JEE ADVANCE 2017 (PAPER - I)

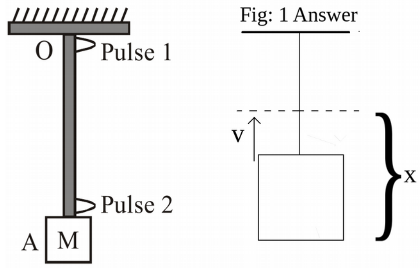
1. A block M hangs vertically at the bottom end of a uniform rope of constant mass per unit length. The top end of the rope is attached to a fixed rigid support at O. A transverse wave pulse (Pulse 1) of wavelength λ_0 is produced at point O on the rope. The pulse takes time T_{OA} to reach point A. If the wave pulse of wavelength λ_0 is produced at point A (Pulse 2) without disturbing the position of M it takes time T_{AO} to reach point O. Which of the following options is/are **correct** ?

(A) The time $T_{AO} = T_{OA}$

(B) The velocities of the two pulses (Pulse 1 and Pulse 2) are the same at the midpoint of rope

(C) The wavelength of Pulse 1 becomes longer when it reaches point A

(D) The velocity of any pulse along the rope is independent of its frequency and wavelength.



<u>Sol^n :</u> Taught directly as Q. No. 26 of Waves on Strings in H.C.V.

Ans:(A, D)

In option **A**, v = √(gx) , as taught when we integrate it from 0 to l, time will be equal by symmetry
In option **B**, Speed will be same but velocities in different in opposite directions
In option **C**, Frequency (ν) is basic nature and does not by reflection or refraction (as taught). When pulse (1) reaches bottom, Tension decreases, v decreases, λ decreases
In option **D**, Velocity v = √(gx) and is dependent on x (or, T and μ) only

2. A human body has a surface area of approximately 1 m^2. The normal body temperature is 10 K above the surrounding room temperature T_0. Take the room temperature to be T_0 = 300 K. For T_0 = 300 K, the value of $\sigma T_0^4 = 460\ Wm^{-2}$ (where σ is the Stefan-Boltzmann constant). Which of the following options is/are **correct** ?

(A) The amount of energy radiated by the body in 1 second is close to 60 Joules

(B) If the surrounding temperature reduces by a small amount $\Delta T_0 << T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time

(C) Reducing the exposed surface area of the body (e.g. by curling up) allows humans to maintain the same body temperature while reducing the energy lost by radiation

(D) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths

<u>Sol^n :</u> Taught directly in class of Stefan's Law and Newton's Law of Cooling.

Ans: (A,B,C) or only (C)

Assuming e=1 (black body for human)
Energy radiated per sec = $\sigma A T^4 = \sigma A (T_o + \Delta T)^4 = \sigma A T_o^4 (1 + \Delta T/T_o)^4$
= 460 (1 + 4 x 10/300) = 520 J
Net Energy Radiated per second = $\sigma A T^4 - \sigma A T_o^4$ = 520 – 460 = 60 J

In option **A**, net word is not written hence wrong. Answer should be 520 J
In option **B**, expression is true, but if person receives less energy due to smaller room temperature (T_o) it should radiate less energy. Hence option B is also wrong.

In option **C**, Decrease in surface area(A) will reduce radiation by body, hence body will remain warm.
In option **D**, If temperature of body increases λ_m decreases. Hence wrong.

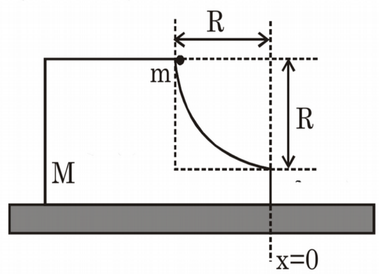
3. A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surface of a fixed table. Initially the right edge of the block is at x = 0, in a *co-ordinate system fixed to the table*. A point mass m is released from rest at the topmost point of the path as shown and it slides down. When the mass loses contact with the block, its position is x and the velocity is v. At that instant, which of the following options is/are **correct** ?

(A) The x component of displacement of the centre of mass of the block M is : $-\dfrac{mR}{M+m}$

(B) The position of the point mass is : $x=-\sqrt{2}\dfrac{mR}{M+m}$

(C) The velocity of the point mass m is : $v=\sqrt{\dfrac{2gR}{1+\dfrac{m}{M}}}$

(D) The velocity of the block M is : $V=-\dfrac{m}{M}\sqrt{2gR}$



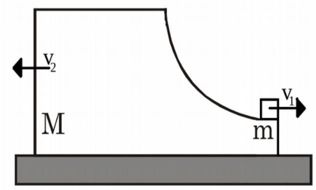


Fig: 3 Answer

Sol^n : Same as that taught directly as in Set(2) of Irodov Class with Theory Class of Center of Mass

For M → x = m . $L_{relative}$ / (m + M) = - m.L /(m + M) option (**A**) correct
By momentum conservation, $mv_1 = MV_2$ ---(1)
By energy conservation, $mgh = \frac{1}{2} mv_1^{\,2} + \frac{1}{2} M (mv_1/M)^2$, by (1)
:. $v_1 = \sqrt{2gR/(1 + m/M)}$ option (**C**) is correct Ans: (A,C)

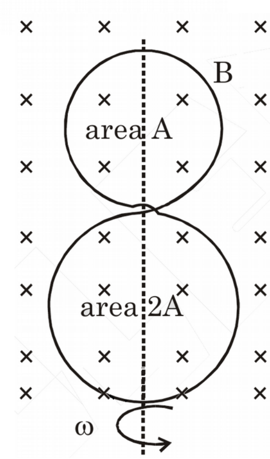
4. A circular insulated copper wire loop is twisted to form two loops of area A and 2A as shown in the figure. *At the point of crossing the wires remain electrically insulated from each other*. The entire loop lies in the plane (of the paper). A uniform magnetic field $\vec{B}$ points into the plane of the paper. At t = 0, the loop starts rotating about the common diameter as axis with a constant angular velocity ω in the magnetic field. Which of the following options is/are correct?

(A) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper

(B) The net emf induced due to both the loops is proportional to cos ωt

(C) The emf induced in the loop is proportional to the sum of the areas of the two loops

(D) The amplitude of the maximum net emf induced due to both the loops is equal to the amplitude of maximum emf induced in the smaller loop alone



Sol^n : Same as that taught directly in Theory Class of EMI

Flux $\Phi_B = B . A = BA \cos \omega t$
$\Sigma = -d\Phi_B / dt = (BA\omega) . \sin\omega t$
:. $\Sigma \ \alpha \ d\Phi_B / dt \ \alpha \ \sin\omega t$
$\Sigma_{net} = \Sigma_{2A} - \Sigma_A = (B. 2A\omega) . \sin\omega t - (BA\omega) . \sin\omega t$
$= (BA\omega) . \sin\omega t$, clockwise in bigger loop and anticlockwise in smaller loop.

Ans. (A,D)

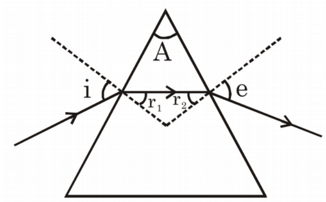
5. For an isosceles prism of angle A and refractive index μ, it is found that the angle of minimum deviation $\delta_m = A$. Which of the following options is/are correct ?

(A) At minimum deviation, the incident angle i_1 and the refracting angle r_1 at the first refracting surface are related by $r_1 = (i_1/2)$

(B) For this prism, the refractive index μ and the angle of prism A are related as $A = \frac{1}{2}\cos^{-1}\left(\frac{\mu}{2}\right)$

(C) For this prism, the emergent ray at the second surface will be tangential to the surface when the angle of incidence at the first surface is $i_1 = \sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2}-1}-\cos A\right]$

(D) For the angle of incidence $i_1 = A$, the ray inside the prism is parallel to the base of the prism.



Sol^n : Same as that taught directly in Theory Class of Prisms (elementary formula) Ans: (A,C,D)

At $\delta_m = A$, $i_1 = i_2$, $r_1 = r_2$, $A = r_1 + r_2 = 2r_1$

$\delta_m = i_1 + i_2 - A = A \Rightarrow 2i_1 = 2A \Rightarrow i_1 = A$:. $r_1 = A/2 = i_1/2$

Option **A** is correct

$\mu = \sin\{(A + \delta_m)/2\}/ \sin (A/2) = \sin (A+A/2) / \sin A/2 = 2\cos A/2$

:. $A = 2\cos^{-1}(\mu/2)$ Option **B** wrong

$\sin r_2 = 1/\mu$, $r_1 = A - r_2$

$\sin i_1 = \mu \sin r_1$, $i_1 = \sin^{-1}(\mu \sin(A - r_2)) = \sin^{-1}[\mu (\sin A. \cos r_2 - \cos A. \sin r_2)]$

$i_1 = \sin^{-1}[\mu (\sin A \sqrt{(1 - 1/\mu^2)} - \cos A. 1/\mu)] = \sin^{-1}[\sin A \sqrt{(\mu^2 - 1)} - \cos A]$

$i_1 = \sin^{-1}[\sin A \sqrt{(4\cos^2 A/2 - 1)} - \cos A]$ (value of μ is taken from above)

Option **C** is correct

At δ_m, ray inside prism is parallel to base in isosceles triangle as taught in class

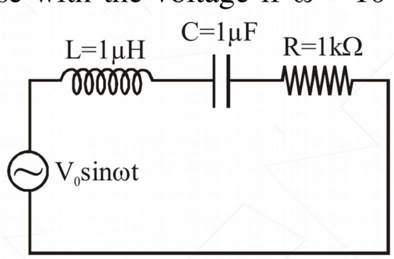
6. In the circuit shown, L = 1 μH, C = 1 μF and R = 1 kΩ. They are connected in series with an a.c. source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct ?

(A) The frequency at which the current will be in phase with the voltage is independent of R.

(B) At ω ~ 0 the current flowing through the circuit becomes nearly zero

(C) At $\omega >> 10^6$ rad.s^{-1}, the circuit behaves like a capacitor.

(D) The current will be in phase with the voltage if $\omega = 10^4$ rad.s^{-1}.



Sol^n : Same as that taught directly in class of Series L-C-R Circuit Ans: (A, B)

In option **A**, In resonance, Φ = 0 and current is in phase with voltage

For Φ = 0, $\omega L = 1/\omega C$. Hence independent of R

In option **B**, At ω ≈ 0 , $I = V_{rms} / \sqrt{\{R^2 + (\omega L - 1/\omega C)^2\}} = V_{rms} / \infty = 0$

In option **C**, resonant $\omega_o = 1/\sqrt{(LC)} = 1/\sqrt{(1 \times 10^{-6} \times 1 \times 10^{-6})} = 10^6$ rad/s (when $X_L = X_c$)

At $\omega >> 10^6$ rad/s → Circuit will behave as inductor

In option **D**, option wrong as $\omega_o = 10^6$ rad/s

7. A flat plate is moving normal to its plane through a gas under the action of a constant force F. The gas is kept at a very low pressure. The speed of the plate v is much less than the average speed u of the gas molecules. Which of the following options is/are true ?

(A) The resistive force experienced by the plate is proportional to v

(B) The pressure difference between the leading and trailing faces of the plate is proportional to uv.

(C) The plate will continue to move with constant non-zero acceleration, at all times

(D) At a later time the external force F balances the resistive force.

Sol^n : Same as that taught directly in Theory Class of Terminal Velocity and Bernoulli's Equation in Fluid Mechanics Ans. (A,B,D)

In option A, Resistive viscous Force α v (**A**) correct

After a long time this viscous force will balance external force F. Then plate will acquire terminal velocity. (**D**) is correct and (**C**) is wrong Then (a = 0)

For option B, By Bernoulli's Equation → pressure difference $\Delta p = \frac{1}{2}\rho[(u+v)^2 - (u-v)^2] = 2\rho u.v$

:. $\Delta p \ \alpha \ u.v$ (**B**) correct

8. A drop of liquid of radius $R = 10^{-2}$ m having surface tension $S = \dfrac{0.1}{4\pi}\text{Nm}^{-1}$ divides itself into K identical drops. In this process the total change in the surface energy $\Delta U = 10^{-3}$ J. If $K = 10^{\alpha}$ then the value of α is

Sol^n : Same as that directly taught in Theory Class of Surface Tension Ans. (6)

Surface Energy, U = S. A. and By Mass Conservation, $\rho . 4/3\, \pi R^3 = k. \rho . 4/3\, \pi r^3 \Rightarrow r = R/k^{1/3}$

$\Delta U = S. \Delta A = S[\,k.\ 4\pi (R/k^{1/3})^2 - 4\pi R^2) = S. 4\pi R^2 [k^{1/3} - 1]$

$\Rightarrow 10^{-3} = (0.1/4\pi) \times 4\pi \times 10^{-4} [k^{1/3} - 1] \Rightarrow 100 = k^{1/3} - 1 \approx k^{1/3} \Rightarrow 10^2 = (10^{\alpha})^{1/3} \Rightarrow 2 = \alpha/3 \Rightarrow \alpha = 6$

9. ^{131}I is an isotope of Iodine that β decays to an isotope of Xenon with a half-life of 8 days. A small amount of a serum labelled with ^{131}I is injected into the blood of a person. The activity of the amount of ^{131}I injected was 2.4×10^5 Becquerel (Bq). It is known that the injected serum will get distributed uniformly in the blood stream in less than half an hour. After 11.5 hours, 2.5 ml of blood is drawn from the person's body, and gives an activity of 115 Bq. The total volume of blood in the person's body, in liters is approximately (you may use $e^x \approx 1 + x$ for $|x| << 1$ and $\ln 2 \approx 0.7$).

Sol^n : Same as that taught directly in Q. No. (44) of H.C.V Nuclear Physics Ans. (5)

Activity $A = A_o e^{-\lambda t}$

$\Rightarrow A_o = A e^{\lambda t} = 115(1 + \lambda t) = 115\{1 + \ln 2/(T_{1/2} \times 11.5)\} = 115\{1 + 0.7/(8 \times 24) \times 11.5) = 119.82$

:. $A_o \approx 120$ Bq Since, 120 Bq is activity of 2.5 ml

:. 2.4×10^5 Bq is activity of $2.5 \times 10^{-3} \times (2.4 \times 10^{-4})/120 = 5$ litre

10. An electron in a hydrogen atom undergoes a transition from an orbit with quantum number n_i to another with quantum number n_f. V_i and V_f are respectively the initial and final potential energies of the electron.

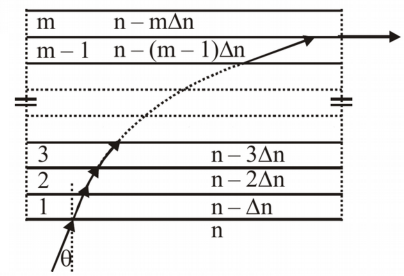
If $\dfrac{V_i}{V_f} = 6.25$, then the smallest possible n_f is.

Sol^n : Same as taught directly in Bohr's Model of H-atom Ans. (5)

$U = -Z^2/n^2 . E_o = -1/n^2 . E_o = -E_o/n^2$

$U_f/U_i = n_f^2/n_i^2 = 6.25 \Rightarrow n_f/n_i = 2.5$ If $n_i = 1$, n_f not equal to 2.5 :. $n_i = 1$, $n_f = 2.5 \times 2 = 5$

11. A monochromatic light is travelling in a medium of refractive index $n = 1.6$. It enters a stack of glass layers from the bottom side at an angle $\theta = 30°$. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\Delta n$, where n_m is the refractive index of the m^{th} slab and $\Delta n = 0.1$ (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m ?



Sol^n : Same as that taught directly in theory Class of Snell's Law

Ans. (8)

n. sinθ = constant

comparing the 1st and last light ray by Snell's Law

n. sin 30° = (n – Δn) sin 90° → with common normal

=> n . ½ = n – m x 0.1 => m = n / 2 x 0.1 = 8

12. A stationary source emits sound of frequency $f_0 = 492$ Hz. The sound is reflected by a large car approaching the source with a speed of 2 ms^{-1}. The reflected signal is received by the source and superposed with the original. What will be the beat frequency of the resulting signal in Hz ? (Given that the speed of sound in air is 330 ms^{-1} and the car reflects the sound at the frequency it has received).

Sol^n : Same as that taught directly as Q. 82 Sound Waves HCV Ans. (6)

Frequency as received by car, $\nu_1 = (V + V_o)/(V - V_S) . \nu = (330 + 2)/ 330 \times 492$ Hz

Now Car will emit ν_1 and 0 will hear

$\nu_2 = (V - V_o)/(V - V_S)$. $N_1 = 330/(330 - 2) \times 332/330 \times 492$ Hz $= 332/328 \times 492$ Hz

:. Beat Frequency = $\nu_2 - \nu = (332/328 - 1) \times 492 = 6$ Hz

A charged particle (electron or proton) is introduced at the origin (x = 0, y = 0, z = 0) with a given initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in column 1, 2 and 3, respectively. The quantities E_0, B_0 are positive in magnitude.

Column-1	**Column-2**	**Column-3**
(I) Electron with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(i) $\vec{E} = E_0\hat{z}$	(P) $\vec{B} = -B_0\hat{x}$
(II) Electron with $\vec{v} = \frac{E_0}{B_0}\hat{y}$	(ii) $\vec{E} = -E_0\hat{y}$	(Q) $\vec{B} = B_0\hat{x}$
(III) Proton with $\vec{v} = 0$	(iii) $\vec{E} = -E_0\hat{x}$	(R) $\vec{B} = B_0\hat{y}$
(IV) Proton with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(iv) $\vec{E} = E_0\hat{x}$	(S) $\vec{B} = B_0\hat{z}$

13. In which case will the particle move in a straight line with constant velocity ?

(A) (II) (iii) (S) (B) (IV) (i) (S) (C) (III) (ii) (R) (D) (III) (iii) (P)

14. In which case will the particle describe a helical path with axis along the positive z-direction ?

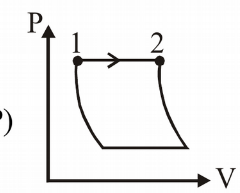
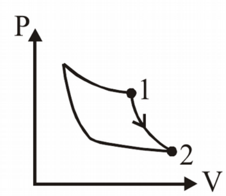
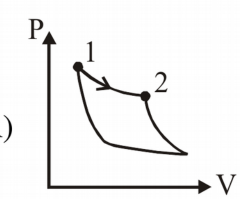
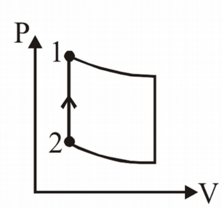
(A) (II) (ii) (R) (B) (IV) (ii) (R) (C) (IV) (i) (S) (D) (III) (iii) (P)

15. In which case would the particle move in a straight line along the negative direction of y-axis (i.e., move along $-\hat{y}$) ?

(A) (IV) (ii) (S) (B) (III) (ii) (P) (C) (II) (iii) (Q) (D) (III) (ii) (R)

13. , 14. ,15. Same as that taught directly in Theory Class of Lorentz (Magnetic Force).
Total force on q can be given by
F = qE + qV x B
13. → F = 0 => q(V x B) = -q E — Ans: (A)
14. E and B must be along z axis (E must be towards +ve z) — Ans: (C)
15. To move towards -ve Y , $v_x = v_z = 0$ and $E_x = E_z = 0$ — Ans: (D)

An ideal gas is undergoing a cyclic thermodynamics process in different ways as shown in the corresponding P–V diagrams in column 3 of the table. Consider only the path from state 1 to state 2. W denotes the corresponding work done on the system. The equations and plots in the table have standard notations as used in thermodynamics processes. Here γ is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas is n.

Column-1	Column-2	Column-3
(I) $W_{1\to2} = \frac{1}{\gamma-1}(P_2V_2 - P_1V_1)$	(i) Isothermal	(P) 
(II) $W_{1\to2} = -PV_2 + PV_1$	(ii) Isochoric	(Q) 
(III) $W_{1\to2} = 0$	(iii) Isobaric	(R) 
(IV) $W_{1\to2} = -nRT \ln \frac{V_2}{V_1}$	(iv) Adiabatic	(S) 

16. Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - P\Delta V$?

(A) (II) (iv) (R) (B) (II) (iii) (P) (C) (II) (iii) (S) (D) (III) (iii) (P)

17. Which one of the following options is the correct combination ?

(A) (III) (ii) (S) (B) (II) (iv) (R) (C) (II) (iv) (P) (D) (IV) (ii) (S)

18. Which one of the following options correctly represents a thermodynamics process that is used as a correction in the determination of the speed of sound in an ideal gas ?

(A) (III) (iv) (R) (B) (I) (ii) (Q) (C) (IV) (ii) (R) (D) (I) (iv) (Q)

16. , **17.** , **18.** Same as that taught directly in Theory Class of Thermodynamics
Adiabatic curves is steeper than isothermal curve
$W_{adia} = (p_1v_1 - p_2v_2)/(r - 1)$, $W_{isothermal} = nRT \ln v_2/v_1$
16. only option (**B**) follow correct sequence Ans: (B)
17. only option (**A**) follow correct sequence Ans: (A)
18. only option (**D**) follow correct sequence Ans: (D)

-These 18 Questions out of total 18 Questions were taught directly in classroom by Prof. Mukul Jha

JEE ADVANCE 2017 (PAPER - II)

1. A rocket is launched normal to the surface of the Earth, away from the Sun, along the line joining the sun and the Earth. The Sun is 3×10^5 times heavier than the Earth and is at a distance 2.5×10^4 times larger than the radius of the Earth. The escape velocity from Earth's gravitational field is $v_e = 11.2$ km s^{-1}. The minimum initial velocity (v_s) required for the rocket to be able to leave the *Sun-Earth system* is closest to (*Ignore the rotation and revolution of the Earth and the presence of any other planet)*

(A) $v_s = 22$ km s^{-1} (B) $v_s = 72$ km s^{-1} (C) $v_s = 42$ km s^{-1} (D) $v_s = 62$ km s^{-1}

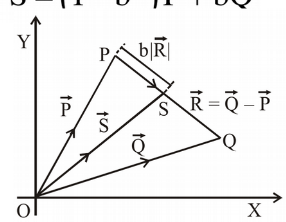
<u>Sol^n :</u> Same as that taught directly in Irodov Class as Third Cosmic Velocity Ans: (C)
To escape from Earth, $v_e = \sqrt{(2GM_e / R_e)} = 11.2$ km/s
To escape from Sun, $v_s = \sqrt{(2GM_s / d)} = 11.2 \times \sqrt{(3 \times 10^5/2.5 \times 10^4)} = 11.2\sqrt{12}$ km/s

Total K. E. needed $\frac{1}{2} mv_3^2 = \frac{1}{2} mv_e^2 + \frac{1}{2} mv_s^2 \Rightarrow v_3 = \sqrt{\{(11.2)^2 + 12 \times (11.2)^2\}} = 11.2\sqrt{13} = 42$ km/s

2. Three vectors $\vec{P}, \vec{Q}$ and $\vec{R}$ are shown in the figure. Let S be any point on the vector $\vec{R}$. The distance between the points P and S is $b|\vec{R}|$. The general relation among vectors $\vec{P}, \vec{Q}$ and $\vec{S}$ is :

(A) $\vec{S} = (1-b)\vec{P} + b^2\vec{Q}$ (B) $\vec{S} = (b-1)\vec{P} + b\vec{Q}$ (C) $\vec{S} = (1-b)\vec{P} + b\vec{Q}$ (D) $\vec{S} = (1-b^2)\vec{P} + b\vec{Q}$

<u>Sol^n :</u> Same as that taught in Theory Class of Vector Addition (Triangle Law) with unit addition



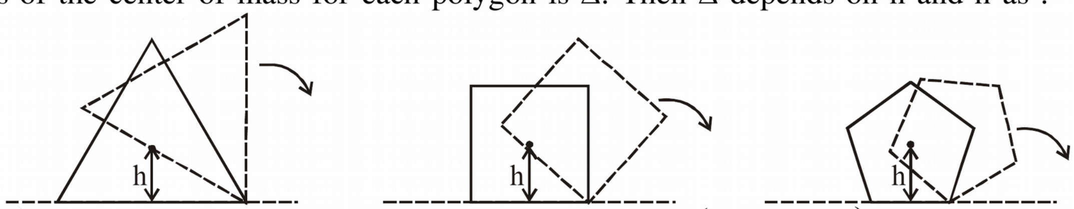
By Triangle Law, P + bR = S :. bR = S – P and P + R = Q :. R = Q – P
:. b (Q – P) = S – P => S = (1 – b) P + bQ Ans: (C)

6. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the *instantaneous* density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point on the surface of the expanding sphere is proportional to :

(A) R^3 (B) $\frac{1}{R}$ (C) R (D) $R^{2/3}$

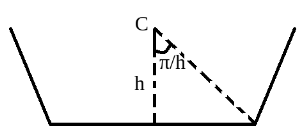
<u>Sol^n :</u> Same as that taught in Theory Class of Errors
Changes Density $\rho = m/V = m/(4\pi R^3/3) = 3m/4\pi R^3$
$\Rightarrow 1/\rho \cdot d\rho/dt = 4\pi R^3/3 \cdot 3m/4\pi \cdot (-3)R^{-4} \cdot dR/dt = -3/R \cdot dR/dt$ As $1/\rho \cdot d\rho/dt$ is constant
Hence $dR/dt \propto R$ Velocity, $v = dR/dt \propto R$ Ans: (C)

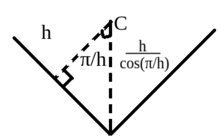
7. Consider regular polygons with number of sides n = 3, 4, 5 ..... as shown in the figure. The center of mass of all the polygons is at height h from the ground. They roll on a horizontal surface about the leading vertex without slipping and sliding as depicted. The maximum increase in height of the locus of the center of mass for each polygon is Δ. Then Δ depends on n and h as :



(A) $\Delta = h\sin^2\left(\frac{\pi}{n}\right)$ (B) $\Delta = h\sin\left(\frac{2\pi}{n}\right)$ (C) $\Delta = h\left(\frac{1}{\cos\left(\frac{\pi}{n}\right)} - 1\right)$ (D) $\Delta = h\tan^2\left(\frac{\pi}{2n}\right)$

<u>Sol^n :</u> Similar to that taught in Q. 26 about polygon in H.C.V
Electromagnetism Rise in c.m.(c)
$\Delta = h/(\cos \pi/n) - h$
$= h\,(1/\cos \pi/n - 1)$ Ans: (C)





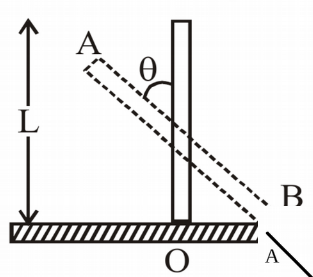
8. A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct ?

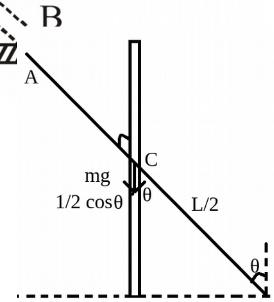
(A) When the bar makes an angle θ with the vertical, the displacement of its midpoint from the initial position is proportional to (1 – cosθ)

(B) The midpoint of the bar will fall vertically downward

(C) Instantaneous torque about the point in contact with the floor is proportional to sinθ

(D) The trajectory of the point A is a parabola

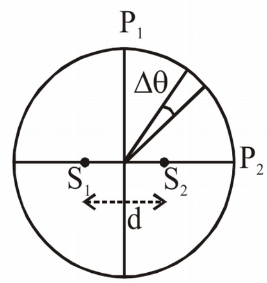




Sol^n : Same as that taught in Theory Class of Rotational dynamics
Ans: (A,B,C)
Due to only external force in vertical direction, c.m(c) of rod will fall vertically downward → option (B)

Fall in c.m.; $\Delta y = ½ – ½ \cos\theta = L/2\,(1 – \cos\theta)$:. $\Delta y \;\alpha\; (1 – \cos\theta)$ Option (A)
Torque about point of contact P = mg $(L/2 \sin\theta)$:. $\tau \;\alpha\; \sin\theta$ Option (C)
w.r.t. centre of mass c for point A , $x = L/2 \cos\theta$ $y = L \sin\theta$:. $x^2/(L/2)^2 + y^2/L^2 = 1$ Path of A is ellipse

9. Two coherent monochromatic point sources S_1 and S_2 of wavelength $\lambda = 600$ nm are placed symmetrically on either side of the center of the circle as shown. The sources are separated by a distance d = 1.8mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct ?



(A) A dark spot will be formed at the point P_2

(B) The angular separation between two consecutive bright spots decreases as we move from P_1 to P_2 along the first quadrant

(C) At P_2 the order of the fringe will be maximum

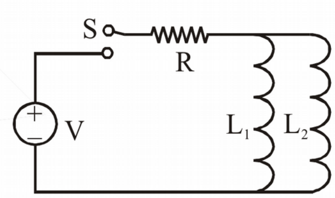
(D) The total number of fringes produced between P_1 and P_2 in the first quadrant is close to 3000

Sol^n : Same as that taught directly in Numerical of Sound Waves Q 32 of HCV Ans: (C , D)
At P_2 → path diff, d = 3000 λ, hence bright spot (A) is wrong
At P_2 → path difference 3000 λ is maximum, hence (C) is correct
$d = 1.8 \times 10^{-3} = n\lambda = n \times 600 \times 10^{-9}$:. n = 3000 (D) is correct

As taught in class, $p = d \cos\theta = n\lambda$ (bright) => $\cos\theta = n\lambda/d$ => $-\sin\theta\, d\theta = dn\,.\,\lambda/D$
:. $d\theta = -dn\,\lambda/ d \sin\theta$ As we move from P_1 to P_2 θ decreases → sin θ deceases → dθ increases (B) wrong

10. A source of constant voltage V is connected to a resistance R and two ideal inductors L_1 and L_2 through a switch S as shown. There is no mutual inductance between the two inductors. The switch S is initially open. At t = 0, the switch is closed and current begins to flow. Which of the following options is/are correct?

(A) The ratio of the currents through L_1 and L_2 is fixed at all times (t > 0)



(B) After a long time, the current through L_1 will be $\frac{V}{R}\frac{L_2}{L_1+L_2}$

(C) After a long time, the current through L_2 will be $\frac{V}{R}\frac{L_1}{L_1+L_2}$

(D) At t = 0, the current through the resistance R is $\frac{V}{R}$

Sol^n : Same as that taught in Irodov Class Q. 44 Set II Ans: (A,B,C)

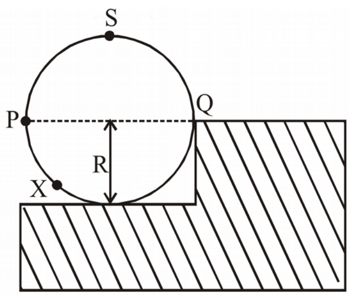
As inductors are in parallel, p.d. $V_{L1} = V_{L2}$

=> $L_1\, dI_1/dt = L_2\, dI_2/dt$:. $L_1I_1 = L_2I_2$ => $I_1/I_2 = L_2/L_1$= constant Option A is correct

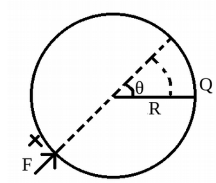
After long time $t \to \infty$ Final Current $I = V/R = I_1 + I_2 = I_1 + L_1 . I_1/L_2$
=> $I_1 = V L_2/R (L_1 + L_2)$ and $I_2 = V L_1/R (L_1 + L_2)$ Option C is correct
At t=0 current through R = 0 as energies are zero Option B is correct

11. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct ?

(A) If the force is applied normal to the circumference at point X then τ is constant
(B) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step
(C) If the force is applied normal to the circumference at point P then τ is zero
(D) If the force is applied at point P tangentially then τ decreases continuously as the wheel climbs

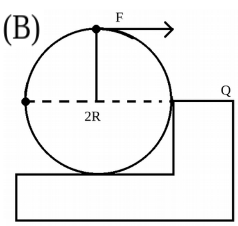


Sol^n: Same as that taught directly in Theory Class of Rotational Dynamics



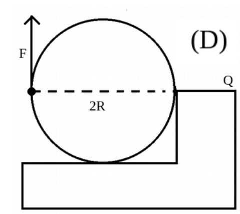
$\tau = F. R\sin\theta$ Hence τ depends on θ and is not constant $\to$ Option A is wrong (as shown in right)

(B)



For Option B(shown in left figure),
τ = F. R not equal to 0, but wheel climbs up $\to$ Option B is incorrect

(D)



For Option C, If force is applied normally at P, $\tau = 0$ about Q $\to$ Option C is correct
For Option D, τ = F. 2R = constant $\to$ Option D is wrong Ans: (C)

12. The instantaneous voltages at three terminals marked X, Y and Z are given by

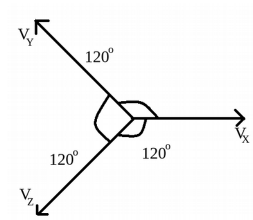
$$V_X = V_0 \sin \omega t \qquad V_Y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) \text{ and } V_Z = V_0 \sin\left(\omega t + \frac{4\pi}{3}\right)$$

An ideal voltmeter is configured to read rms value of the potential difference between its terminals. It is connected between points X and Y and then between Y and Z. The reading(s) of the voltmeter will be:-

(A) $V_{XY}^{rms} = V_0$ (B) $V_{YZ}^{rms} = V_0\sqrt{\frac{1}{2}}$

(C) Independent of the choice of the two terminals (D) $V_{XY}^{rms} = V_0\sqrt{\frac{3}{2}}$

Sol^n: Same as that taught directly in Phasor Diagram of Series LCR Circuit in Theory



class of Alternating Current Ans: (C,D)

p.d. between X, Y = $V_{XY} = V_X - V_Y = \sqrt{(V_0^2 + V_0^2 + 2V_0 V_0 \cos 60^\circ)} = V_0\sqrt{3}$

:. $(V_{XY})_{rms} = V_0\sqrt{3} / \sqrt{2}$ → Option D is correct

This will be same as $(V_{YZ})_{rms}$ → Option C is correct

13. A point charge +Q is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct ?

(A) The circumference of the flat surface is an equipotential

(B) The electric flux passing through the curved surface of the hemisphere is $-\dfrac{Q}{2\varepsilon_0}\left(1-\dfrac{1}{\sqrt{2}}\right)$

(C) Total flux through the curved and the flat surfaces is $\dfrac{Q}{\varepsilon_0}$

(D) The component of the electric field normal to the flat surface is constant over the surface.

Sol^n: Same as that taught directly in Irodov Class Q. 45 Set 2 and Gauss Law

Solid angle by flat surface on Q = $2\pi(1 - \cos\theta)$ as taught

Total solid angle at Q = 4π , for which total flux $\Phi = Q/\epsilon_o$

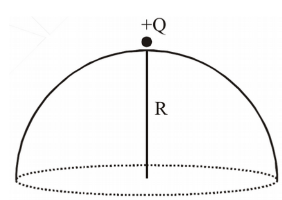
:. Flux through flat surface = $2\pi(1 - \cos\theta) / 4\pi \, . \, Q/\epsilon_o$

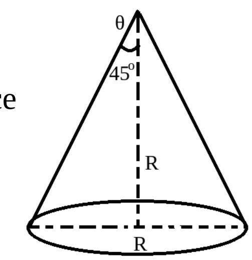
= $Q/2\epsilon_o \, .(1 - \cos\theta)$

= $Q/2\epsilon_o \, . \, (1 - 1/\sqrt{2})$

:. Flux through curve surface = $-Q/2\epsilon_o \, . \, (1 - 1/\sqrt{2})$

:. Option B is correct





All points in circumference of flat surface are at equal distance $R\sqrt{2}$ from Q. Hence they are on equipotential → Option A is correct.

Total flux through curve and flat surface = 0 (as $q_{en} = 0$) → Option C wrong

Option D is wrong as component goes on decreasing outward.

Ans: (A,B)

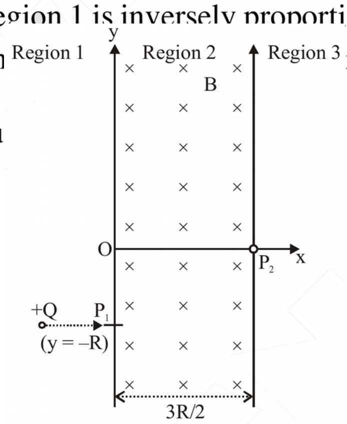
14. A uniform magnetic field B exists in the region between x = 0 and x = $\dfrac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge +Q and momentum p directed along x-axis enters region 2 from region 1 at point P_1(y = –R). Which of the following options(s) is/are correct ?

(A) For $B = \dfrac{8}{13}\dfrac{p}{QR}$, the particle will enter region 3 through the point P_2 on x-axis

(B) For $B > \dfrac{2}{3}\dfrac{p}{QR}$, the particle will re-enter region 1

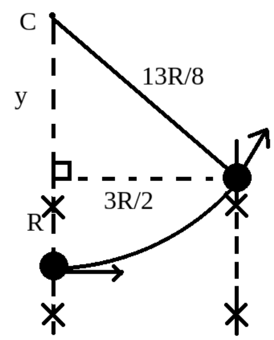
(C) For a fixed B, particle of same charge Q and same velocity v, the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle.

(D) When the particle re-enters region ible path in region 2, the magnitude of the chage in its linear momentu farthest point from y-axis is $\dfrac{p}{\sqrt{2}}$.



Sol^n: Same as that taught directly in Q. 51 Set II of Irodov Class and Q. 39 of HCV Magnetic Field by current Ans: (A,B)

For B = 8p/13QR , radius r = p/qB = p. 13QR / Q. 8p = 13/8 . R
:. y = √{$(13R/8)^2 – (3R/2)^2$} = 5R/8



:. Total Vertical = y + R = 5R/8 + R = 13R/8
→ Option A is correct
For B = 2/3 . p/QR , radius, r = p/QB = p.3QR/Q.2p = 3R/2

:. For B > 2/3 . p/QR , r' < 3R/2 and particle will reenter zone 1 with deviation of π as taught in HCV Q. 39 → Option B is correct
Change in momentum = p + p = 2p → Option D is wrong
distance = 2r' α m → Option C is wrong

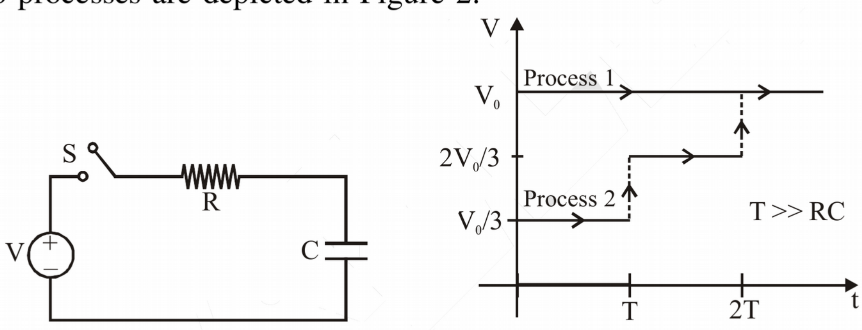
PARAGRAPH–1

Consider a simple RC circuit as shown in figure 1.

Process 1 : In the circuit the switch S is closed at t = 0 and the capacitor is fully charged to voltage V_0 (i.e., charging continues for time T >> RC). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time T >> RC. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time T >> RC. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.

These two processes are depicted in Figure 2.



15. In Process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by :-

(A) $E_C = E_D$ (B) $E_C = 2E_D$ (C) $E_C = \frac{1}{2}E_D$ (D) $E_C = E_D \ln 2$

Sol^n: Taught directly in Theory Class of Capacitors

Energy stored in Capacitor = $\frac{1}{2} CV_o^2 = E_c$ $W_{battery} = \Delta q . \epsilon = Cv_o . V_o = CV_o^2$

:. Heat = $W_{battery} - U_{capacitor} = CV_o^2 - \frac{1}{2} CV_o^2 = \frac{1}{2} CV_o^2$:. $E_D = E_C$ Ans: (A)

16. In Process 2, total energy dissipated across the resistance E_D is :-

(A) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$ (B) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$ (C) $E_D = \frac{1}{2}CV_0^2$ (D) $E_D = 3CV_0^2$

Sol^n: Taught directly in numerical Q.No. 45 and 48 of HCV and Q.No. 37 of Set II of Irodov Class

In process 2 first part,

Charge on Capacitor $q_1 = CV_o/3$ Energy in Capacitor = $q_1^2/2C = (CV_o/3)^2 /2C = CV_o^2/18$

$W_{battery} = q_1 . \epsilon = CV_o/3 . V_o/3 = CV_o^2/9$

Heat Loss = $W_{battery} - U_{capacitor} = CV_o^2 /9 - CV_o^2 /18 = CV_o^2 /18$

This gets repeated for other two parts to get total heat loss = $1/3 . (\frac{1}{2} CV_o^2)$ Ans: (A)

-These 13 Questions out of total 18 Questions were taught directly in classroom by Prof. Mukul Jha