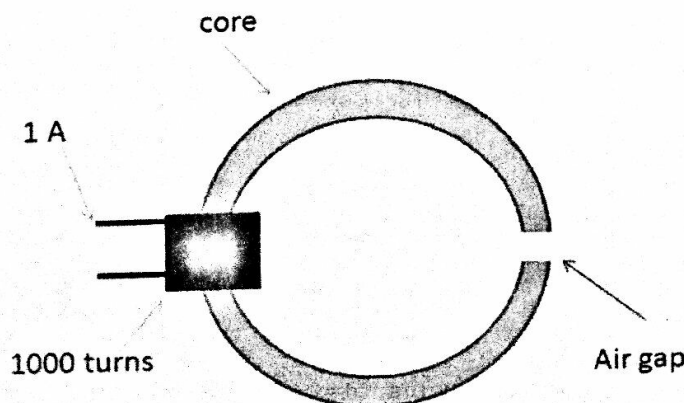
3.4: Determine the magnetic flux passing through a rectangular surface defined by the radial range $a \leq r \leq b$ and axial range $0 \leq z \leq 1$ m. Take the current $I_1 = 1$ A in the \hat{z} direction and the current $I_2 = 1$ A in the $-\hat{z}$ direction.

Section 4: Magnetic Circuits

Answer only 3 of the 4 questions in this section

Each question is worth 3 point

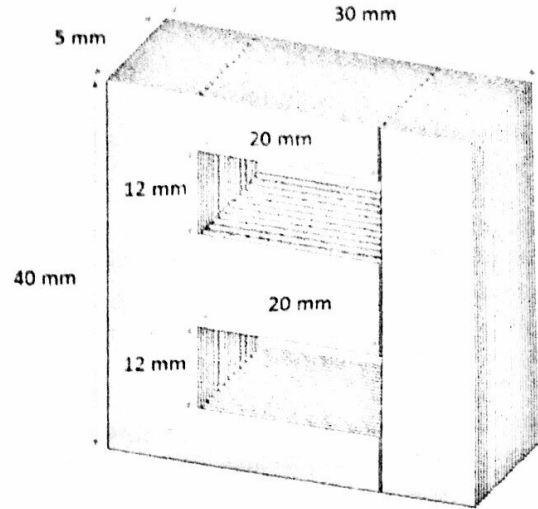
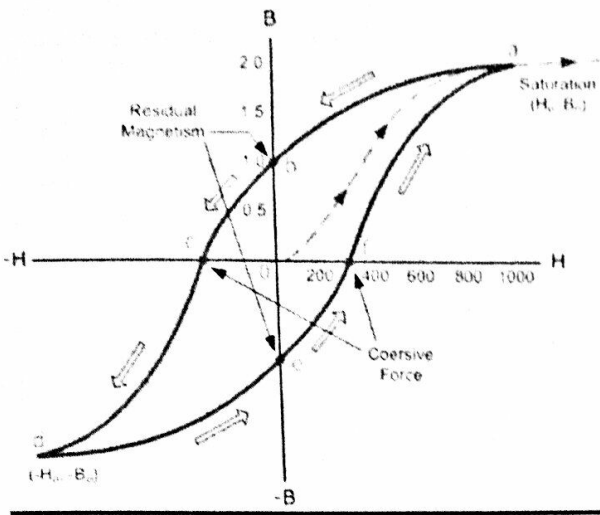
4.1: The cast iron magnetic core is shown in the figure has a cross-section area of 4 cm^2 , length of 0.438 m and relative permeability of 400 . The air gap has a length of 2 mm. The attached coil has 1000 turns and flows a current of 1 A. Determine the mmf, reluctance of the core and air gap and the magnetic flux in the core material.



$$H \cdot l = I$$

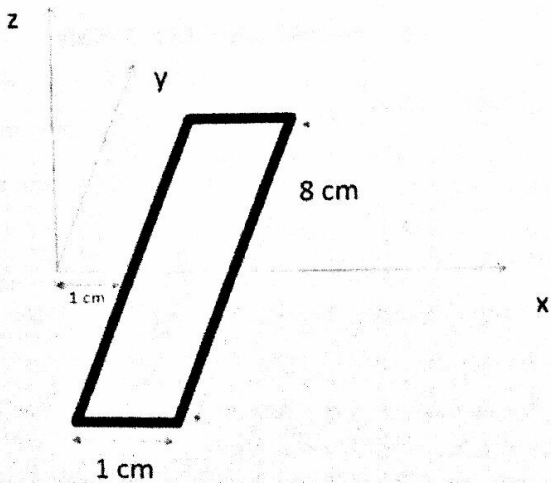
RS

4.2: A transformer is manufactured using a material with the hysteresis curve shown in the figure. The core material has the shape and dimensions as shown. Determine the hysteresis power loss in the core when operated at 60 Hz and magnetic properties follows the hysteresis curve to saturation. Note that an exact answer is not required, but show and describe your procedure used for your calculations.



4.3: A transformer is rated at 10 KVA and operated at 60 Hz. The turns ratio is 60:40. A 100 volt peak AC voltage is connected to the transformer and used to step up the voltage delivered to a 100 Ω resistive load. Draw the circuit diagram including the transformer. Determine the peak AC voltage, peak AC current and peak apparent power dissipated in the resistor.

4.4: In a region of space the magnetic field increases linearly with respect to the x coordinate distance as given by the following $\vec{B} = 2x\hat{z}$ (tesla). A metal loop that rests in the (x, y) plane is pulled at a constant speed towards increasing x with a velocity of 2 m/s. The resistance of the metal loop is 5 Ω. Determine the expression for the current in the loop and make a plot of current versus time for the interval $0 \leq t \leq 2s$. The figure below shows the geometry involved at $t = 0s$. The sides of the loop are straight and parallel to the coordinate axis.



RM

Section 5: Electrical Power and Motors

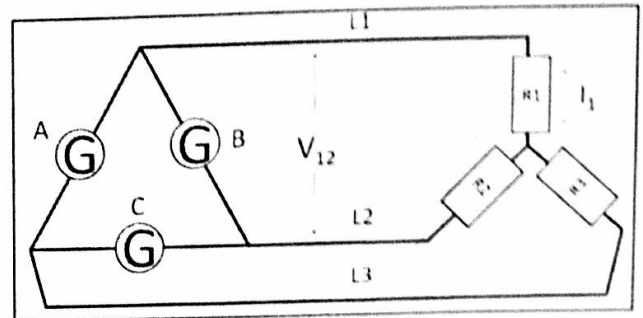
$$Z_{\Delta} = 3 Z_Y$$

Answer only 6 of the 7 questions in this section

Each question is worth 3 point

5.1: Identify and describe the two dominant loss mechanisms present in a real transformer. Indicate how these loss mechanisms are minimized in transformer design. Identify at least one other non ideal property of a transformer and discuss its origin.

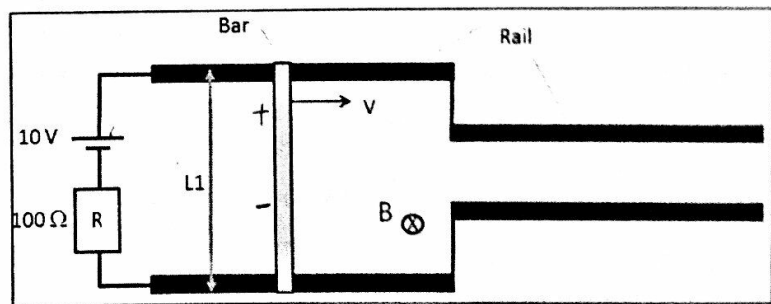
Diagram and description for questions 5.2 and 5.3. A segment of a three phase transmission system is shown in the figure. The generators are balanced and supply 200 V AC. The relative phases for the generators is $A = 0^\circ$, $B = 120^\circ$ and $C = 240^\circ$ and the rotation sequence is ABC. The generators are connected in a delta configuration. The load consists of three identical resistors connected in the star configuration. The individual resistance value is $1 \text{ k}\Omega$.



5.2: Determine the line to line voltage phasor V_{12} . Make sure to indicate the line to line voltage phase relative to the phase of generator A. Draw the phase diagram.

5.3: Determine the current phasor I_1 flowing in resistor R1. Make sure to indicate the current's phase angle relative to the phase of generator A. Draw the phase diagram showing the voltage current relative angles.

5.4: A linear device is shown in the figure. It consists of a movable bar, length $L1 = 1 \text{ m}$, in electrical contact with two metal rails. The bar is set moving to the right at constant velocity of 2 m/s . The magnetic field is uniform over the entire structure, pointing into the page and has a magnitude of 1 tesla. Determine the following:



- The emf induced across the bar.
- The current magnitude and direction (up or down) in the resistor.
- Is the structure operating as a motor or a generator?

5.5: A device known as a commutator is a key component in many D.C. motors. Describe the commutator and indicates its role for the D. C. Motor.

5.6: Select either the synchronous motor or the induction motor. Using diagrams and explanation text indicate the structure of the motor you chose and how shaft rotation is obtained. As an indication as to the depth of answer required, I should be able to provide your description to mechanical engineer, with some electrical background, and he can build the motor based on your description.

24

P V I_a W

5.7: A permanent magnet dc motor has the following nameplate information: 50 hp, 200 V, 200 A, 1200 rpm and armature resistance of 0.05 Ω. Determine the output power if the voltage is lowered to 150 V and the current is 200 A. Assume rotational losses are proportional to speed. Determine the **efficiency** of motor not including field coil excitation?

