UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL I (SEMESTER II) EXAMINATION – NOVEMBER/DECEMBER 2015

SUBJECT: PHYSICS

COURSE 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

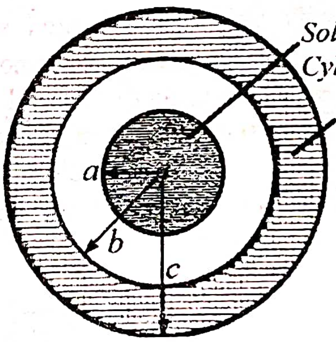
All symbols have their usual meaning.

$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{Hm^{-1}}$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2N^{-1}m^{-2}}$ $\quad g = 9.8\,\mathrm{ms^{-2}}$ $\quad e = 1.6\mathrm{x}10^{-19}\ \mathrm{C}$

Part A

a) State the Gauss's law in electrostatics.

b) The figure shows a cross section of an infinitely long coaxial cable that consists of a charged (volume charge density ρ) solid cylinder of radius a surrounded by an uncharged solid conducting cylindrical shell of inner and outer radii b and c respectively.



(i) Use Gauss's law to find an expression for the electric field $\bar{E}_1$ at a distance r, $(r < a)$ from the axis of the cable.

(ii) Use Gauss's law to find an expression for the electric field $\bar{E}_2$ at a distance r, $(a < r < b)$ from the axis of the cable.

(iii) What should be the electric field at a distance r, $(b < r < c$ *inside the conductor*$)$ from the axis? Use this result and the Gauss's law to deduce the total electric charge (Q_{inner}) on a length L of the inner surface of the conducting shell.

(iv) Using the value you obtained in part (iii), find the surface charge density (σ_{inner}) of the inner surface of the shell **and** the charge on a length L of the outer surface (Q_{outer}) of the shell.

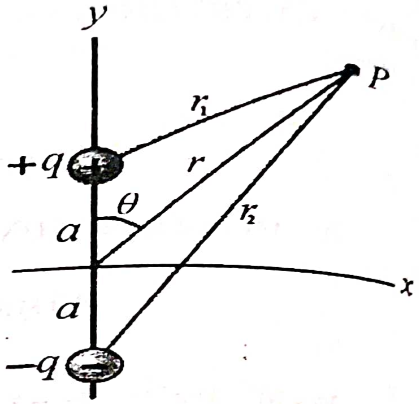
2. (a) (i) Write down an expression for the electric potential V at a distance r from a point charge q. (Assume that $V = 0$ when $r \to \infty$).

If the electric potential $V(x)$ is given as a function of a coordinate x, write down an expression for the **electric field** E_x at a point x.

(ii) Consider an electric dipole that is located along the y axis as shown in the figure. Show that the electric potential at a point P is given by,

$$V = k_e q(r_2 - r_1)/(r_2 r_1).$$

Also show that $V \approx 2k_e aq \cos\theta \,/\, r^2$ approximately when the point P is located far away (i.e. $r >> a$) from the dipole.

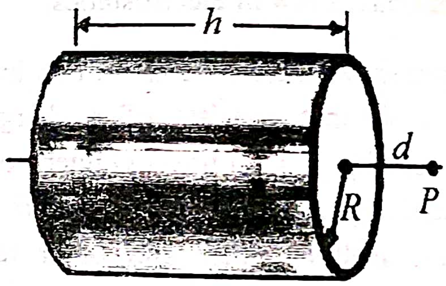


(iii) Using $r = \sqrt{x^2 + y^2}$ and $\cos\theta = y/\sqrt{x^2 + y^2}$, express V in the approximated result in part (ii) above, express V in terms of Cartesian coordinates **and** calculate the electric field component E_x at point P.

(b) (i) Show that the electric potential $V(x)$ at a distance x from center along the axis perpendicular to the plane of a charged ring of radius a and total charge Q could be written as,

$$V = \frac{k_e Q}{\sqrt{a^2 + x^2}}$$

(ii) A cylindrical shell of radius R and length h with no end caps is uniformly charged with a total charge Q. Using the result in (b)(i) and by treating the cylinder as a collection of charged rings, show that the electric potential at a point P on the central-axis of the cylinder, which is at a distance d from the right end of the cylinder (as shown in figure) could be written as,



$$V = \left(\frac{k_e Q}{h}\right) \ln\left[\frac{d + h + \sqrt{(d+h)^2 + R^2}}{d + \sqrt{d^2 + R^2}}\right]. \quad \left(\textit{Note: } \int \frac{dx}{\sqrt{a^2 + x^2}} = \ln\left[x + \sqrt{a^2 + x^2}\right]\right)$$

3. (a) Write down an expression for the capacitance C of a parallel plate capacitor of plate area A and plate separation d. If the total charge of the capacitor is Q, write down an expression for the total **energy stored** U, in the capacitor in terms of V and C.

(b) A parallel plate capacitor of plate-separation d is constructed using square plates of side length L. The capacitor is connected to a battery of voltage V. Then the capacitor is placed so that the plates are in contact with a liquid of dielectric constant κ and density ρ as shown in the figure. The liquid is pushed up to a height h due to an electrostatic force until it is balanced by gravitational force. Neglect forces due to surface tension.

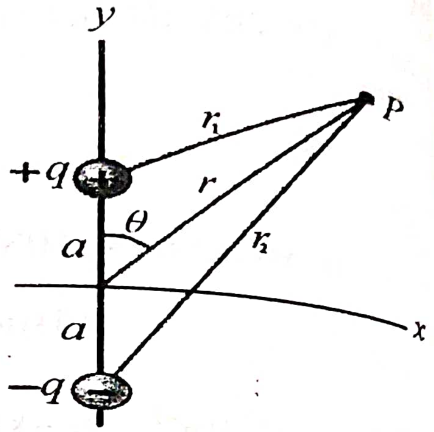
2. (a) (i) Write down an expression for the electric potential V at a distance r from a point charge q. (Assume that $V = 0$ when $r \to \infty$).

If the electric potential $V(x)$ is given as a function of a coordinate x, write down an expression for the **electric field** E_x at a point x.

(ii) Consider an electric dipole that is located along the y axis as shown in the figure. Show that the electric potential at a point P is given by,

$$V = k_e q(r_2 - r_1)/(r_2 r_1).$$

Also show that the above expression leads to $V \approx 2k_e aq \cos\theta / r^2$ approximately when the point P is located far away (i.e. $r >> a$) from the dipole.



(iii) Using $r = \sqrt{x^2 + y^2}$ and $\cos\theta = y/\sqrt{x^2 + y^2}$, in the approximated result in part-(ii) above, express V in terms of Cartesian coordinates **and** calculate the electric field component E_x at point P.

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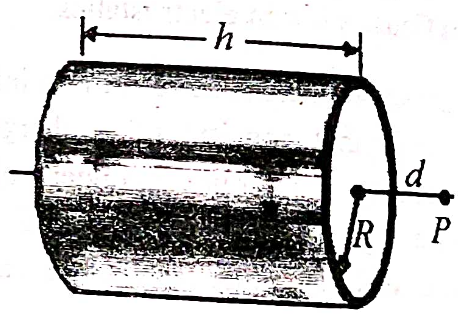
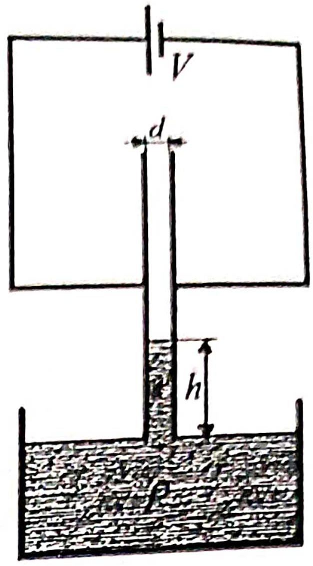


$$V = \left(\frac{k_e Q}{h}\right) \ln\left[\frac{d + h + \sqrt{(d+h)^2 + R^2}}{d + \sqrt{d^2 + R^2}}\right]. \quad \left(\textbf{Note: } \int \frac{dx}{\sqrt{a^2 + x^2}} = \ln\left[x + \sqrt{a^2 + x^2}\right]\right)$$

3. (a) Write down an expression for the capacitance C of a parallel plate capacitor of plate area A and plate separation d. If the total charge of the capacitor is Q, write down an expression for the total **energy stored** U, in the capacitor in terms of V and C.

(b) A parallel plate capacitor of plate-separation d is constructed using square plates of side length L. The capacitor is connected to a battery of voltage V. Then the capacitor is placed so that the plates are in contact with a liquid of dielectric constant κ and density ρ as shown in the figure. The liquid is pushed up to a height h due to an electrostatic force until it is balanced by gravitational force. Neglect forces due to surface tension.

(i) By considering the system as two capacitors connected together, show that the equivalent capacitance C of the system is given by, $C = \dfrac{\epsilon_0 L[L + h(\kappa - 1)]}{d}$



(ii) Using the result in (b)(i), show that the stored energy in the capacitor is given by, $U = \dfrac{\epsilon_0 V^2 L[L + h(\kappa - 1)]}{2d}$

(iii) If the magnitude of the electrostatic force acting on the liquid is given by $F = \dfrac{dU}{dh}$, show that F could be written as,

$$F = \frac{\epsilon_0 V^2 L(\kappa - 1)}{2d}$$

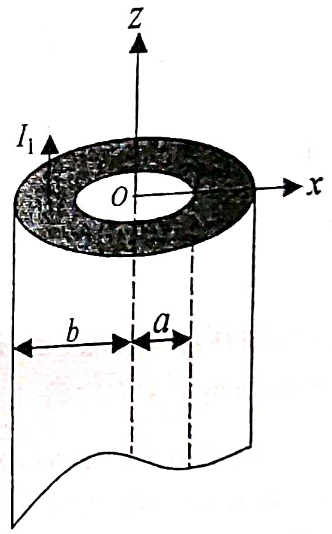
(iv) Using the result in (b)(iii), show that the height h is given by,

$$h = \frac{\epsilon_0 V^2(\kappa - 1)}{2d^2 \rho g}$$

Part B

(a) State the Amphere's circuital law.

(b) An infinitely long hollow cylindrical conductor of inner radius a and outer radius b carries a current I_1 as shown below. I_1 is uniformly distributed over the cross section of the conductor.



(i) Write down an expression for the current density (J) in the conductor.

(ii) Find the magnetic field at a distance x along the x axis. Consider three cases $0 < x < a$, $a < x < b$ and $x > b$ separately.

(c) Another infinitely long cylindrical conductor (radius$< a$) which carries a current I_2 in the opposite direction is placed along the axis of the hollow cylinder.

(i) Find the magnetic field at a point along the x axis where $x>b$.

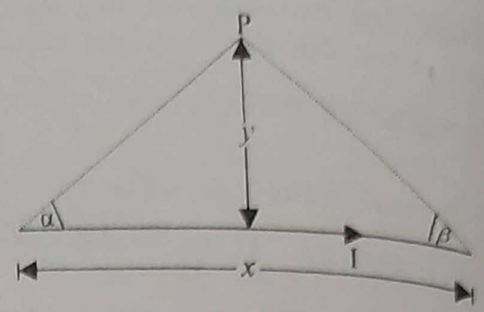
(ii) If $I_1=I_2$, find the magnetic fields when $x=a$ and $x=b$.

State the Biot-Savart law in vector form.

(a) Write down an expression for the magnetic field at the center of a circular ring of radius a and carrying a current I.

(b) A straight conducting wire of length x carries a current I as shown in the figure.

The magnitude of the magnetic field $(\vec{B})$ at point P, at a distance y from the conductor is given by, $B = \dfrac{\mu_0 I(\cos\alpha + \cos\beta)}{4\pi y}$.

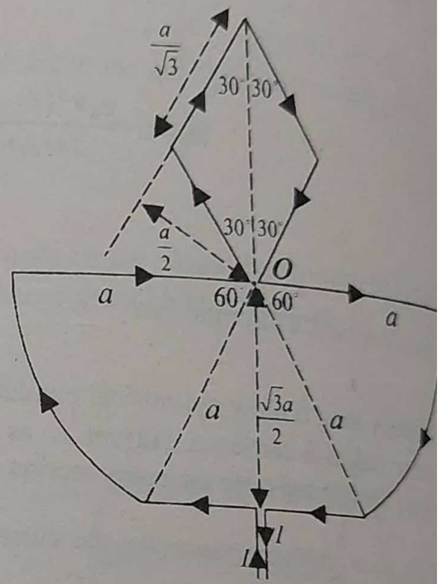


i) Sketch the variation of B with y.

ii) If the conductor is infinitely long, find the direction and magnitude of the magnetic field at p
P.

(c) A straight wire is bent into 12 parts (10 linear parts and 2 circular parts) as shown in the figure. If the current passing through the wire is I, find the magnetic field at the center (point O) of the circular parts in terms of $\boldsymbol{a}$ and $\boldsymbol{I}$. Indicate the direction of the magnetic field at the point O.

$(\cos 120° = -0.5$, $\cos 60° = 0.5$ and $\cos 30° = \frac{\sqrt{3}}{2})$



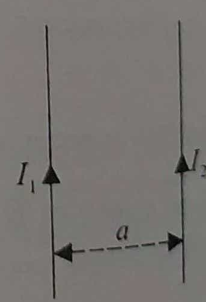
6. (a) The force $(\vec{F})$ acting on a current (I) carrying straight conductor of length l placed in a magnetic
$\vec{B}$ is given by $\vec{F} = I(\vec{l} \times \vec{B})$.

If the angle between the conductor and the magnetic field is θ, find the magnitude of the force on the conductor in following cases.

(i) when $\theta = 0$. (ii) when $\theta = \frac{\pi}{2}$ (iii) when $\theta = \pi$.

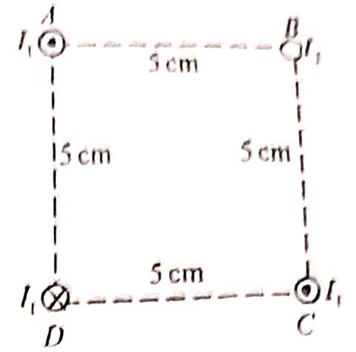
(b) Two identical infinitely long parallel current carrying straight conductors are placed at a distance a apart as shown in the figure. Show that the magnitude of the force acting on a length l of one conductor is given by $F = \dfrac{\mu_0 I_1 I_2 l}{2\pi a}$.

What is the direction of the force?



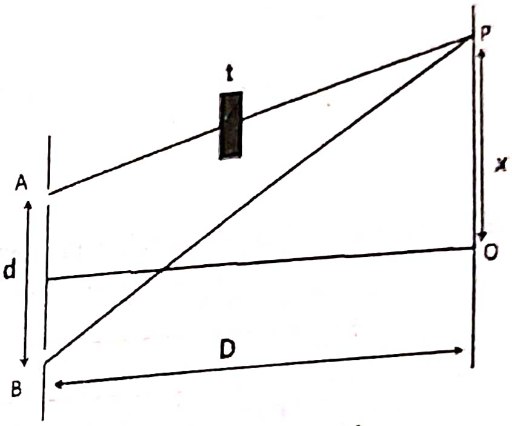
) Top view of four infinitely long parallel current carrying wires (A, B, C & D) is shown in the figure.

If the resultant force acting on a unit length of the wire D is zero find the magnitude and the direction of the current passing through the wire B.



Part C

onsider two coherent light sources, A and B, located at uidistance from the point O as shown in the diagram. hen a transparent plate of thickness t and refractive dex μ is introduced into the path as shown, the bright inge which was originally at O is shifted to P. Time ken by a light wave to travel from B to P in air is equal the time taken by a light wave to travel from A to P rough air and the plate. Suppose the velocity of light in r and in plate medium are c_0 and c, respectively.



) Using the given quantities and the lengths BP and AP, write down an expression (should be a function of time) for
(i) time T_1 taken by a light wave to travel the distance BP.
(ii) time T_2 taken by a light wave to travel the distance AP through the plate.

b) Using the result in *part (a)*, show that $BP - AP = (\mu - 1)t$.

c) If the point P is occupied by the n^{th} bright fringe before inserting the plate
(i) show that $(\mu-1)t = n\lambda$.
(ii) obtain an expression for the distance x in terms of n, d, λ and D.
(iii) show that the thickness of the plate is $\dfrac{xd}{D(\mu-1)}$.

(d) When a thin glass plate of thickness $3.4\times10^{-4} cm$ is inserted in to the beam path as shown in the above figure, it is found that the central bright fringe shifts to the position of the 4th bright fringe. Find the refractive index of the glass plate if the wavelength used in this experiment is 546 nm.

(e) Explain how you would modify the equation in *part (c)(i)* if the corresponding experiment is done under water of refractive index μ_w.

8. (a) What is meant by ***diffraction*** of light?

(b) By drawing a suitable figure, explain the intensity distribution of a ***Fraunhofer*** diffraction pattern obtained on a screen using a monochromatic light source.

(c) What is the difference between ***interference*** and ***diffraction***?

(d) What are the important differences in the observations that you would expected to see when yo shine white light on a prism and on a diffraction grating?

(e) Find the angular width of the central bright maxima in the Fraunhofer diffraction pattern of a slit width $12\times10^{-5}\,cm$ when the slit is illuminated by the light of wavelength equal to 600 nm.

(f) A diffraction grating used at normal incidence shows a spectral line for wavelength 600 nm certain order (***n***) overlaps with the $(n+1)^{th}$ order of another spectral line of wavelength equal to 45 nm. If the angle of diffraction is 30° calculate the number of grating lines in a one-centimeter of grating.

9. (a) Write short notes on ***<u>four</u>*** of the following topics

(i) Transverse waves	(iv) Circularly polarized light
(ii) Polarizer	(v) Quarter wave plate
(iii) Plane polarized light	(vi) Half wave plate

(b) Suppose that the following optical components are given to you. The vertical arrow polarizer(/analyzer) and quarter(/half) wave plate shows the direction of transmission axis and optic axis respectively. These axes can be rotated to a desired angle if needed.

1	Unpolarized monochromatic light source	
2	Polarizer	
3	Analyzer	
4	Quarter wave plate	
5	Half wave plate	

(i) By drawing a suitable figure, show how you would arrange only the necessary components in the correct order to obtain plane-polarized light.

(ii) By using the analyzer in the correct place show a way to completely block the plane polarized light.

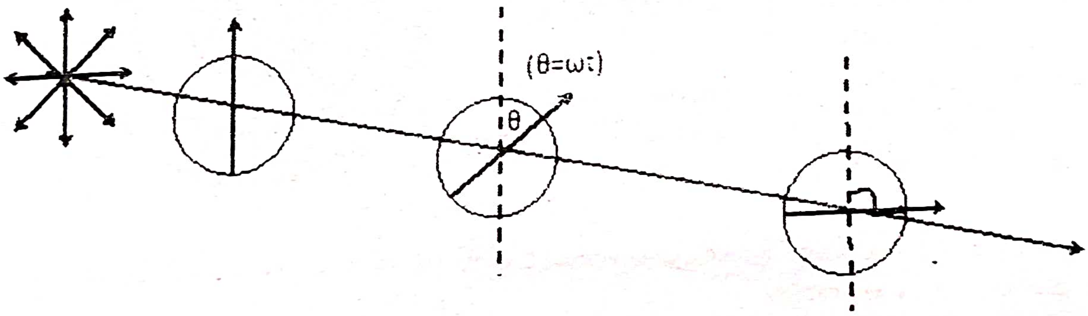
(iii) By drawing a suitable figure, show how you would place the necessary optical component in the correct order to obtain circularly polarized light.

(iv) By drawing a suitable figure, show how you would arrange the necessary components to obtain horizontally polarized light by using vertically polarized light.

c) Suppose that the transmission axis of the two polarizing disks are perpendicular to each other as shown in the following figure. Let the middle polarizing disk be rotated around the common axis with an angular speed ω. Show that if unpolarized light is incident the left disk with an intensity I_0, the intensity of the beam emerging from the right disk is

$I = \frac{1}{2} I_0 \cos^2 \omega t \cdot \sin^2 \omega t$.

Note: **The intensity of the light after the first left polarizer is given to you as** $\frac{I_0}{2}$



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