A LEVEL ELECTROMAGNETISM AND AC CIRCUITS SCENARIO ITEMS

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ITEM 1

Magnetized steel bars have several life applications such as lifting and moving heavy objects like cars, holding metal parts in place for welding, drilling or assembly. An electrician is looking for one of this steel bar magnets to be used in one of the above applications but he is told that it can be magnetized and demagnetized but he doesn't know how this happens. Further more, he is told that with such a magnet, increase in its temperature destroys it's magnetism and he wants clarity on this. In his research, there reached a point where he needed an explanation using domain theory how data is stored in magnetic materials like hard drives and magnetic tapes. On his way back home, he found geophysicists carrying out geophysical exploration. He notes that the

angel of dip varies as one moves from the magnetic equator up to the north pole. He discovered that the Earth's magnetic field has various life applications which includes: protecting life from solar radiation, safeguarding satellites and power grids. He needs help from some experienced physicist to explain all the incidences found at the exploration grounds and hence carry out an experiment to measure the Earth's horizontal components Bh, Vertical component Bv and hence angle of dip @.

Task

As a physics student, help the researcher in

(a) (i) Explaining in terms of molecular theory, how steel bar gets magnetized and demagnetized

(ii) Explain why increase in temperature destroys the magnetism of a magnet

(iii) How data is stored in magnetic materials like hard drives and magnetic tapes.

(b) Explain the variation of the angle of dip as one moves from the magnetic equator up to the north

(c) Describe an experiment to measure the Earth's horizontal components Bh, Vertical component Bv and angle of dip.

ITEM 2

Magnetic flux is the key principle behind how generators produce electricity. A student is carrying out a project but doesn't know the clear steps of how magnetic flux can be generated to produce current in the circuits. He has a rectangular coil with 50 turns and is placed in a uniform magnetic field of 0.2T. Each turn has an area of 0.04m². The coil is initially positioned so that the magnetic field is perpendicular to the plane of the coil. Later, he rotates the coil so that the magnetic field makes an angle of 60º with the normal to the coil. He wants to know the initial magnetic flux through the coil , the magnetic flux after the rotation and hence the chance in magnetic flux. In his findings,

he needs to describe a simple experiment on how magnetic flux density between the poles of a permanent magnet can be measured.

Task

This student has approached you as a fellow colleague in the subject for help, help him to

(a) Know the meaning of magnetic flux and explain to him the clear steps for the generation of magnetic flux to produce current in the circuit.

(b) Find the

(i) Initial magnetic flux through the coil

(ii) The magnetic flux after rotation and hence the chance in the magnetic flux.

(c) Describe an experiment to measure the magnetic flux density between the poles of a permanent magnet

ITEM 3

A laboratory technician is trying to understand the relationship between magnetic flux density B and current I to help in designing electromagnets for lifting, holding and separating magnetic materials. He needs assistance to carry out an experiment to investigate this. He has these sample data: A coil of 50 turns and radius 4cm placed with its plane in the Earth's magnetic meridian. A campus needle is placed at the center of the coil. When a current if 0.1A passes through the coil, the campus needle deflects through 40º. When the current is reversed, the needle deflects through 43º in the opposite direction. He needs to know the horizontal component of the Earth's magnetic field and the magnetic flux density of the earth at the place where the angle of dip is 15º. In his second study, he picked a particle accelerator that has just been delivered in the school laboratory. It was written on the instructional manual that the force on a charged particle moving in a magnetic field is Fq = BqVsin@ and that the kinetic energy it gains

when it moves in a uniform magnetic field is given by K E = 0.5m(Bqr/m)². He needs to derive the expressions so that they can be used to find the force on the electron, period and the radius of the path described by the beam where mass of the election is Me = 9.1 X 10^-31 kg when an election beam moving with a velocity of 10^6m/s moves through a uniform magnetic field of flux density 0.1T which is perpendicular to the direction of the beam.

Task

As a physics student in A level, help the lab technician to

(a) Carry out an experiment to investigate the dependence of the magnetic flux density B at the center of the circular coil on the current I through the coil.

(b) Calculate the

(I) Horizontal component of the Earth's magnetic field

(ii) The magnetic flux density of the earth at the place where the the angle of dip is 15^o.

(c) Draw a sketch diagram to show the pattern of the motion of the electron in the uniform magnetic field and hence use it to derive the expressions for the force Fq on the electron and the Kinetic energy gain K.E

(d) Calculate the

(i) Force on the electron

(ii) The period

(iii) The radius of the path described by the beam

ITEM 4

A s.5 student is designing a hall effect sensor to be used in detecting position or speed in devices like smartphones as his project. In his research, he found that he needs to

know the magnetic flux density, B of the field using hall effect and hence derive the expression Vh = BI/ net where Vh is the magnitude if the hall voltage and use it to find the magnetic flux density for a metallic strip of width 2.5 cm and thickness of 0.1 cm which carries a current of 10A. When a magnet is applied normally to the broad side of the strip, a hall voltage of 2mV develops and the conduction election density is 6.0 X 10^{28} m^-3. In his experiment, he discovered that there is the origin of the force that causes the motion of a current carrying conductor placed across a magnetic field but he did not know how this arises. He realized that his experiment showed that the magnitude of the force should be proportional to some factors which he could not analyze.

Task

He has approached you as a classmate in A level, help him to

(a) Determine the magnetic flux density B of the field using Hal effect

(b) Derive the expression for the magnitude of Hall voltage and use it to find the magnetic flux density if the conduction electron density is 6.0 X 10^{28} m^-3

(c) (i) Explain the origin of the force that causes motion of a current carrying conductor placed across a magnetic field.

(ii) State the factors affecting the magnitude of force on a current carrying conductor

ITEM 5

The school has bought an electromagnetic relay where the force between the two straight conductors switches the current on and off. The electrician in the school needs to know how this is done and is in need of a scientific explanation. He recalls theory about magnetic field due to the straight wire carrying current but he was not well versed with it. He recalls that for two wires carrying current say X and Y of negligible cross sectional area, and of lengths Lx and Ly carrying current Ix and It separated by the distance d, a force Fy is experienced by wire Y due to the magnetic field of wire X and is

given by Fy = IxIyLxLy/2¢d. In the machine, two parallel wires of length 75cm are placed 1.0 cm apart. When the same current is passed through the wires, a force of 5.0 X 10^-5 N develops between the wires. He wants to know the magnitude of the current and hence understand the meaning of the Ampere.

Task

He has approached you one of the A level physics student, help him to

(a) by sketching the magnetic field pattern to explain the behavior of the magnetic field and the force between the two straight conductors Carrying current in order to make him understand the operation of the relay switch.

(b) Derive the expression for the force Fy

(c) Calculate the magnitude of the current and hence help him understand the meaning of an Ampere in electromagnets.

ITEM 6

An electrician at the factory in Jinja is designing a custom DC motor for an irrigation pump. Though he is skilled in making it, he is missing something he needs to include in the write up as his winds up with his project and still he is not well conversant with the theoretical part of it. He needs the knowledge of the torque - on - coil principle that that will enable him to optimize its efficiency for agricultural use. The expression for the torque= BIANcos@ is a necessity for calculating the rotation force. He has a vertical rectangular coil which is suspended from from the middle of of its upper side with its plane parallel to the uniform horizontal magnetic field of 0.06T, the coil has 50 turns and the length of its vertical and horizontal sides are 4cm and 5cm respectively. He wants to get the torque on the coil when the current of 4A is passed through it. In his telecom company in Kampala, he uses a moving coil galvanometer to troubleshoot a faulty circuit in a network router, pinpointing the issue with the precise current measurement. He sometimes faces challenges in electrical measurements and testing and he was told

that this machine can either be converted to an ameter or voltmeter for different ranges of measurements. He has a galvanometer of resistance 4 ohms and f.s.d 10mA which is to be used for the purpose of measuring current up to 1.0A. He also designs actuators for precision motion control which uses magnetic moment in the coil.

Task

As a physics student, help this electrician by

(a) Deriving the expression for the torque and use it to calculate the torque on the coil when the current of 4A is passed through it.

(b) With a clear well labeled diagram, explain the mode of operation of the moving coil galvanometer.

(c) Explain how the galvanometer can be converted to either an ameter or voltmeter hence help him to find the value of the shunt that can be used for the purpose of measuring current up to 1.0A.

(d) Derive the expression for the magnitude moment of the coil, M that will be used in actuators for precision control

ITEM 7

A hospital in a rural area in Uganda needs a reliable power source and there's need for the type of the generator (a.c) to serve this purpose. However, they were advised that a.c generators are not strong enough for some devices and so they were advised to upgrade to a d.c for batteries to charge on solar powered systems. Before they buy it, they need to understand the losses that could occur in the generator and the significance of back e.m.f in the DC motor. The efficiency of the motor is related to the back e.m.f and the magnetic flux density and so there are discrepancies that: when a d.c motor is switched on, the initial current decrease to a steady value when the motor is running to a constant speed. If the motion of the d.c motor is slowed down, the current rises and then falls again when the motor is allowed to run freely. A DC motor

has an amature of resistance 0.5 ohms and is converted to a 240V supply. The amature current taken by the coil is 3.0A. There is need to calculate the back e.m.f generated by the motor, power supplied in the amature, the mechanical power developed by the motor and hence the efficiency of the motor.

Task

As a physics student, help the hospital personnel by

(a) (i) Explaining the mode of operation of an a c generator with a well labeled diagram

(ii) Explain how can this generator be converted to dc motor

(b) (i) What are the energy losses in the DC motor

(ii) Give the significance of back e.m.f in the DC motor

(c) Explain why

(i) When the DC motor is switched on, the initial current decreases to a steady value when the motor is running to a constant speed

(ii) If the motion of the DC motor is slowed down, the current rises and then falls again when the motor is allowed to run freely

(d) Calculate

(i) back e.m.f generated by the motor

(ii) Power supplied in the amature

(iii) The mechanical power developed by the motor and hence the efficiency of the motor

ITEM 8

An old man went to the Tech-savvy folks in Kampala which sells compatible phones with wireless charging pads. He wanted to know how it works before buying one but the

shopkeeper could not explain to him. However, in its design, the principle of mutual induction play a significant role in its performance. This man has a small farm in lira and he needs to buy an induction motor to pump water for irrigation which will be efficient, reliable and helpful in growing crops and he still needs clarity on how this machine works before he purchases it. In the machine, the principle of self induction plays a significant role in its performance.

This man owns a company that uses current electricity to operate machines and other appliances. One day, as the workers were trying to switch on the lights, they noticed that all the bulbs were dim. Subsequently, the business person called an electrician to asses the problem who later established that the mains supply of 415V was low and needed to be increased to 2000V. The electrician assured the business person that for the problem to be solved, he must buy an efficient device such that the power loss doesn't exceed 5 watts. However the business person doesn't have any information on practical ways of how to minimize energy losses in the device.

You have been contacted by the business person for help. (Hint: Cables of resistance 2ohms supply 2KW of electrical power if it's transmitted at 2000V)

Task

(a) (i) Explain how mutual induction enables the device to operate

(ii) Apply the concept of self induction to explain how the motor works to enable him better understand it's operation so that he can buy the induction motor.

(b) Help the business man understand the design and mode of operation of the device needed to sort out the issue.

(d) Determine whether the device is efficient so that you can educate the business man.

ITEM 9

An engineering student during his period of internship went in an engineering company

and consulted how to design safe, efficient bulbs and heaters. He was not well conversant about the root mean square value and peak value of the sinusoidal voltages that can be used for effective power calculations. The relationship between the two was significant. On top of his research, he needs to know the mode of operation of an a.c generator and the factors that determine the peak value of the induced e.m.f. He needs to explain in his findings the structural modifications that are made to an a.c generator in order to obtain a DC generator. He sampled a flat circular coil with 200 turns and each of radius 10cm rotated at a uniform rate of 400 revolutions per minute about it's diameter at right angles to a uniform magnetic field of flux density 5 X 10^-3 T. He needs to know the peak value of the e.m.f induced in the coil, the r.m.s value of the induced e.m.f. In his local garage at home, he needs to use a moving iron ameter for measuring motor currents.

Task

He has consulted you as a physics student working at the company during holidays for help,

(a) (i) Help him understand the difference between the root mean square value and peak value of the sinusoidal voltage.

(ii) Write down the relationship between the two.

(b) (i) With the aid of a lebelled diagram, describe the mode of operation of an a.c generator and state what factors determine the peak value of the induced e.m.f.

(ii) Explain the structural modifications that are made to the generator in (b) (i) above in order to obtain a d.c generator.

(c) Help him calculate

(i) The peak value of the induced e.m.f in the coil

(ii) The r.m.s value of the induced e.m.f

(d) With a clear well labeled diagram, explain to him the mode of operation of the moving iron ameter.

ITEM 10

In radios like in local FM stations, reactance helps to select frequencies for tuning circuits and in industries like in factories in Jinja, impedance matching improves efficiency an engineers in power companies like in UECDL deal with impedance for grid efficiency and work with reactance in gadgets. In signal checks, they use thermocouple meter to measure high frequency a.c currents like in antenas and RF circuits.

Task

As a physics student, basing on these applications

(a) Explain the difference between reactance and impedance as applied to alternating current circuits.

(b) A 240V, 60Hz alternating voltage is applied across a capacitor of capacitance 10microfarad. Calculate the

(i) r.m.s value of the current which flows.

(ii) Power expanded

(c) Describe with the aid of a well labeled diagram how a a thermocouple meter works.

(d) A galvanometer gives a full scale deflection when a current of 10mA flows through it. Describe how a moving coil galvanometer can be converted to an ameter capable of measuring 3.0A if the resistance of the galvanometer is 5ohms.

(e) (i) What are Eddy currents

(ii) Explain why a metal plate freely swinging in a uniform magnetic field comes to stop faster than when there is no magnetic field.

(iii) Give the applications of Eddy currents.

COMPILED BY

MR NAKHOKHO JOB, ST. LEONARD SS MADDU - GOMBA

0784542073/0747063948