UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL I (SEMESTER II) EXAMINATION – SEPTEMBER/OCTOBER 2020

SUBJECT: PHYSICS

COURSE UNIT: PHY1214 : General Physics II

PART II **TIME: 2 hours & 30 minutes**

Answer FIVE (05) Questions only

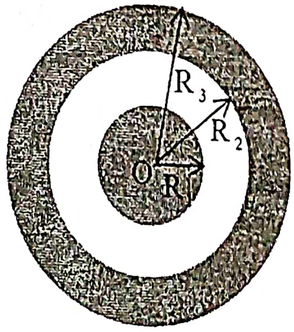
All symbols have their usual meaning.

$\mu_0 = 4\pi\times10^{-7}\ \text{Hm}^{-1}$, $\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$, $k = \frac{1}{4\pi\varepsilon_0}$, $\int\frac{1}{x}dx = \ln x$

1. a) State Gauss's law in electrostatics, in words and in mathematical form.

[04 marks]

b) Positive charges Q_1 and Q_2 are uniformly distributed over a non-conducting sphere of radius R_1 and a non-conducting spherical shell of inner radius $R_2\ (= 2R_1)$ and outer radius $R_3\ (= 3R_1)$ respectively. How the sphere is placed inside the spherical shell is shown in the sketch below.



(i) Define the volume charge density (ρ) and calculate the volume charge densities of inner sphere, ρ_1 and outer spherical shell, ρ_2.

[08 marks]

(ii) If $\rho_2 = \rho_1$, show that $Q_2 = 19Q_1$.

[02 marks]

c) Assuming that $\rho_2 = \rho_1 = \rho$, determine the magnitude of the electric field, E, in terms of ρ and as a function of distance, r, from the center O for the following positions of r.

(i) $r < R_1$

(ii) $R_2 < r < R_3$

(iii) $r > R_3$

[08 marks]

d) If $\rho = 8.85\times10^{-9}\ \text{C m}^{-3}$ and $R_1 = 0.027$ m, calculate the magnitude of the electric field on the outer surface of non-conducting spherical shell.

[03 marks]

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

[02 marks]

b) A parallel plate capacitor with $A = 0.01\ m^2$ and $d = 0.01m$ is charged by a 100 V battery. The battery is then removed. Calculate the followings.

(i) The capacitance C and the charge Q on each plate of the capacitor.

[04 marks]

(ii) The magnitude of the electric field $\vec{E}$, between the plates.

[02 marks]

(iii) The energy (U) stored in the capacitor and the energy density (u) of the capacitor.

[04 marks]

c) Describe, briefly, the conservative property of an electrostatic field.

[03 marks]

d) Consider a conducting sphere of radius R and charge Q.

(i) If Q is a positive charge, indicate the distribution of charges on the conducting sphere.

(ii) Show how electric potential varies with the distance r measured from the center of the sphere, using a sketch.

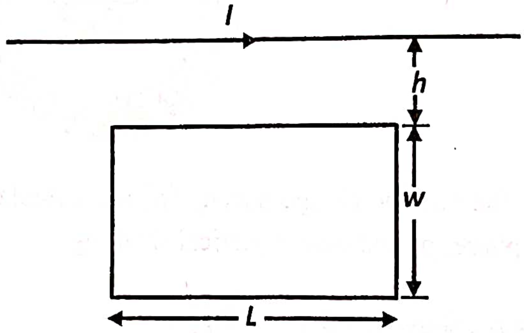
(iii) If $Q = 100$ C and $R = 0.02$ m, calculate the electric potential at the positions 0.01 m and 0.04 m away from the center of the sphere.

[10 marks]

3. 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 table top as shown below.



(i) Determine the magnetic flux, Φ, through the loop due to current I in the wire.

[05-marks]

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

[02-marks]

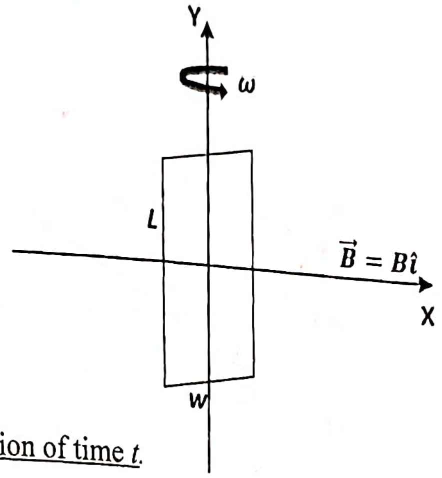
(iii) What is the direction of the induced current in the rectangle? Explain your answer.

[03-marks]

(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 values if any.

[04-marks]

c) Assume that the current carrying wire is removed now. The above rectangular loop which has a resistance R is now placed in the XY plane as shown in the sketch. A uniform magnetic field is applied along the X-axis through the center of the loop. The loop rotates with uniform angular velocity ω around the Y axis.



Find the followings as a function of time t.

(i) Find the total flux through the loop. [03-marks]

(ii) Calculate the induced emf of the loop. [01-marks]

(iii) Find the induced current in the loop. Hence, find the torque on the loop. [04-marks]

4. a) Write down in words, what is meant by the inductance of a coil.

[02-marks]

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

[05-marks]

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

(i) Calculate the mutual inductance of two solenoids.

(ii) Find the inductance of P?

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

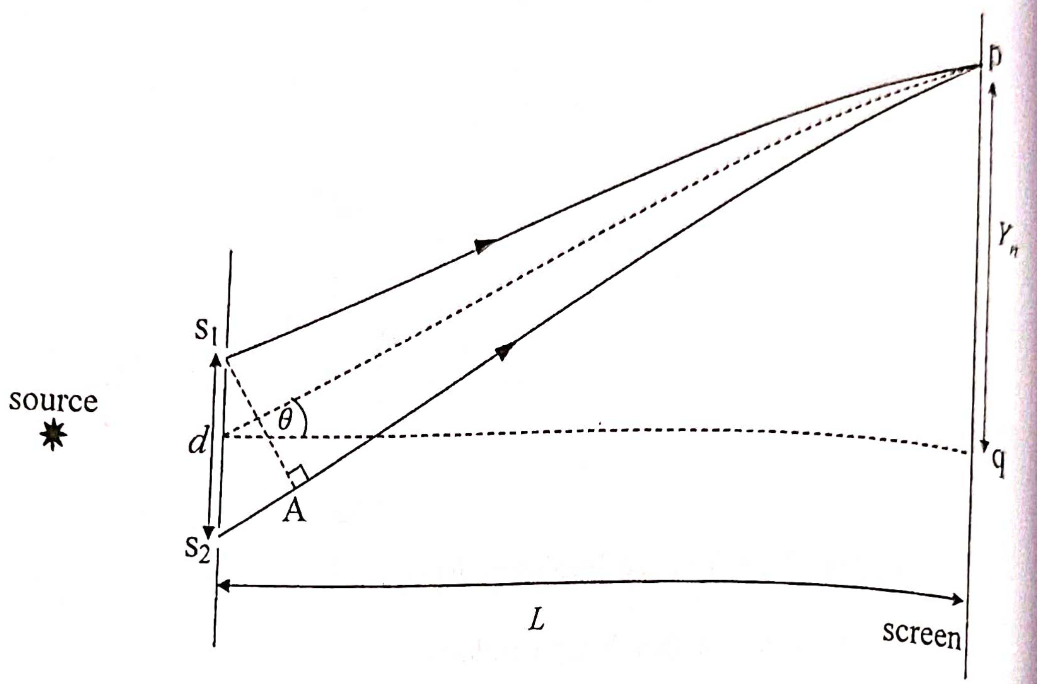
[09-marks – 03 marks for each part]

d) A 6 V battery is connected into a series circuit containing a 4 Ω resistor, an 8 mH inductor and a switch.

(i) Find the current in the circuit as a function of time t. [05-marks]

(ii) Find the self-induced emf at 1 ms after the switch is closed. [04-marks]

5. a)



A sketch of a ray diagram in the Young's double slit experiment is shown in the above figure.

(i) Write down the approximations that are being used here.

(ii) Obtain an expression for the path difference (δ) and show that $\delta = \frac{dY_n}{L}$.

(iii)Show that for bright fringes $Y_n = \frac{n\lambda L}{d}$, where n is an integer.

(iv)Show that for dark fringes $Y_n = \frac{\left(n+\frac{1}{2}\right)\lambda L}{d}$, where n is an integer.

(v) Derive an expression for fringe separation.

[15-marks (- 03 for each part)]

b) In Young's double slit experiment, the source is a sodium light of wavelength 589 nm. When a glass plate of thickness t and refractive index μ (=1.5) is introduced in the path S_1P, the path difference becomes $t(\mu - 1)$ (***no need to derive this equation***) and the central bright fringe is shifted by 3mm to the point P where it was previously occupied by the 6th order bright fringe.

(i) Calculate the thickness of the glass plate.

(ii) Calculate the fringe separation.

[10-marks (-05 for each part)]

The intensity distribution of the diffraction pattern from a grating with N slits is given by the following equation.

$$I = I_0\left(\frac{\sin^2\beta}{\beta^2}\right)\left(\frac{\sin^2 N\gamma}{\sin^2\gamma}\right) \quad \text{where} \quad \gamma = \frac{\pi d\sin\theta}{\lambda} \quad \text{and} \quad \beta = \frac{\pi b\sin\theta}{\lambda}$$

(i) Find the condition for principal maxima.

(ii) Obtain the grating equation.

(iii)A diffraction grating with 8000 $lines/$cm is exposed to light of 500 nm. Calculate the diffraction angle (θ) of the first order maxima.

[15-marks (-05 for each part)]

(i) State ***Malus law***.

(ii) Unpolarized light falls on two ideal polarizing sheets placed one over the other. What must be the angle between their transmission axes, for the intensity of the light transmitted after both polarizers to be one fourth the intensity of the incident light? (note: Intensity of unpolarized light will be reduced by half after transmitting through an ideal polarizer.)

[10-marks (- 05 for each part]

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