UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL I (SEMESTER II) EXAMINATION – NOVEMBER/DECEMBER 2016

UBJECT: PHYSICS (FOR REPEATERS ONLY)

OURSE UNIT: PHY1214 : general physics II TIME: 2 hours & 30 minutes

PART II

Answer FIVE (05) Questions only

Answer minimum of ONE (01) question from each of the parts A, B and C

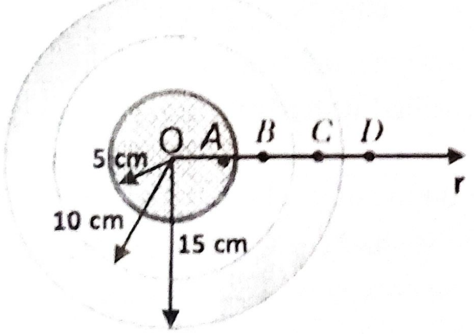
All symbols have their usual meaning.

$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{Hm^{-1}}$ $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2N^{-1}m^{-2}}$ $k = \dfrac{1}{4\pi\varepsilon_0}$

Part A

a) State the Gauss's law in electrostatics. [03-marks]

b) A solid insulating sphere of radius 5 cm carries a net positive charge of 3 μC, uniformly distributed throughout its volume. Concentric with this sphere is a conducting spherical shell with inner radius 10 cm and outer radius 15 cm, having net charge -1 μC, as shown in figure below.



(i) Find electric field vectors at points A, B, C and D on the horizontal axis located at respective distances A=4 cm, B=8 cm, C=12 cm and D=16 cm from the center O. [07-marks]

(ii) Sketch how electric field varies with r. [05-marks]

(iii) What are the charge densities in inner and outer surfaces of the conducing shell. [04-marks]

(iv) Find electric potential on surfaces at radii 5 cm, 10 cm and 15 cm. [06-marks]

2. a) Write down the electric potential at distance ***r*** from an isolated positive point charge q.

[03-marks]

b) An electric dipole with magnitude $p = 2qa$ is located along the y axis as shown below.

(i) The point R is far from the dipole ($r >> a$).
Show that the electric potential at R is

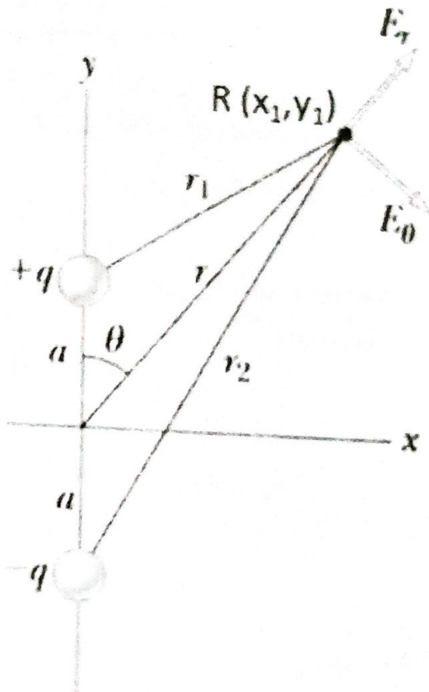
$$V = \frac{kp\cos\theta}{r^2}$$

[05-marks]

(ii) Calculate the radial component E_r and the tangential component E_θ of the associated electric field where $E_r = -\frac{\partial V}{\partial r}$ and $E_\theta = -\left(\frac{1}{r}\right)\left(\frac{\partial V}{\partial \theta}\right)$. Find E_r and E_θ at the two locations where $\theta = 0°$ and $\theta = 90°$. Using geometrical method, verify your answers.

[12-marks]

(iii) Express V using coordinates (x_1, y_1) where $r = (x_1^2 + y_1^2)^{1/2}$ and $\cos\theta = \frac{y_1}{(x_1^2+y_1^2)^{1/2}}$
Hence, express electric filed component in x and y directions, E_x and E_y. **[05-marks]**



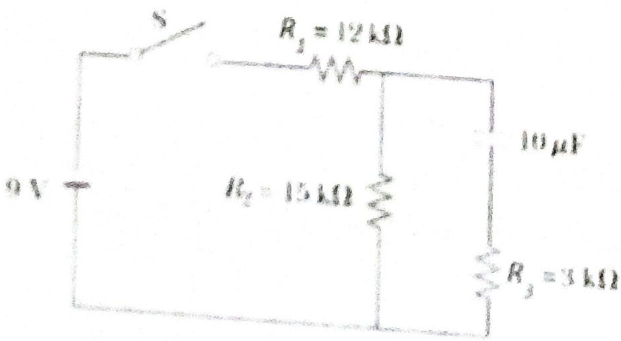
3. a) Write down an expression for the capacitance of a parallel plate capacitor, of plate area A and separation d.

[02-marks]

b) A parallel plate capacitor with A = 25 cm^2 and d = 1.5 cm is charged to a potential difference 250 V and disconnected from the source. Then it is immersed in distilled water. Dielectric constant of distilled water is 80 and assume that it is an insulator. Determine

(i) the charge on the plates before and after immersion. **[04-marks]**
(ii) the capacitance and potential difference after immersion. **[03-marks]**
(iii) the change in energy of the capacitor. **[03-marks]**

c)



Suppose the switch, S, in the above circuit has been closed for a sufficiently long time interval so that the capacitor is fully charged.

(i) Find the steady-state current across each resistor. **[03-marks]**

(ii) Calculate charge Q on the capacitor. **[03-marks]**

(iii) The switch is now opened (t = 0). Obtain an equation for the current across R_2 as a function of time. **[05-marks]**

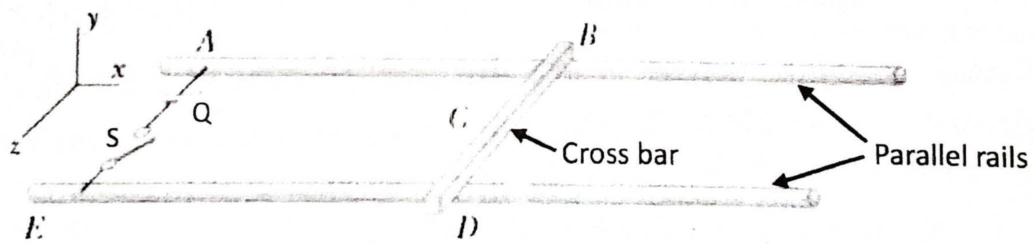
(iv) Find the time interval required for the charge on the capacitor to drop to one-fifth of its initial value. **[02-marks]**

Part B

a) State Biot-Savart law, defining each term. **[04-marks]**

b) Using Biot-Savart law, obtain an expression for the magnetic field at a perpendicular distance a from an infinitely long, straight wire carrying an electric current I. **[08-marks]**

c) A tabletop model railgun shown below consists of two long, parallel, horizontal bars placed 3.5 cm apart, bridged by a crossbar (BD) of mass 3 g. The crossbar is at rest at the midpoint of the rails and is free to slide without friction when a force is applied. When the switch S is closed, an electric current is quickly established in the circuit ABDE. The rails and the crossbar have low electrical resistance, and a large constant current value of 24 A is supplied by the power supply, Q.



(i) What is the magnetic field at a perpendicular distance 1.75 cm from a single very long, straight wire carrying a current 24 A? Hence find the magnitude and direction of the magnetic field $\left(\vec{B}_C\right)$ at the midpoint of the crossbar (at C), immediately after the switch is closed. (Note that the bar is at the midpoint of the rails).

(ii) At other points along the crossbar, the field is in the same direction as at point C, but is larger in magnitude. Assume that the average magnetic field on the crossbar can be taken as five times the field at C (i.e $5\vec{B}_C$). Using this assumption, find the magnitude and direction of the force on the crossbar.

(iii) What is the acceleration of the crossbar when it is in motion?

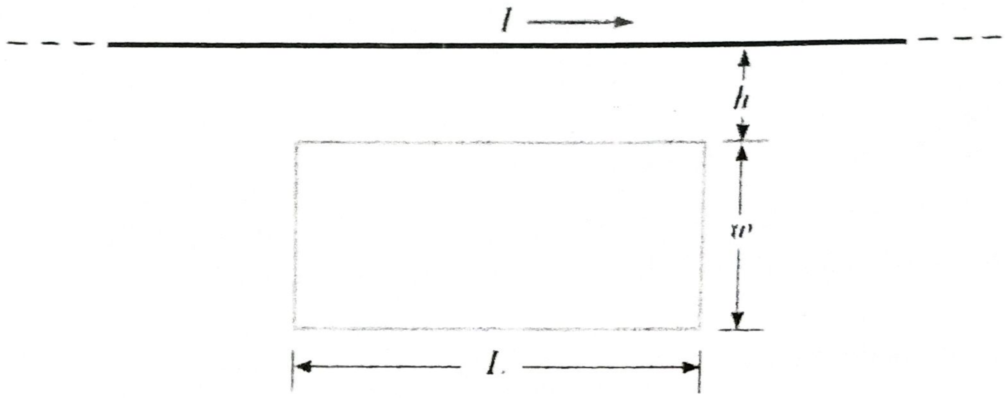
(iv) If the crossbar moves with a constant acceleration, what is its the velocity after it has traveled 130 cm (i.e. at the end of the rails).

[13-marks]

5. a) Considering a single current loop, state the Faraday's law of electromagnetic induction.

[03-marks]

b) A rectangular loop of wire with length L and width w, and a long straight wire carrying a current I lie on a tabletop as shown below.



(i) Determine the magnetic flux through the loop due to the current I.

(ii) Suppose that the current is changing with time according to $I = a + bt$, where a and b are constants. Determine the emf induced in the loop if b =10 A/s, h = 1 cm, w =10 cm and L =100 cm.

(iii) What is the direction of the induced current in the rectangle? Explain your answer.

(iv) What would be the induced emf if h = 5 cm ? Compare this value with the value obtained under (ii) above, and give reasons for the difference in valuesif any.

[14-marks]

c) A rectangular loop of wire with area A and resistance R, placed in the XY plane, rotates in a uniform magnetic field $\vec{B} = B\hat{i}$ with uniform angular velocity ω around the Y axis going through the center of the loop.

(i) Find the total flux through the loop as a function of time t.

(ii) Calculate the induced emf of the loop as a function of time t.

(iii) Find the induced current in the loop as a function of time t. Hence; find the torque on the loop as a function of time t.

[08-marks]

6. a) Describe, briefly, what is meant by the inductance of a coil using relevant equations.

[05-marks]

b) Obtain an expression for the inductance of an air-core solenoid of cross sectional area A with N turns and length ℓ .

[05-marks]

c) Two coaxial solenoids A and B, with same radii and same length have 400 and 700 turns. respectively. A current of 3.5 A in coil A produces an average flux of 300 μWb through each turn of A and a flux of 90 μWb through each turn of B.

(i) Calculate mutual inductance of two solenoids.

(ii) Find inductance of A?

(iii) What is the emf induced in B when the current in A increases at the rate of 0.5 A/s?

[06-marks]

d) An inductor with inductance 1 mH and a capacitor with capacitance 1 μF are connected in series. Current in the circuit is described by I = (20 As^{-1}) **t**, where **t** is in seconds and I is in amperes. The capacitor initially has no charge.

Determine

(i) the voltage across the inductor as a function of time.

(ii) the voltage across the capacitor as a function of time.

(iii) The time it takes for the stored energy in capacitor and inductor to become equal.

[09-marks]

Part C

Consider two sinusoidal waves, $y_1 = a\sin(\omega t)$ and $y_2 = a\sin(\omega t + \delta)$, traveling in the same direction.

a) Use the Principle of Superposition to obtain an expression for the resultant wave. Further, write down its angular frequency, amplitude and phase constant.

note: $\sin(c) + \sin(d) = 2\sin\left(\frac{c+d}{2}\right)\cos\left(\frac{c-d}{2}\right)$

[08-marks]

b) What are the maximum and minimum amplitudes of the resultant wave? Write down possible values of δ that produce maxima and minima of amplitudes.

[04-marks]

c) Assume that light waves having above sinusoidal forms y_1 and y_2 emitted from two coherent sources superimpose at an arbitrary point ***P***. If the path difference between these two waves at point ***P*** is equal to $\lambda/6$,

(i) find corresponding phase difference between them.

(ii) calculate the amplitude of the resultant wave.

(iii)find the ratio of the intensity at point ***P***, $\mathbf{I_p}$, to the intensity at the point with maximum amplitude, $\mathbf{I_{max}}$.

[08-marks]

d) Two light waves with identical frequency and constant phase difference have intensities in the ratio 81:1. If the two waves superimpose, calculate ratio of the maximum intensity to minimum intensity of the resultant wave. **[05-marks]**

a) The intensity produced by ***two slit Fraunhofer diffraction*** pattern is given by $I = 4I_0\left(\frac{\sin^2\beta}{\beta^2}\right)\cos^2\gamma$. The term $\frac{\sin^2\beta}{\beta^2}$, represents the diffraction pattern produced by a single slit of width ***b*** where $\beta = \frac{\pi b\sin\theta}{\lambda}$. The term $\cos^2\gamma$, represents the interference pattern produced by two point sources separated by distance ***d*** where $\gamma = \frac{\pi d\sin\theta}{\lambda}$.

(i) Show that the condition satisfied for a diffraction minima is $b\sin\theta = m\lambda$, where $m = \pm1, \pm2, \ldots\ldots$.

(ii) Show that the condition satisfied for a interference maxima is $d\sin\theta = n\lambda$ where $n = 0, \pm 1, \pm 2, \ldots\ldots$

[06-marks]

b) In a ***two slit Fraunhofer diffraction*** arrangement, the widths of the two slits are 7×10^{-3} cm each and the opaque portion between them is 14×10^{-3} cm. The slits are illuminated using a monochromatic light of $\lambda = 630$ nm. If the screen is placed at a distance 5m from the double slit,

(i) find first 3 missing orders of interference maximas, of the interference pattern.

(ii) find the distance between first two missing interference maximas, of the interference pattern.

(iii) sketch the resultant intensity distribution covering the zeroth and 1st order diffraction maximas.

[15-marks]

c) Calculate maximum number of principal maxima that can be viewed with a diffraction grating of 1000 lines per cm using light of wavelength 500 nm.

[04-marks]

9. a) (i) What is a polarizer?

(ii) Explain, briefly, two methods of producing ***plane polarized light*** using ***unpolarized light***.

(iii) State ***Malus law***.

(iv) Unpolarized light falls onto two ideal polarizing sheets placed one on the other. What must be the angle between their transmission axes, for the intensity of final transmitted light to be one third of the intensity of incident light?
(note : Intensity of the ***unpolarized*** light is reduced by 50% after transmitting through a polarizer)

[12-marks]

b) (i) State ***Brewster's law***.

(ii) A plate of flint glass having refractive index 1.67 is immersed in water. Calculate ***Brewster angles*** for reflections at water/glass and glass/water interfaces.

[07-marks]

c) Discuss, briefly, characteristics and properties of half-wave plate and quarter-wave plate.

[06-marks]