UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL I (SEMESTER II) EXAMINATION – MARCH/APRIL 2019

SUBJECT: PHYSICS

COURSE UNIT: PHY1214

PART II TIME: 2 hours & 30 minutes

Answer FIVE (05) Questions only

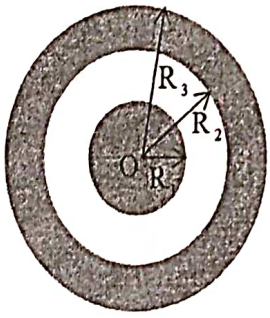
All symbols have their usual meaning.

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

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

[03 marks]

b) A non-conducting sphere of radius R_1 is uniformly charged with a volume charge density ρ. It is surrounded by a concentric non-conducting spherical shell of inner radius $R_2 = 2R_1$ and outer radius $R_3 = 3R_1$ as shown in the figure below. Outer shell also carries a uniform charge density ρ.



(i) Determine electric field, E as a function of distance, r from the center O, for each of the following positions of r.

(i) $0 < r < R_1$

(ii) $R_1 < r < R_2$

(iii) $R_2 < r < R_3$

(iv) $r > R_3$

[12 marks]

c) If $\rho = 8.85 \times 10^8\ \mathrm{C\,m^{-3}}$ and $R_1 = 0.1$ m, calculate the magnitudes of the electric field on the inner and outer surfaces of non-conducting spherical shell and the surface of non-conducting sphere.

[10 marks]

2. A capacitor consists of two plates, each with area A, placed parallel to each other with distance d apart in air. Show that the capacitance between the plates is $C = \varepsilon_0 \frac{A}{d}$. [04 marks]

A parallel plate capacitor, with A = 100 cm^2 and d = 10 mm, is charged by a 150 V battery. The battery is then removed. Calculate the following.

a) The capacitance C. [03 marks]

b) The charge Q on each plate of the capacitor. [02 marks]

c) The electric field $\vec{E}$, between the plates. [02 marks]

d) The energy E_0 stored in the capacitor. [03 marks]

A slab of mica with dielectric constant k = 5.2 is now placed between the plates of the capacitor. Calculate the following.

e) The capacitance C'. [02 marks]

f) The potential difference V'. [02 marks]

g) The electric field $\vec{E}'$ between the plates. [02 marks]

h) The energy E_0' stored in the capacitor. [03 marks]

i) Calculate the work done in moving the mica slab between the plates of the capacitor. [02 marks]

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

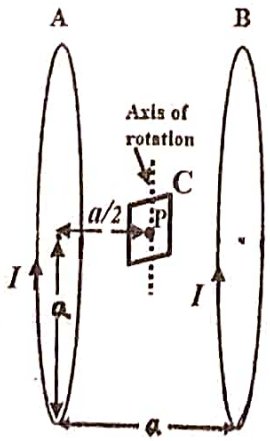
b) A circular wire loop of radius a carrying a steady current I is placed in the YZ plane. Using Biot-Savart law, obtain an expression for the magnetic field on the axis of the loop, as a function of the distance x from the center of the loop. [07 marks]

c) A circular loop of wire, A, having radius a and carrying current I is placed at the origin of XYZ coordinate system and the plane of the loop is in YZ plane as shown in the figure below. A second identical loop, B, also carrying a current I is placed at a distance a from the origin. Point P is on X axis at a distance $a/2$ from the center of the loop A.

(i) Find the magnitude and direction of magnetic field, B_1, at point P due to current in loop A. [02 marks]

(ii) Hence, find the magnitude and direction of the net magnetic field, B_{net} due to both loops A and B, at point P. [02 marks]

A small square loop of wire, C, with each side length s and resistance R is now placed at point P with its plane parallel to the plane of each loop. Assume that there is no effect by the loop C to the system of two current carrying loops A and B.



(iii) The loop C is now rotated about an axis in its plane (as marked in the figure) at an angular speed ω. Find the total magnetic flux through the loop C as a function of time t.

(Assume that the magnetic field is uniform in the region of the loop C and has magnitude B_{net}) [03 marks]

(iv) Calculate the induced emf on the loop C as a function of time t. [02 marks]

(v) Find the induced current in the loop C as a function of time t. Hence, find the torque on the loop as a function of time t. [05 marks]

a) Considering a single current loop, state the Faraday's law of electromagnetic induction. [03 marks]

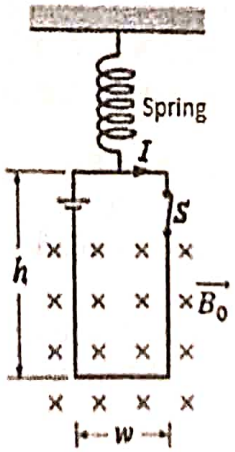
b) A square loop of wire with each side length x and resistance R is pulled upward out of a constant uniform magnetic field ($\vec{B}$), at a constant speed v_0. The plane of the loop is perpendicular to $\vec{B}$ directed into the plane of the page.

(i) What is the direction of the induced current in the loop as the loop moves upward out of the magnetic field. Explain your answer. [03 marks]

(ii) Derive an expression for the magnitude of this induced current. [05 marks]

(iii) Derive an expression for the power dissipated in the loop as the loop is pulled at constant speed out of the field. [03 marks]

c) A loop of wire of width w and height h contains a light switch (S) and a light battery and is connected to a spring of force constant k, as shown below. The loop carries a current I in a clockwise direction. The lower part of the loop is in a constant, uniform magnetic field ($\overrightarrow{B_0}$) directed into the plane of the page. Assume that the loop can still be considered as a perfect loop with side lengths h and w.



(i) Draw a rough sketch of the loop and indicate direction of the magnetic force, on each side of the loop. [02 marks]

(ii) The switch, S is now open. The loop eventually comes to rest at a new equilibrium position, a distance x from its initial equilibrium position.

Derive an expression for the magnitude of the uniform magnetic field, B_0, in terms of I, w, k and x. [05 marks]

(iii) Suppose the current passing through the loop is doubled to $2I$. If $I = 2\text{A}$, $w = 10$ cm, B_0 = 5 T and $k = 20\ \text{Nm}^{-1}$, find the distance to the new equilibrium position from its former equilibrium position mentioned in part (ii).

[04 marks]

5. a) Consider two sinusoidal waves $y_1 = a\sin(\omega t + \phi)$ and $y_2 = a\sin(\omega t)$ traveling in the same direction. By using the Principle of Superposition, derive an expression for the resultant wave. Further write down its angular frequency, amplitude and phase constant.

$\left\{\text{You may use: } \sin(c)+\sin(d) = 2\sin\left(\frac{c+d}{2}\right)\cos\left(\frac{c-d}{2}\right)\right\}$ [06-marks]

b) Find the maximum and minimum amplitudes of the above resultant wave with respect to phase difference ϕ.

[04-marks]

c) Monochromatic light passes through two narrow slits, which are 0.40 mm apart. The third-order bright fringe of the interference pattern, observed on a screen 1.0 m away from the slits, is 3.6 mm away from the central maximum. Find the wavelength of the incident light.

[07-marks]

d) A thin film of refractive index 1.5 is illuminated by white light normal to its surface. Thickness of this thin film is 4×10^{-5}cm. What will be the colour of this thin film that appears in reflected light?

[08-marks]

6. a) In Fraunhoffer diffraction pattern, show that the angular width of the central maximum is twice as wide as the angular width of the first secondary maximum (second maximum).

[07-marks]

b) To observe Fraunhoffer diffraction due to a narrow slit, a screen is placed 2 m away from the lens. If the width of the slit is 0.3 mm and the first minimum lie 5 mm on either side of the central maximum, find the wavelength of incident light.

[06-marks]

c) A diffraction grating has 5600 lines per cm. For this grating, calculate angles of diffraction for violet (λ = 400 nm) and red (λ = 650 nm) wavelengths in the first order of spectrum. Further, find the angular width of the visible spectrum in the first order spectrum.

[07-marks]

d) Calculate the maximum number of principal maxima that can be formed with a grating of 5600 lines per cm for light of wavelength 500 nm.

[05-marks]

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