National University of Computer and Emerging Sciences, Lahore Campus				
	Course:	**Applied Physics**	**Course Code:**	**EE117**
	Program:	**BS (CS), BS (DS), BS (SE)**	**Semester:**	**Fall 2020**
	Duration:	**4 years**	**Total Marks:**	**50**
	Date:	**24-11-2020**	**Weightage:**	**15%**
	Section(s):	**All**	**Page(s):**	**5**
	Exam:	**Midterm 2**	**Max. Time**	**90 minutes**
	Name:		**Roll No./Section**	
Instructions/Notes:	**Attempt all questions.** **Write your answer within the space provided only.** **Do not attach any rough sheet with the paper.**			

Question 1 (a). The equation of a transverse wave traveling along a string is

$$y = (2.0mm)\sin[(20m^{-1})\,x - (600s^{-1})t.]$$

Find (a) amplitude, (b) frequency, (c) velocity (including sign) and (d) wavelength of the wave. Also find the maximum transverse speed of a particle in the string.

(2+2+2+2+2=10)

(a) The amplitude is $y_m = 2.0\ mm$

(b) $\omega = 600\ rad/s$; $f = \frac{\omega}{2\pi} = \frac{600}{2\pi} \simeq 95\ Hz$

(c) As $k = 20\ rad/m$; $v = \omega/k = 600/20 = 30\ m/s$ in $+x$ direction

(d) (wavelength) $\lambda = \frac{2\pi}{k} = \frac{2\pi}{20}\ m = 0.31m$

(e) $$y = y_m \sin(kx - \omega t)$$

$$\dot{y} = -\omega y_m \sin(kx - \omega t)$$

$$\dot{y}_{max} = \omega y_m = (600)(2.0)\ mm/s = 1200\ mm/s = 1.2\ m/s$$

Question 1 (b): Calculate the expression for the time period of torsion pendulum. Also draw the diagram for a torsion pendulum. **(3+2=5)**

For small twists the restoring torque in the wire is proportional to angular displacement (Hooke's Law), so that

$$\tau = -\kappa\theta$$

κ is torsional constant & depends on properties of wire.

The equation of motion for such a system can be written using angular form of Newton's 2nd Law

$$\sum \tau_z = I\alpha_z = I\, d^2\theta/dt^2$$

I is rotational inertia of disk

We can write!

$$-\kappa\theta = I\, d^2\theta/dt^2$$

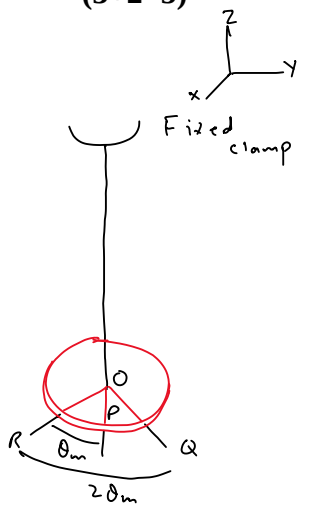
OR

$$\frac{d^2\theta}{dt^2} = -\left(\kappa/I\right)\theta \quad \text{— (1)}$$

Equation (1) is similar to equation of motion of Simple Harmonic oscillator with a variable θ with solution $\theta = \theta_m \cos(\omega t + \phi)$

$$\omega^2 = \frac{\kappa}{I} \Rightarrow \boxed{T = 2\pi\sqrt{I/\kappa}}$$

$I = \frac{1}{2}MR^2$ for disk with rotational axis in middle of disk.



The line OP oscillates b/w OQ & OR

θ_m is angular amplitude

Oscillation takes place in xy-plane

Z-axis is along wire!

Question 1 (c): A particle rotates counterclockwise in a circle of radius 3.00 m with a constant angular speed of 8.00 rad/s. At t =0, the particle has an x coordinate of 2.00 m and is moving to the right. Determine the x coordinate as a function of time. **(5)**

(Amplitude of particles motion) A = Radius of circle = 3m.

ω = 8 rad/s

We have $x = A\cos(\omega t + \phi)$

$$x = 3m\cos(8t + \phi)$$

x = 2m at t = 0

$$2m = 3m\cos(\phi)$$

$$\cos(\phi) = 2/3$$

$$\phi = \pm 0.841 \text{ radians}$$

$\dot{x} = -A\omega\sin(\omega t + \phi)$

At t = 0, particle is moving to right i.e $v > 0$ (+ve direction)

$\dot{x} = -A\omega\sin\phi > 0$

$-A\omega\sin\phi > 0$ only if ϕ is -ve

So, ϕ should be -ve

$$\boxed{\phi = -0.841 \text{ radians}}$$

Question 2 (a): Consider three point charges located at the corners of a right triangle as shown in Figure 1, where $q_1 = q_3 = 5.0\ \mu C$, $q_2 = 2.0\ \mu C$, and $a = 0.10$ m. Find the resultant force exerted on q_3 in unit vector notation.

Also discuss what happens if the signs of all the charges were changed to the opposite signs. How would this effect the result for the resultant force. **(8+2=10)**

$$\theta = \tan^{-1}(a/a) = 45^\circ$$

$$|\vec{F}_{13}| = k\frac{|q_1||q_3|}{r^2} = 8.99\times10^9\ \frac{(5\times10^{-6}\,C)(5\times10^{-6}\,C)}{2(0.1)^2}\ N \qquad r = \sqrt{2}a$$

$$|\vec{F}_{13}| = 11\,N$$

$$|\vec{F}_{23}| = k\frac{|q_2||q_3|}{r^2} = 8.99\times10^9\ \frac{(2\times10^{-6}\,C)(5\times10^{-6}\,C)}{(0.1)^2}\ N \quad ; \ r = a$$

$$|\vec{F}_{12}| = 9.0\,N$$

$$\vec{F}_{23} = -(9.0\,N)\hat{e}_x$$

$$\vec{F}_{13} = (11\,N)\cos(45^\circ)\hat{e}_x + (11\,N)\sin(45^\circ)\hat{e}_y$$

$$\vec{F}_{13} = (7.9\,N)\hat{e}_x + (7.9\,N)\hat{e}_y$$

$$\vec{F} = \vec{F}_{12} + \vec{F}_{13}$$

$$= -(9.0\,N)\hat{e}_x + (7.9\,N)\hat{e}_x + (7.9\,N)\hat{e}_y$$

$$\boxed{\vec{F} = -(1.1\,N)\hat{e}_x + (7.9\,N)\hat{e}_y}$$

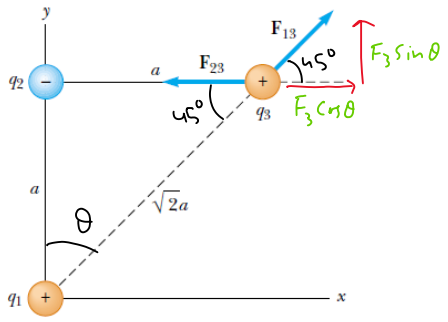


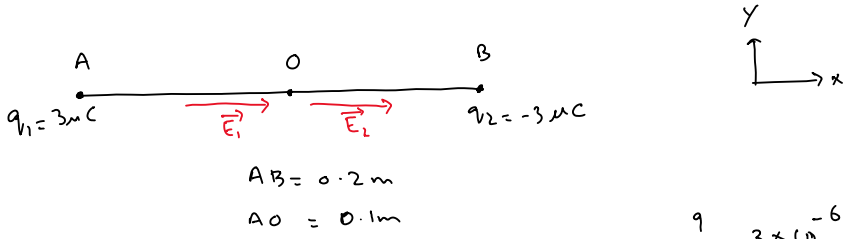
Fig. 1

What if sign of all three charges were changed to opposite signs?

The charge q_3 would still be attracted towards q_2 and repelled from q_1 with forces of same magnitude.

Thus the final result of $\vec{F}$ would be exactly the same!

Question#2(c): Two point charges q1 = $+3\mu C$ and q2= $-3\mu C$ are located 20cm apart in vacuum. What is the electric field at the mid-point O of the line AB joining the two charges? **(5)**



$AB = 0.2\,m$

$AO = 0.1\,m$

(E-field at point-O due to 3μC charge) $\vec{E_1} = \frac{k|q_1|}{r^2}\hat{e}_x = \frac{9\times10^{9}\times 3\times10^{-6}}{(0.1)^2}\ N/C$

$= (2.7\times10^{6}\ N/C)\,\hat{e}_x$

(Electric field at point O due to -3μC charge) $\vec{E_2} = \frac{k|q_2|}{r^2}\hat{e}_x = \frac{9\times10^{9}\times 3\times10^{-6}}{(0.1)^2}\ N/C\ \hat{e}_x$

$= (2.7\times10^{6}\ N/C)\,\hat{e}_x$

(E-field at point-O) $\vec{E} = \vec{E_1} + \vec{E_2}$

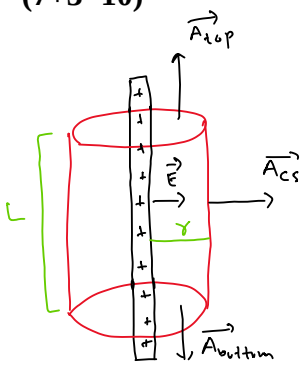
$= (2.7\times10^{6}\ N/C)\hat{e}_x + (2.7\times10^{6}\ N/C)\,\hat{e}_x$

$\vec{E} = (5.4\times10\ N/C)\,\hat{e}_x$

Question 3(a): Find the electric field a distance *r* from a wire of positive charge of infinite length and constant charge per unit length λ. Also draw the diagram for the positively charged rod.

(7+3=10)

$\vec{A}_{cs}$ corresponds to area of curved surface!



$$\Phi_{total} = \Phi_{cs} + \Phi_{top} + \Phi_{bottom}$$

$$= \vec{E}\cdot\vec{A}_{cs} + \vec{E}\cdot\vec{A}_{top} + \vec{E}\cdot\vec{A}_{bottom}$$

$$= EA_{cs}\cos(0) + EA_{top}\cos(90^\circ) + EA_{bottom}\cos(90)$$

$$= EA_{cs} + 0 + 0$$

$$\Phi_{total} = E(2\pi rL)$$

$$Q_{inside} = \lambda L$$

Using Gauss's Law

$$\Phi = \frac{Q_{inside}}{\varepsilon_0}$$

$$E(2\pi rL) = \frac{\lambda L}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r\varepsilon_0}$$

(Magnitude of E-field at a distance r

Direction is perpendicular to line of charge!

Question 3(b): Find the value of the electric field at a distance r = 10cm from the center of a non-conducting sphere of radius R=1cm which has an extra positive charge equal to 7 Coulomb uniformly distributed within the volume of the sphere. **(5)**

If the charge at sphere (of radius R) is uniformly distributed, for a distance r from center of sphere r such that $r > R$, the E-field created by it is same as the electric field of the same amount of point charge located at the center of center of sphere. We also get the same result using Gauss's law

$$(\text{E-field outside sphere}) = \frac{kq}{r^2} = \frac{9\times10^9 \times 7}{(0.1)^2}\ \frac{N}{C} = \boxed{6.3\times10^{12}\ N/C}$$

$q = 7C$

$r = 0.1m$

direction of E-field is out of sphere along the unit vector of sphere's surface!