NATIONAL UNIVERSITY OF COMPUTER AND EMERGING SCIENCES FAST
Fall-2022
Final Exam
2nd January 2023 (08:30 a.m. – 11:30 a.m.)

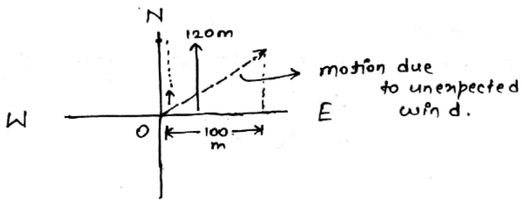
Course Code: NS-1001	**Course Name: Applied Physics**
Instructor Name / Names: Mr. Adeel , Mr. Javaid Qureshi , Ms. Rabia Tabassum , Mr. Rameez, Mr. Waqar	
Student Roll No:	**Section :**

Instructions: Return the question paper with your answer sheet. Read each question completely before answering it. There are **10 questions and 2 pages.** All the questions must be solved according to the sequence given in the question paper.

Total Time: 3 hours Max Marks: 115

Q1: Vector (Total Marks 5 , Estimated Time :5 mints) CLO 1

(a) A ship sets out to sail to a point 120 km due north. An unexpected storm blows the ship to a point 100 km due east of its starting point. (i) How far and (ii) in what direction must it now sail to reach its original destination? (03)



a) Ship position from the starting point O is 120m North and 100 m East.

Distance $= \sqrt{(120)^2 + (100)^2}$ [By pythagoras theorem]

$= 156.2$ m

b) Ship has to sail in south-west direction to reach its original point.

(b) Find the angle between the vectors **A** = 4**i** -3**j**+5**k** and **B** = 3**i** +2**j**+5**k**. (02)

$\theta = \text{Cos}^{-1}$ (A.B/AB) = Cos^{-1}(31/7.07x6.16)= Cos^{-1}(31/43.58) = 44.65°

Q2: Motion in 1D and 2D (Marks 10, Estimated Time:10 mints) CLO2

(a) A stone is tied to a rope is rotated in a vertical circle with uniform speed. if the difference between maximum and minimum tension in the rope is 20N, Find the mass of the stone. (g=10m/s^2)? (04)

The difference between the maximum and minimum tension is,

$T_{max} - T_{min} = 2mg$

& $T_{max} - T_{min} = 20$ N

The mass of the stone, $F = mg$

$\Rightarrow m = \frac{F}{g}$

$= \frac{20}{2 \times 10}$

$m = 1$ kg

(b) The position of a particle moving in an xy plane is given by
r = (2.00t^3 - 5.00t)i + (6.00 - 7.00t^4)j,
with **r** in meters and t in seconds. In unit-vector notation, calculate (i) velocity vector, and (ii) acceleration vector for t= 2.00 sec. (iii) What is the angle between the positive direction of the x axis and a line tangent to the particle's path at t 2.00 s? (06)

(i) v(t)=(6.00t^2−5.00)i−28.0t^3=19i-224j m/s
(ii) a(t)=12.0ti−84.0t^{2}j=(24.0i−336j)m/s^2

The angle of $\vec{v}$, measured from +x, is either

$\tan^{-1}\left(\frac{-224 \text{ m/s}}{19.0 \text{ m/s}}\right) = -85.2°$ or $94.8°$

where we settle on the first choice (–85.2°, which is equivalent to 275° measured counterclockwise from the +x axis) since the signs of its components imply that it is in the fourth quadrant.

Q3: Motion in 2D (Marks 10, Estimated Time: 10 mints) CLO3

(a) You throw a ball toward a wall at speed 25.0 m/s and at an angle of 40 degree above the horizontal. The wall is at a distance 'd' is 22.0 m from the release point of the ball. (i) How far above the release point does the ball hit the wall? What are the (ii) horizontal and (iii) vertical components of its velocity as it hits the wall? (iv) When it hits, has it passed the highest point on its trajectory? (05)

horizontal component of the velocity of the ball is $v_x = v_0\cos 40.0°$, the time it takes for the ball to hit the wall is

$$t = \frac{\Delta x}{v_x} = \frac{22.0\text{m}}{(25.0\text{m/s})\cos 40.0°} = 1.15\text{s}.$$

(a) The vertical distance is

$$\Delta y = (v_0\sin\theta_0)t - \tfrac{1}{2}gt^2 = (25.0\text{m/s})\sin 40.0°(1.15\text{s}) - \tfrac{1}{2}(9.80\text{m/s}^2)(1.15\text{s})^2 = 12.0\text{m}.$$

(b) The horizontal component of the velocity when it strikes the wall does not change from its initial value: $v_x = v_0\cos 40.0° = 19.2\text{m/s}$.

(c) The vertical component becomes (using Eq. 4-23)

$$v_y = v_0\sin\theta_0 - gt = (25.0\text{m/s})\sin 40.0° - (9.80\text{m/s}^2)(1.15\text{s}) = 4.80\text{m/s}.$$

(d) Since $v_y > 0$ when the ball hits the wall, it has not reached the highest point yet.

(b) A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 90 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity after 0.50s. (05)

At t = 0..50s the x–and y- coordinates are

$$x = v_{0x}t = (9.0\text{ms}^{-1})(0.50\text{ s}) = 4.5\text{m}$$

$$y = -\frac{1}{2}gt^2 = -\frac{1}{2}(10\text{ms}^{-2})(0.50\text{s})^2 = -\frac{5}{4}\text{m}$$

the negative value of y shows that this time the motorcycles is below its starting point.

The motorcycle's distance from the origin at this time.

$$r = \sqrt{x^2+y^2} = \sqrt{\left(\frac{9}{2}\right)^2 + \left(\frac{5}{4}\right)^2} = \frac{\sqrt{349}}{4}\text{m}$$

The components of velocity at this time are

$$v_x = v_{0x} = 9.0\text{ms}^{-1}$$

$$v_y = -gt = (-10\text{ms}^{-2})(0.50\text{s}) = -5\text{ms}^{-1}$$

The speed (magnitude of the velocity) at this time is

$$v = \sqrt{v_x^2 + v_y^2}$$

$$= \sqrt{(9.0\text{ms}^{-1})^2 + (-5\text{ms}^{-1})^2} = \sqrt{106}\text{ms}^{-1}$$

Q4: Newton's Law (Marks 10, Estimated Time :10 mints)CLO4

(a) When two objects having masses **m_1= 4kg** and **m_2= 6kg** are hung vertically over a frictionless pulley of negligible mass, determine the magnitude of the acceleration of the two objects and the tension in the lightweight cord. (04)

$a = (m_2-m_1/m_2+m_1)g = 2/10 \times 10 = 2\text{ ms}^{-2}$

(b) You are riding a sled (a vehicle usually on runners for transportation especially on snow) with frictionless runners down a hill with a 30-degree angle slope. The combined mass of you and the sled is 90 kg. As the sled moves, you drag your heels in the snow to keep your speed under control. What force must you exert parallel to the slope to make the sled slow down at a rate of 2.0 m/s^2. (03)

(c) To push a box up a ramp, is the force required smaller if you push horizontally or if you push parallel to the ramp? Why? (03)

To push up a block up a ramp at a constant speed, the force exerted on the block parallel to the surface of the block will be less than the force exerted on the block horizontally as the normal force, hence the force of kinetic friction on the block, in the former case will be less than the normal force, hence the force of kinetic friction on the block, in the latter case will be.

Q5: Oscillation (Marks 10, Estimated Time :15mints)CLO5

(a) On a frictionless, horizontal air track, a glider oscillates at the end of an ideal spring of force constant 2.50 N/m. The graph in Fig-1 shows the acceleration of the glider as a function of time. Find (i) the mass of the glider; (ii) the maximum displacement of the glider from the equilibrium point; (iii) the maximum force the spring exerts on the glider. (05)

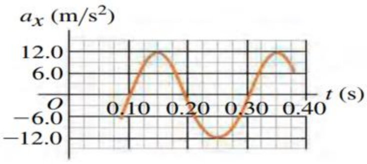


Fig-1

(i) Since, $m = k/\omega^2$,
where ω from graph is $2\pi/T = 2\pi/(0.3-0.1) = 2\pi/0.2 = 31.415$ rad/s
Now, $m = 2.5/(31.415)^2 =$ **$2.53\text{x}10^{-3}$ kg**

(ii) Since, $a = -\omega^2 x$; $(31.415)^2$
or $x = 12/(986.9) =$ **1.22 cm**

(iii) $F = kx = (2.5)(0.0122) =$ **$3.04\text{x}10^{-2}$ N**

(b) A mass is vibrating at the end of a spring of force constant 225 N/m. Fig -2 shows a graph of its position x as a function of time t. (i) At what times is the mass not moving? (ii) How much energy did this system originally contain? (iii) How much energy did the system lose between t = 1.0 s and t = 4.0 s? Where did this energy go? (05)

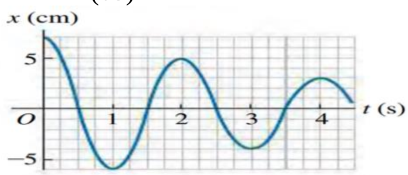


Fig-2

(i) The times at which the particle is not moving ($v_{ins} = 0$) are 0s, 1s, 2s, 3s, 4s.

(ii) Since, $E = 1/2\ k\ x^2 = 1/2\ (225\ \text{N/m})\ (0.07\ \text{m})^2 =$ **0.55 J**

(iii) At 1s ; $E_{(1)} = 1/2\ k\ (0.06\text{m})^2 = 0.405$ J
At 4s ; $E_{(4)} = 1/2\ k\ (0.03\text{m})^2 = 0.101$ J

Therefore, approximately 0**.405-0.101 = 0.304 J** of energy is lost due to damping.

Q6: Wave motion (Marks 10, Estimated Time : 15 mints)CLO6

(a) The function $y(x, t) = (15.0\ \text{cm}) \cos(\pi x - 15\pi t)$, with x in meters and t in seconds, describes a wave on a taut string. What is the transverse speed for a point on the string at an instant when that point has the displacement y = +12.0 cm? (05)

With length in centimeters and time in seconds, we have

$$u = \frac{du}{dt} = (225\pi) \sin(\pi x - 15\pi t) .$$

Squaring this and adding it to the square of $15\pi y$, we have

$$u^2 + (15\pi y)^2 = (225\pi)^2 [\sin^2(\pi x - 15\pi t) + \cos^2(\pi x - 15\pi t)]$$

so that

$$u = \sqrt{(225\pi)^2 - (15\pi y)^2} = 15\pi\sqrt{15^2 - y^2} .$$

Therefore, where $y = 12$, u must be $\pm\ 135\pi$. Consequently, the *speed* there is 424 cm/s = 4.24 m/s.

(b) Two sinusoidal waves with the same amplitude and wavelength travel through each other along a string that is stretched along an x axis. Their resultant wave is shown twice in Fig-3, as the antinode A travels from an extreme upward displacement to an extreme downward displacement in 6.0 ms. The tick marks along the axis are separated by 10 cm;

height H is 1.80cm. Let the equation for one of the two waves be of the form $y(x, t) = y_m \sin(kx + \omega t)$. In the equation for the other wave, what are (i) y_m, (ii) k, and (iii) ω (05)

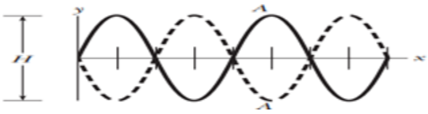


Fig-3

(i) $\mathbf{y_m = 1/2\ H = 0.9\ cm}$

(ii) since one full cycle of the wave (one wavelength) is 40cm,
Therefore, $\mathbf{k = 2\pi/\lambda = 15.707\ m^{-1}}$

(iii) Since, $T = 12ms = 12\times10^{-3}s$
Now, $\mathbf{\omega = 2\pi/T = 523.6\ rad/s}$

<u>Q7: Electrostatics & Gauss's Laws (Marks 12+12, Estimated Time : 45 mints) CLO7</u>

(a) Consider three point charges located at the corners of a right triangle as shown in Fig-4. where $\mathbf{q_1 = q_3 = 5\mu C}$, $\mathbf{q_2 = -2\ \mu C}$ and $\mathbf{a = 0.10m.}$ Find the resultant force exerted on q_3. (06)

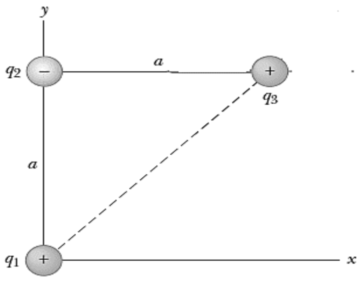


Fig-4

The magnitude of $\mathbf{F}_{23}$ is

$$F_{23} = k_e \frac{|q_2||q_3|}{a^2}$$

$$= (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(2.0 \times 10^{-6}\ \text{C})(5.0 \times 10^{-6}\ \text{C})}{(0.10\ \text{m})^2}$$

$$= 9.0\ \text{N}$$

In the coordinate system shown in Figure 23.8, the attractive force $\mathbf{F}_{23}$ is to the left (in the negative x direction).

The magnitude of the force $\mathbf{F}_{13}$ exerted by q_1 on q_3 is

$$F_{13} = k_e \frac{|q_1||q_3|}{(\sqrt{2}a)^2}$$

$$= (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(5.0 \times 10^{-6}\ \text{C})(5.0 \times 10^{-6}\ \text{C})}{2(0.10\ \text{m})^2}$$

$$= 11\ \text{N}$$

The repulsive force $\mathbf{F}_{13}$ makes an angle of 45° with the x axis. Therefore, the x and y components of $\mathbf{F}_{13}$ are equal, with magnitude given by $F_{13}\cos 45° = 7.9$ N.

Combining $\mathbf{F}_{13}$ with $\mathbf{F}_{23}$ by the rules of vector addition, we arrive at the x and y components of the resultant force acting on q_3:

$$F_{3x} = F_{13x} + F_{23x} = 7.9\ \text{N} + (-9.0\ \text{N}) = -1.1\ \text{N}$$

$$F_{3y} = F_{13y} + F_{23y} = 7.9\ \text{N} + 0 = 7.9\ \text{N}$$

We can also express the resultant force acting on q_3 in unit-vector form as

$$\mathbf{F}_3 = (-1.1\hat{\mathbf{i}} + 7.9\hat{\mathbf{j}})\ \text{N}$$

(b) Why are sparks often seen or heard on a dry day when fabrics are removed from a clothes dryer in dim light? (03)

Clothes rub against your body and electrons are transferred so a charge builds up.

(c) Two charges are placed at a certain distance apart. A metallic sheet is placed between them. What will happen to the force between the charges? (03)

In Coulomb's law, permittivity constant of material comes in the denominator.
Since a metallic sheet is put in between and metals are good conductors, the permittivity is greatly increased and hence the force between two charges will decrease.

(d) A 70 mC charge is at the center of a cube of side 12 cm. (i) what is the total flux through the cube ? (ii) What is the flux through the face ? (iii) would your answers to (i) or (ii) change if the charge were not at the center? (06)

(iv) The total flux through the surface of the cube is: $\mathbf{\phi_E = q_{in}/\epsilon_o = 70\times10^{-3} / 8.85\times10^{-12} = 7.9\times10^{9}\ N\cdot m^2/C}$

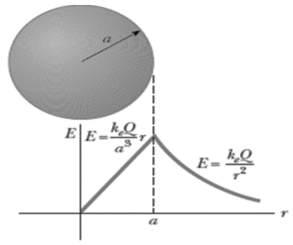
(v) $(\phi_E)_{oneface} = 1/6\ \phi_E = \mathbf{1/6\ (7.9\times10^9/6) = 1.318 \times 10^9\ N\cdot m^2/C}$

(vi) **The answer to part (i) would be unchanged because the flux through the entire closed surface depends only on the total charge inside the surfaces. The answer to part (ii) would change because the charge could now be at different distances from each face of the cube.**

(e) A spherical Gaussian surface surrounds a point charge q. Describe what happens to total flux through the surface if: (i) A charge is tripled? (ii) The radius of the surface is doubled? (iii)The surface is changed to a cube? (03)

(i) the flux is tripled because the charge is tripled. (ii) the flux remains the same because the charge is the same. (iii) the flux remains the same because the charge is the same i.e., flux does not depend on the geometry or surface.

(f) Show the variations of the electric field with respect to the distance for a symmetrical spherical charged distribution with the help of graphs only.(Plot must start from the origin up to the surface of the conducting sphere). (02)



<u>Q8: Electric Current (Marks 12, Estimated Time : 25 mints) CLO7</u>

(a) A rectangular block of iron has dimensions 1.2 cm x 1.2 cm x 15 cm. A potential difference is to be applied to the block between parallel sides and in such a way that those sides are equipotential surfaces. What is the resistance of the block if the two parallel sides are (a) the square ends (with dimensions 1.2 cm x 1.2 cm) and (b) two rectangular sides (with dimensions 1.2 cm x 15 cm)? (04)

For arrangement 1, we have $L = 15$ cm = 0.15 m and

$$A = (1.2\ \text{cm})^2 = 1.44 \times 10^{-4}\ \text{m}^2.$$

Substituting into Eq. 26-16 with the resistivity ρ from Table 26-1, we then find that for arrangement 1,

$$R = \frac{\rho L}{A} = \frac{(9.68 \times 10^{-8}\ \Omega\cdot\text{m})(0.15\ \text{m})}{1.44 \times 10^{-4}\ \text{m}^2}$$
$$= 1.0 \times 10^{-4}\ \Omega = 100\ \mu\Omega.$$

Similarly, for arrangement 2, with distance $L = 1.2$ cm and area $A = (1.2\ \text{cm})(15\ \text{cm})$, we obtain

$$R = \frac{\rho L}{A} = \frac{(9.68 \times 10^{-8}\ \Omega\cdot\text{m})(1.2 \times 10^{-2}\ \text{m})}{1.80 \times 10^{-3}\ \text{m}^2}$$
$$= 6.5 \times 10^{-7}\ \Omega = 0.65\ \mu\Omega.$$

(b) The Fig- here shows three cylindrical copper conductors along with their face areas and lengths. Rank them according to the current through them, greatest first, when the same potential difference V is placed across their lengths. (Give reasons mathematically) (03)

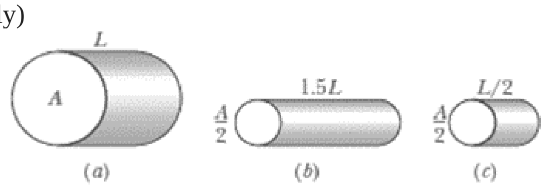


Fig-5

$R_a:R_b:R_c = \rho L/A : \rho 3/2L/A/2 : \rho L/2/A/2$
$R_a:R_b:R_c = \rho L/A : 3\rho L/A : \rho L/A$
$R_a:R_b:R_c = 1:3:1$
∴ Rb>Ra=Rc
Hence, $\mathbf{I_a = I_c > I_b}$

(c) A fluid with resistivity 8.5 Ωm seeps into the space between the plates of 120pF parallel plate air capacitor when the space is completely filled, what is the resistance between plates? (03)

$C = \varepsilon_o \frac{A}{d} \Rightarrow \frac{C}{\varepsilon_o} = \frac{A}{d} = 1.355$

$R = \rho \frac{L}{A}$

$= \frac{\rho}{\frac{A}{L}} = 8.5/1.355$

$= 6.27\ \Omega$

(d) How does the resistance for copper and for silicon change with temperature? Why are the behaviors of these two materials different? (02)

The resistance of copper increases with temperature, while the resistance of silicon decreases with increasing temperature. The conduction electrons are scattered more by vibrating atoms when copper heats up. Silicon's charge carrier density increases as temperature increases and more atomic electrons are promoted to become conduction electrons.

<u>Q9: Capacitors (Marks 12, Estimated Time : 25mints)CLO 8</u>

(a) Why is the electric field reduced by inserting dielectric material between the plates of capacitors? (03)

The strength of the electric field is reduced due to the presence of dielectric. If the total charge on the plates is kept constant, then the potential difference is reduced across the capacitor plates. In this way, dielectric increases the capacitance of the capacitor.

(b) How many capacitors, each of 8μF and 25V are required to form a composite capacitor of 16μF and 100V? (03)

To have 100 V tolerance, you need to stack up four 8 μF capacitor in series. The equivalent capacitance of 4 such capacitors is:

Ceq=8/4 μ F = 2μF

To make a total of 16 μF that tolerates 1000V, you need 8 set of them arranged in parallel such that

Ceq′=8×2μF=16μF

∴ Total number of capacitors **=8×4=32**

(c) A 54 μF capacitor is connected across a programmed power supply. During the interval from t = 0 to t =5s the output voltage of the supply is given by $V(t) = 12t + 5t^2 - 2t^3$ volts. At t = 1.5 s find (i) the charge on the capacitor, (ii) the current into the capacitor, and (iii) the power output from the power supply. (03)

(i) Q=CV or C=Q/V = $54\times10^{-6}/22.5$ = 2.4 μC
(ii) I = Q/t = 1.6 μA
(iii) P = VI = 36 μWatt

(d) In Fig-6, the battery has a potential difference (V) of 10 V and the five capacitors each have a capacitance of 10.0 μF. Calculate equivalent capacitance and the charge on C_1. (03)

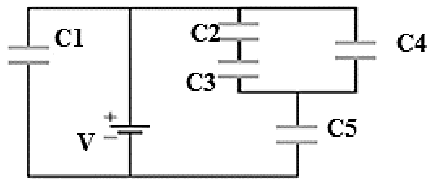


Fig-6

C_{23} = 10/2 = 5 μF , C_{234} = 15 μF, C_{2345} = 6 μF
C_{eq} = 16 μF

Charge on C_1 => Q=CV = 10x16μF = 160 μC

<u>Q10: Magnetic Field (Marks 12, Estimated Time : 25mints)CLO9</u>

(a) Why can't we separate the north and south poles of a magnet? Give the reason. (03)

Magnetic monopoles do not exist in nature. Even if a magnet is broken in half, each half has one north pole and one south pole. Hence, we cannot isolate the north and south poles of a magnet.

(b) Can a magnetic field cause change in the speed of a charged particle that enters the magnetic field? Discuss the work done by the magnetic field on a charged particle. . (03)

The magnetic field does no work, so the kinetic energy and speed of a charged particle in a magnetic field remain constant. The magnetic force, acting perpendicular to the velocity of the particle, will cause circular motion.

(c) What is Lorentz's force? Can a particle pass through the region unaffected by the two fields (Electric and Magnetic)?(03)

We know, when a charged particle q moves through a region with both an electric and a magnetic field, it experiences a force given by, $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$

Under the case in which electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle, The electric force and magnetic forces are exactly opposite to each other.

$qE = qvB$

So the required condition for no deflection is

$$v = \frac{E}{B}$$

(d) A proton moves through a uniform magnetic field given by **B** = X**i** + (4.5X)**j**. At a particular instant, the electron has velocity **v** = (2.5**i** + 4.3**j**)m/s and the magnetic force acting on it is (6.4x 10^{-10} N)**k**. Find X. (03)

F=e(vxB) = 6.4x10^{-10} k = 1.6x10^{-19} (11.12) Xk
Or X = 5.75 x10^{8} Tesla

Good Luck ☺