KUMAR PHYSICS CLASSES

E 281 BASEMENT M BLOCK MAIN ROAD GREATER KAILASH 2 NEW DELHI

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IIT JEE PHYSICS PAPER SOLUTION
26 JUNE 2022
EVENING SHIFT

QUESTIONS BASED ON CONSTRAINT MOTION,MUTUAL INDUCTANCE COUPLING,EFFECTIVE HALF LIFE & AMPLITUDE MODULATION ARE TRICKY

Q1: The dimension of mutual inductance is:

(A) $[ML^2T^{-2}A^{-1}]$

(B) $[ML^2T^{-3}A^{-1}]$

✓ (C) $[ML^2T^{-2}A^{-2}]$

(D) $[ML^2T^{-3}A^{-2}]$

ANS - 1

$\phi = Mi = BA$

$M = \frac{BA}{I}$

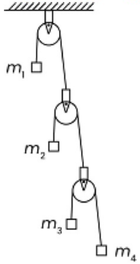
$F = qvB \Rightarrow B = F/qv$

$M = \frac{F}{qv}\frac{A}{I}$

$= \frac{MLT^{-2}L^2}{AT\,LT^{-1}A}$

$= \frac{ML^3T^{-2}}{A^2L} = ML^2T^{-2}A^{-2}$

Q2: In the arrangement shows in figure a_1, a_2, a_3 and a_4 are the acceleration of masses m_1, m_2, m_3 and m_4 respectively. Which of the following relation is true for this arrangement?



(A) $4a_1 + 2a_2 + a_3 + a_4 = 0$ ✓

(B) $a_1 + 4a_2 + 3a_3 + a_4 = 0$

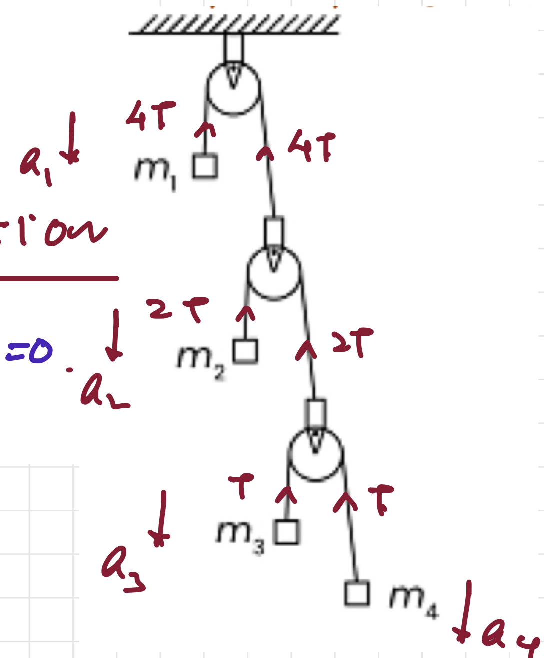
(C) $a_1 + 4a_2 + 3a_3 + 2a_4 = 0$

(D) $2a_1 + 2a_2 + 3a_3 + a_4 = 0$

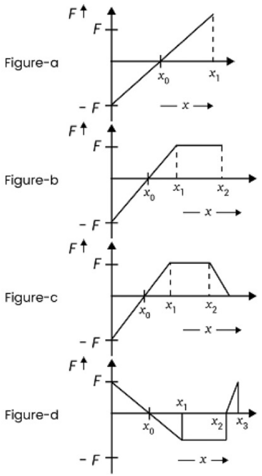
Using constraints motion

$$-4Ta_1 - 2Ta_2 - Ta_3 - Ta_4 = 0$$

$$4a_1 + 2a_2 + a_3 + a_4 = 0$$



Q3: Arrange the four graphs in descending order of total work done; where W_1, W_2, W_3 and W_4 are the work done corresponding to figure a, b, c and d respectively.



(A) $W_3 > W_2 > W_1 > W_4$ ✓

(B) $W_3 > W_2 > W_4 > W_1$

(C) $W_2 > W_3 > W_4 > W_1$

(D) $W_2 > W_3 > W_1 > W_4$

W = AREA OF POSITIVE SIDE OF THE GRAPH − AREA OF NEGATIVE SIDE OF THE GRAPH

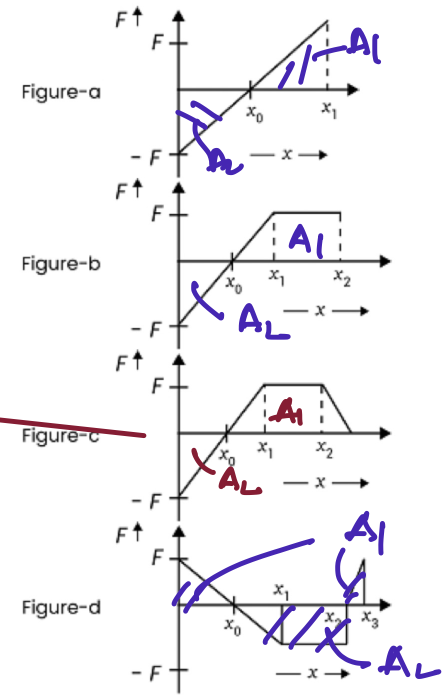


figure-(c)

$A_1 > A_2$

figure-b

$A_1 > A_2$

figure-a

$A_1 > A_2$

figure-d

$A_2 > A_1$

Hence $W_3 > W_2 > W_1 > W_4$

Q4: A solid spherical ball is rolling on a frictionless horizontal plane surface about its axis of symmetry. The ratio of rotational kinetic energy of the ball to its total kinetic energy is -

(A) $\frac{2}{5}$

(B) $\frac{2}{7}$ ✓

(C) $\frac{1}{5}$

(D) $\frac{7}{10}$

ANS-4

$$\frac{(KE)_R}{(KE)_T} = \frac{\frac{1}{2} I \omega^2}{\frac{1}{2} m v^2 + \frac{1}{2} I \omega^2}$$

$$= \frac{\left(\frac{2}{5} MR^2\right) \omega^2}{M v^2 + \frac{2}{5} MR^2 \omega^2}$$

$$= \frac{\frac{2}{5} MR^2 \omega^2}{MR^2 \omega^2 + \frac{2}{5} MR^2 \omega^2}$$

$$= \frac{2/5}{7/5} = \frac{2}{7}$$

Q5: Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: If we move from poles to equator, the direction of acceleration due to gravity of earth always points towards the center of earth without any variation in its magnitude.

Reason R: At equator, the direction of acceleration due to the gravity is towards the center of earth.

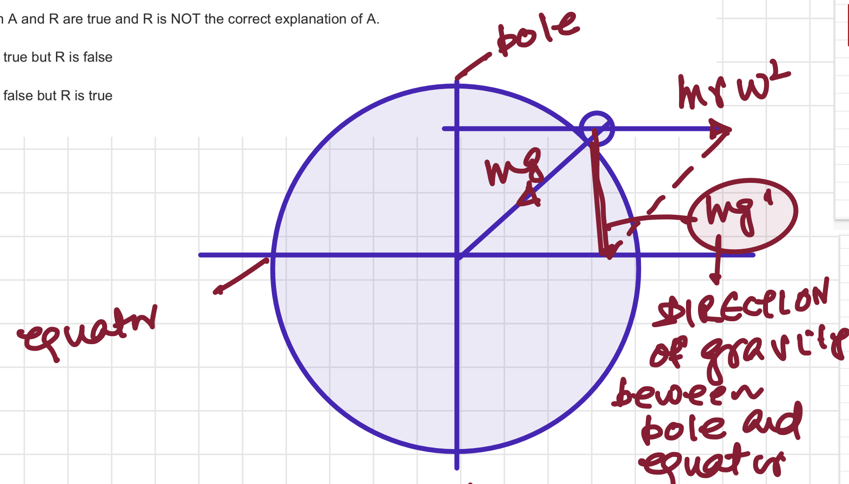
In the light of above statements, choose the correct answer from the options given below

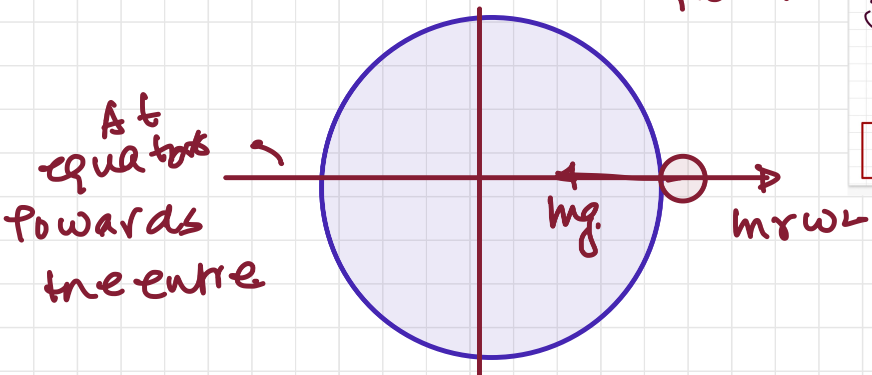
(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true and R is NOT the correct explanation of A.

(C) A is true but R is false

(D) A is false but R is true ✓





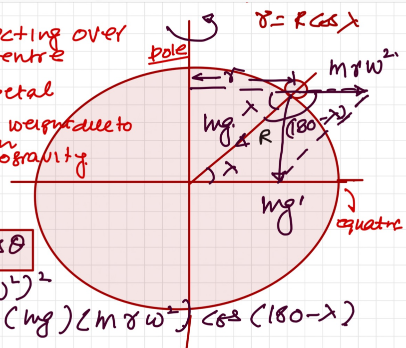
DERIVATION

mg → force acting over the centre

$mr\omega^2$ → centripetal force

mg' → Apparent weight due to Acceleration due to gravity

λ → Angle of latitude



$$R^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$$

$$(mg')^2 = (mg)^2 + (mr\omega^2)^2 + 2(mg)(mr\omega^2)\cos(180-\lambda)$$

$$(g')^2 = g^2 + (r\omega^2)^2 + 2g\,r\omega^2(-\cos\lambda)$$

$$(g')^2 = g^2 + (r\omega^2)^2 + 2g\,r\omega^2(-\cos\lambda)$$

$$(g')^2 = g^2 + [R\cos\lambda\,\omega^2]^2 + 2gR\cos\lambda\,\omega^2(-\cos\lambda)$$

$$(g')^2 = g^2 + R^2\omega^4\cos^2\lambda - 2gR\omega^2\cos^2\lambda$$

$$(g')^2 = g^2\left[1 + \frac{R^2\omega^4}{g^2}\cos^2\lambda - \frac{2R\omega^2}{g}\cos^2\lambda\right]$$

$$g' = g\left[1 + \left(\frac{R\omega^2}{g}\right)^2\cos^2\lambda - 2\left(\frac{R\omega^2}{g}\right)\cos^2\lambda\right]^{1/2}$$

(ignore)

$$g' = g\left[1 - \frac{1}{2}\cdot 2\left(\frac{R\omega^2}{g}\right)\cos^2\lambda\right]$$

$$g' = g - R\omega^2\cos^2\lambda$$

R = 6400 km

$$\frac{R\omega^2}{g} = \frac{6400\times10^3\times4\pi^2}{9.8\times(24\times60\times60)^2} = \frac{1}{289}$$

Q6: If p is the density and η is coefficient of viscosity of fluid which flows with a speed v in the pipe of diameter d, the correct formula for Reynolds number R_e is:

(A) $R_e = \frac{\eta d}{\rho v}$

(B) $R_e = \frac{\rho v}{\eta d}$

(C) $R_e = \frac{\rho v d}{\eta}$ ✓

(D) $R_e = \frac{\eta}{\rho v d}$

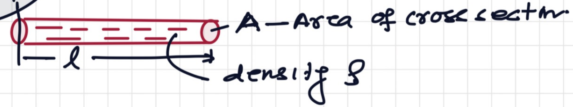
NOTES

PHYSICAL - SIGNIFICANCE REYNOLD. NO

DESCRIBES
Ratio of the inertial force per unit area to viscous force per unit area for a flowing fluid.

$N_R = \frac{\rho v^2}{\eta v / r} = \frac{\rho v^2 r}{\eta v}$

$N_R = \frac{\rho v r}{\eta}$



$F.\Delta t = m.\Delta v$

$F = \frac{m.\Delta v}{\Delta t} = \frac{A(l)\rho\,(v-0)}{(t-0)} = A\left(\frac{l}{t}\right)\rho v = A v \rho v = A\rho v^2$

INERTIAL FORCE

Inertial force per unit area → $\frac{F}{A} = \rho v^2$

Viscous force per unit area →

$F = \eta A \frac{dv}{dx}$

$\frac{F}{A} = \eta \frac{dv}{dx} = \eta \frac{(v-0)}{(r)} = \frac{\eta v}{r}$

$N_R = \frac{\text{Inertia force per unit area}}{\text{viscous force per unit area}}$

Reynolds number

$= \frac{\text{Inertial force per unit area}}{\text{viscous force per unit area}}$

$= \frac{\rho v^2}{\eta v / d} = \frac{\rho v d}{\eta}$

Explanation

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Q7: A flask contains argon and oxygen in the ratio of 3 : 2 in mass and the mixture is kept at $27^{\circ} C$. The ratio of their average kinetic energy per molecule respectively.

(A) 3 : 5

(B) 9 : 4

(C) 2 : 3

(D) 1 : 1

ANS-7

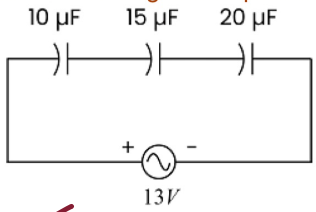
$$\frac{M_A}{M_O} = \frac{3}{2} \quad 27^{\circ}C$$

$$(KE)_{Avg} = \frac{f}{2} kT$$

$$\frac{(KE)_1}{(KE)_2} = \frac{\frac{f_1}{2} kT}{\frac{f_2}{2} kT}$$

$$= \frac{f_1}{f_2} = \frac{3}{5}$$

Q8: The charge on capacitor of capacitance $15\mu F$ in the figure given below is:



✓ (A) $60\mu c$

(B) $130\mu c$

(C) $260\mu c$

(D) $585\mu c$

ANS-18

$$\frac{1}{C_{eq}} = \frac{1}{10} + \frac{1}{15} + \frac{1}{20}$$

$$\frac{1}{C_{eq}} = \frac{6+4+3}{60}$$

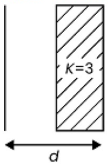
$$C_{eq} = \frac{60}{13}$$

$$q = (C_{eq})V$$

$$= \left(\frac{60}{13}\right)(13)$$

$$= 60\mu C$$

Q9: A parallel plate capacitor with plate area A and plate separation d = 2 m has a capacitance of $4\mu F$. The new capacitance of the system if half of the space between them is filled with a dielectric material of dielectric constant K = 3 (as shown in figure) will be:

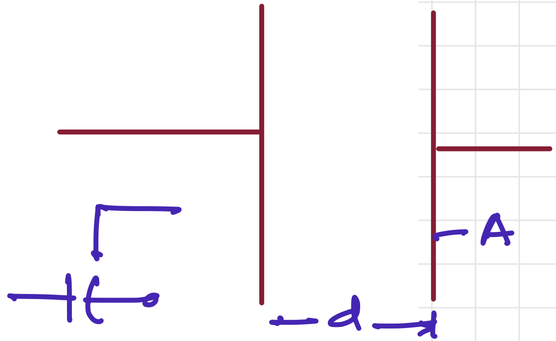


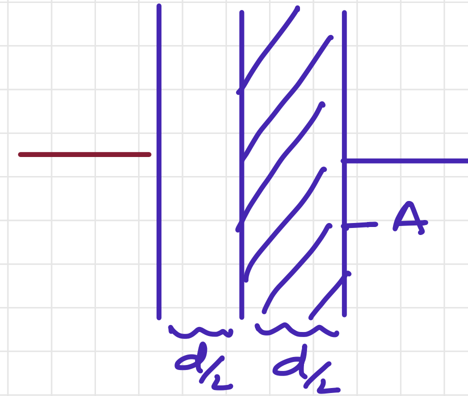
(A) $2\mu F$

(B) $32\mu F$

(C) $6\mu F$ ✓

(D) $8\mu F$





$$C = \frac{\epsilon_0 A}{d} = 4\mu F$$

$$C = \frac{\epsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$$

$t = d/2, \quad K = 3$

$$C = \frac{\epsilon_0 A}{d - \frac{d}{2}\left(1 - \frac{1}{3}\right)} = \frac{\epsilon_0 A}{d - \frac{d}{2}\left(\frac{2}{3}\right)}$$

$$C = \frac{\epsilon_0 A \, 3}{2d}$$

$$\frac{\epsilon_0 A}{d} = 4\mu F$$

$$C = \frac{\epsilon_0 A}{d}\left(\frac{3}{2}\right)$$

$$C = 4\left(\frac{3}{2}\right) = 6\mu F$$

Q10: Sixty four conducting drops each of radius 0.02 m and each carrying a charge of $5\mu C$ are combined to form a bigger drop. The ratio of surface density of bigger drop to the smaller drop will be:

(A) 1 : 4

(B) 4 : 1 ✓

(C) 1 : 8

(D) 8 :1

ANS

$q_1 = 5\mu C$

$q_2 = (64)(5)\mu C$

$64\left(\frac{4}{3}\pi r_s^3\right) = \frac{4}{3}\pi r_b^3$

$4 r_s = r_b$

$\frac{r_s}{r_b} = \frac{1}{4}$

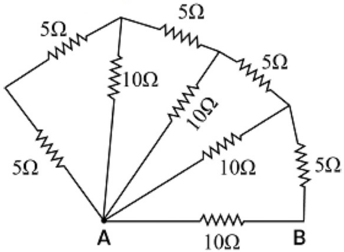
$$\frac{\sigma_b}{\sigma_s} = \frac{q_2/4\pi r_b^2}{q_1/4\pi r_s^2} = \frac{q_1}{4\pi r_b^2} \times \frac{4\pi r_s^2}{q_2}$$

$$= \left(\frac{q_2}{q_1}\right)\left(\frac{r_s^2}{r_b^2}\right)$$

$$= \left(\frac{64 \times 5}{5}\right)\left(\frac{1}{4}\right)^2$$

$$= \frac{64}{16} = \frac{4}{1}$$

Q11: The equivalent resistance between points A and B in the given network is:

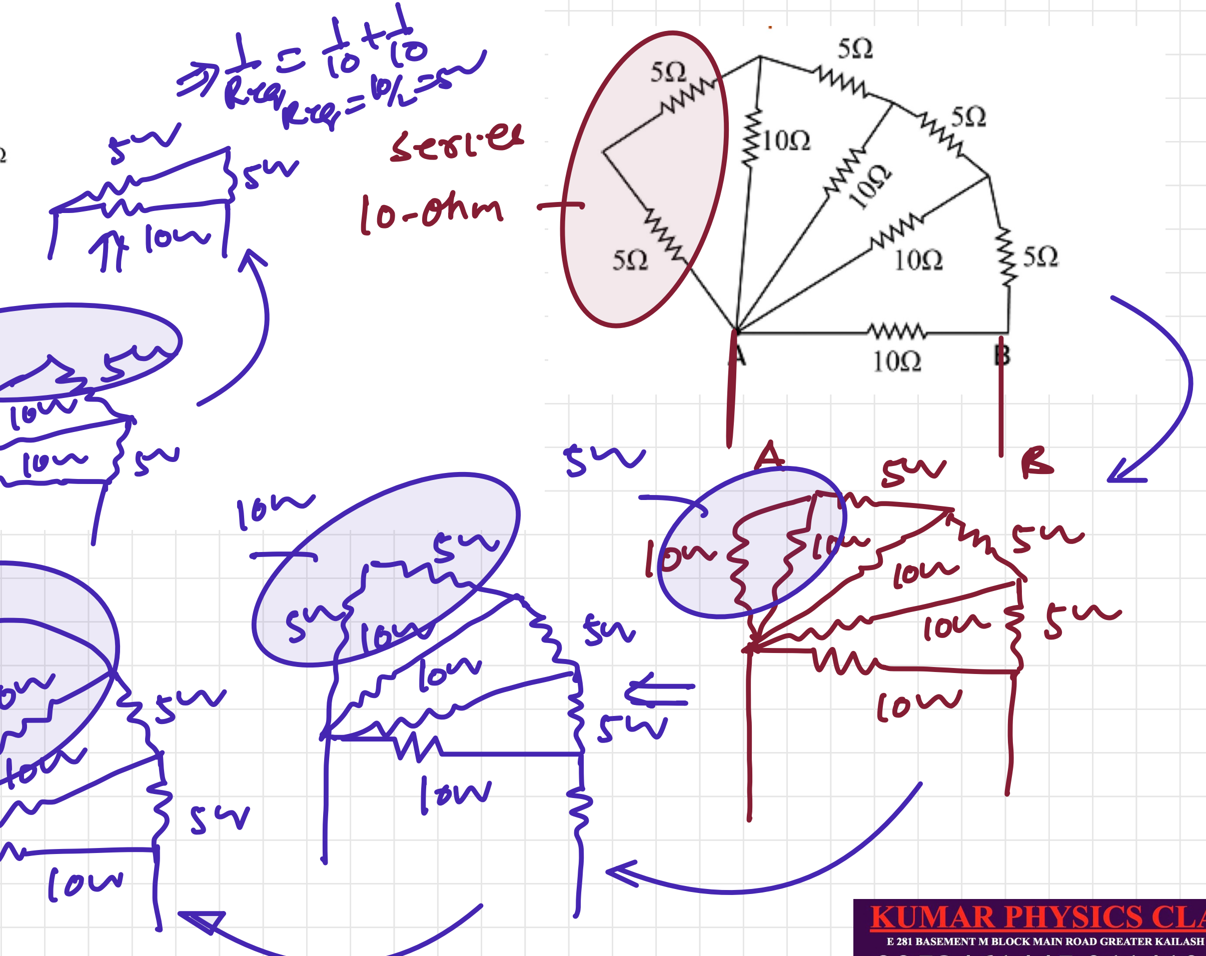


(A) 65Ω

(B) 20Ω

(C) 5Ω ✓

(D) 2Ω



Q12: A bar magnet having a magnetic moment of $2.0 \times 10^5 JT^{-1}$, is placed along the direction of uniform magnetic field of magnitude $B = 14 \times 10^{-5} T$. The work done in rotating the magnet slowly through 60° from the direction of field is:

(A) ✓ 14 J

(B) 8.4 J

(C) 4 J

(D) 1.4 J

$M = 2.0 \times 10^5 J/T$

$B = 14 \times 10^{-5} T$

$\theta_1 = 0^\circ$, $\theta_2 = 60^\circ$

$W_1 = -MB\cos 0^\circ$ $\quad W_2 = -MB\cos 60^\circ$

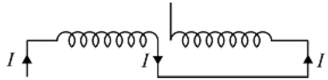
$W_1 = -MB$ $\quad W_2 = -MB/2$

$U = W_2 - W_1$

$= -\frac{MB}{2} - (-MB) = MB - MB/2 = \frac{MB}{2}$

$= \frac{(2.0 \times 10^5)(14 \times 10^{-5})}{2} = 14 J$

Q13: Two coils of self inductance L_2 and L_2 are connected in series combination having mutual inductance of the coils as M. The equivalent self inductance of the combination will be:



(A) $\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{M}$

(B) L_1+L_2+M

(C) L_1+L_2+2M

(D) L_1+L_2-2M ✓

ANS-13

$L_{eq} = L_1 + L_2 \pm 2M$

if current is the same direction

$L_{eq} = L_1 + L_2 - 2M$

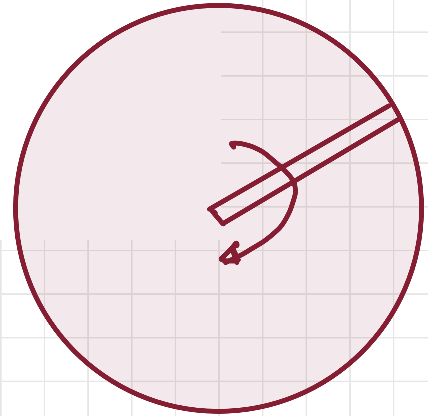
Q14: A metallic conductor of length 1m rotates in a vertical plane parallel to east-west direction about one of its end with angular velocity $5 rad\, s^{-1}$. If the horizotnal component of earth's magnetic field is $0.2 \times 10^{-4} T$,then emf induced between the two ends of the conductor is:

(A) $5 \mu V$

(B) $50 \mu V$ ✓

(C) $5 mV$

(D) $50 mV$



$l = 1$ mt

$\omega = 5$ rad/sec

$B_H = 0.2 \times 10^{-4}$ T

$$e = \frac{1}{2} B \omega l^2$$

$$= \frac{1}{2}(0.2 \times 10^{-4})(5)(1)^2$$

$$= 50 \times 10^{-6} \text{ volt}$$

$$= 50 \mu V$$

Q15: Which is the correct ascending order of wavelengths?

(A) $\lambda_{visible} < \lambda_{X-ray} < \lambda_{gamma-ray} < \lambda_{microwave}$

(B) $\lambda_{gamma-ray} < \lambda_{X-ray} < \lambda_{visible} < \lambda_{microwave}$ ✓

(C) $\lambda_{X-ray} < \lambda_{gamma-ray} < \lambda_{visible} < \lambda_{microwave}$

(D) $\lambda_{microwave} < \lambda_{visible} < \lambda_{gamma-ray} < \lambda_{X-ray}$

LEARN BELOW TABLE BY HEART

TYPE	Wavelength range (m)	Frequency range (Hz)	Production	Detection
Radio waves	0.3 to 6×10^{2}	10^{9} to 5×10^{5}	Oscillating circuit or Rapid acceleration and retardation of electrons in aerials	Receivers aerials
Micro wave	10^{-3} to 0.3	3×10^{11} to 1×10^{9}	Klystron valve or magnetron valve	Point contact diodes
Infrared	8×10^{-7} to 1×10^{-3}	4×10^{14} to 3×10^{11}	Vibrations of atoms and molecules	Thermopile, Bolometer, Infrared photographic films
Visible light	4×10^{-7} to 8×10^{-7}	8×10^{14} to 4×10^{14}	Excitation of valency electrons in atoms	Human eye, photo cells, photographic plate
Ultra violet	6×10^{-9} to 4×10^{-7}	5×10^{16} to 8×10^{14}	Excitation of atoms, spark and arc lamps	Photo cells, Photographic film
X-rays	1×10^{-13} to 3×10^{-8}	3×10^{21} to 1×10^{16}	X-ray tubes or excitation of inner shell electron	Photographic film, Geiger tubes
Gamma rays	0.6×10^{-14} to 1×10^{-10}	5×10^{22} to 3×10^{18}	Nuclear origin	Photographic film, Ionization chamber

ANS

$\lambda_{gamma\ ray} < \lambda_{x\ RAY} < \lambda_{visible} < \lambda_{microwave}$

Q16: For a specific wavelength 670 nm of light coming from a galaxy moving with velocity v, the observed wavelength is 670.7 nm.

The value of v is:

(A) $3 \times 10^{8} ms^{-1}$

(B) $3 \times 10^{10} ms^{-1}$

(C) ✓ $3.13 \times 10^{5} ms^{-1}$

(D) $4.48 \times 10^{5} ms^{-1}$

ANS-16

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$ → DOPPLER'S EFFECT

$$v = \frac{\Delta\lambda}{\lambda}(c)$$

$$= \left(\frac{0.7}{670}\right)(3 \times 10^{8})$$

$$= 3.13 \times 10^{5}\ mt/sec$$

Q17: A metal surface is illuminated by a radiation of wavelength $4500\mathring{A}$. The ejected photo-electron enters a constant magnetic field of 2 mT making an angle of with the magnetic field. If it starts revolving in a circular path of radius 2 mm, the work function of the metal is approximately:

90°

(A) 1.36 eV ✓

(B) 1.69 eV

(C) 2.78 eV

(D) 2.23 eV

ANS-17 → when electron enters ⊥ to the magnetic field.

$$r = \frac{mv}{qB} \Rightarrow v = \frac{qBr}{m}$$

$$\frac{hc}{\lambda} = W_0 + \frac{1}{2}mv^2$$

$$\frac{hc}{\lambda} - \frac{1}{2}m\left(\frac{qBr}{m}\right)^2 = W_0$$

$$\frac{hc}{\lambda} - \frac{m}{2}\frac{q^2B^2r^2}{m^2} = W_0$$

$$\frac{hc}{\lambda} - \frac{1}{2}\frac{q^2B^2r^2}{m} = W_0$$

$$\frac{6.6\times10^{-34}\times3\times10^8}{4500\times10^{-10}} - \frac{1}{2}\frac{(1.6\times10^{-19})^2(2\times10^{-3})^2(2\times10^{-3})^2}{9.1\times10^{-31}} = W_0$$

$$W_0 = 1.36\ eV$$

Q18: A radioactive nucleus can decay by two different processes. Half-left for the first process is 3.0 hours while it is 4.5 hours for the second process. The effective half-life of the nucleus will be:

(A) 3.75 hours

(B) 0.56 hours

(C) 0.26 hours

(D) 1.80 hours

A

$(T_{1/2})_1 = 3.0$ hour (half life of first process)

$(T_{1/2})_2 = 4.5$ hour (half life of second process)

$$\lambda_{eq} = \lambda_1 + \lambda_2 \qquad \lambda = \frac{0.693}{T_{1/2}}$$

$$\frac{0.693}{(T_{1/2})_{eq}} = \frac{0.693}{(T_{1/2})_1} + \frac{0.693}{(T_{1/2})_2}$$

$$(T_{1/2})_{eq} = \frac{(T_{1/2})_1 (T_{1/2})_2}{(T_{1/2})_1 + (T_{1/2})_2} = \frac{3 \times 4.5}{7.5} = \frac{3 \times 3}{5} = \frac{9}{5} = 1.8 \text{ hour}$$

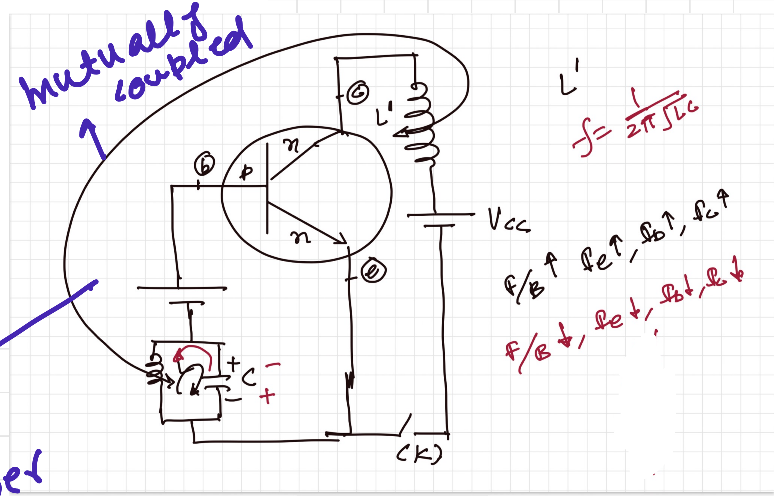
Q19: The positive feedback is required by an amplifier to act an oscillator. The feedback here means:

(A) External input is necessary to sustain ac signal in output

(B) A portion of the output power is returned back to the input. ✓

(C) Feedback can be achieved by LR network

(D) The base-collector junction must be forward biased



A portion of the output power is returned back to the input

Q20: A sinusoidal wave $y(t) = 40\sin(10 \times 10^6 \pi t)$ is amplitude modulated by another sinusoidal wave $x(t) = 20\sin(1000\pi t)$. The amplitude of minimum frequency component of modulated signal is:

(A) 0.5

(B) 0.25

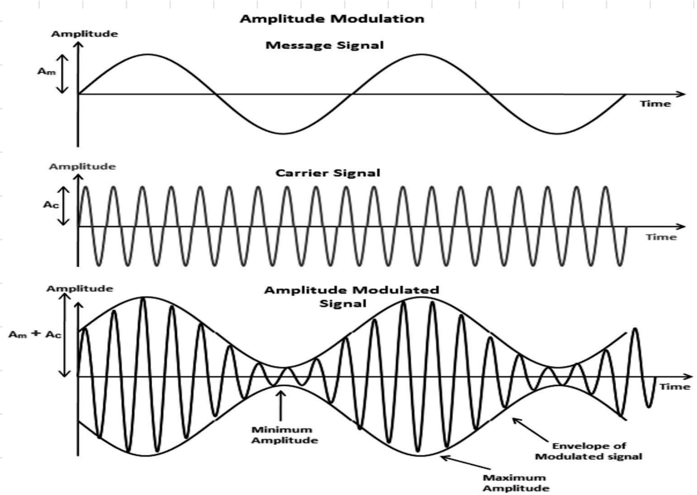
(C) 20

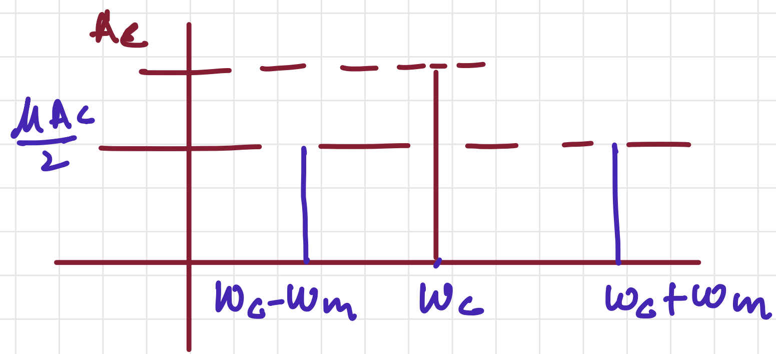
(D) 10 ✓

$$\mu = \frac{A_m}{A_c} = \frac{20}{40} = \frac{1}{2}$$

Modulated amplitude $= \frac{\mu A_c}{2}$

$$= \frac{1}{2} \times \frac{40}{2} = 10$$



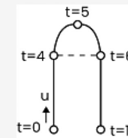


Q21: A ball is projected vertically upward with an initial velocity of $50ms^{-1}$ at $t = 0s$. At $t = 2s$, another ball is projected vertically upward with same velocity. At $t =$ 6 s,second ball will meet the first ball $(g = 10ms^{-2})$

6 sec

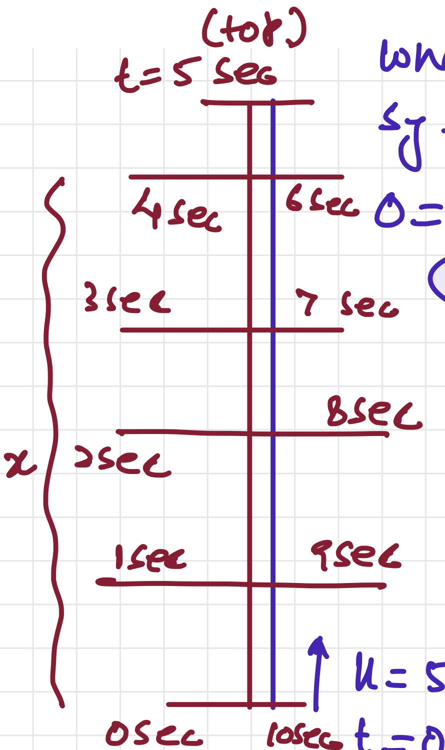
Solution:

$u = 50$



$T = \frac{2\times u}{g} = \frac{2\times 50}{10} = \frac{100}{10} = 10$

$t_a = t_d = 5$



what time this ball will come back.

$s_y = u_y t + \frac{1}{2} a_y t^2$

$0 = 50(t) - \frac{1}{2}\times 10 t^2$

$t = 10$ sec

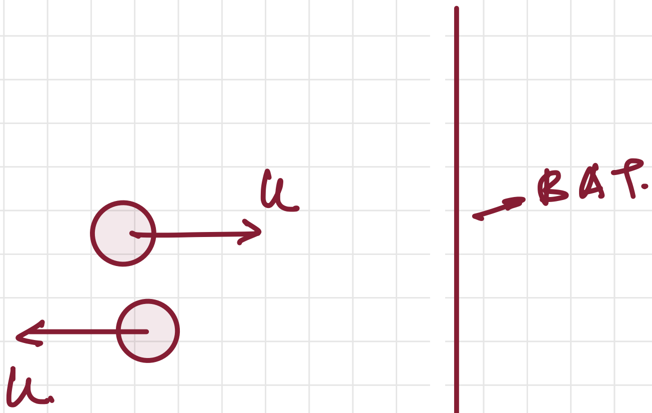
FIRST BALL REACH AT DISTANCE x in $t = 6$ sec

IInd BALL REACH AT DISTANCE x in 4sec.

Hence Answer is 6sec

Q22: A batsman hits back a ball of mass 0.4 kg straight in the direction of the bowler without changing its initial speed of $15 ms^{-1}$.The impulse imparted to the ball is _____ Ns.

12 N sec



$$F.\Delta t = m(\Delta v)$$

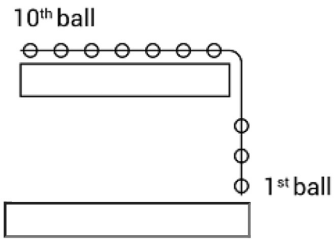
$$F.\Delta t = m(u-(-u))$$

$$F.\Delta t = 2mu$$

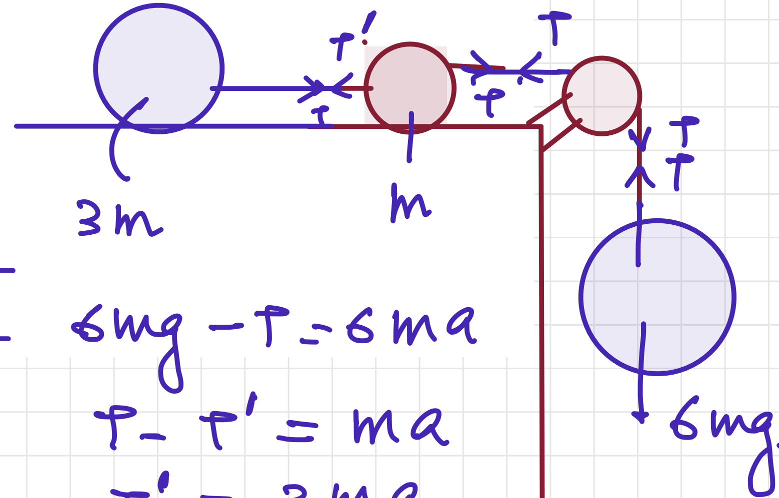
$$= 2 \times 0.4 \times 15$$

$$= 12 \text{ N sec}$$

Q23: A system to 10 balls each of mass 2 kg are connected via massless and un stretchable string. The system is allowed to slip over the edge of a smooth table as shown in figure. Tension on the string between the 7^{th} and 8^{th} ball is 36 N when 6^{th} ball just leaves the table.



⟹ REDRAW DIAGRAM



$$6mg - T = 6ma$$

$$T - T' = ma$$

$$T' = 3ma$$

ADD $6mg = 10ma$

$$a = \frac{6g}{10}$$

$$T' = 3m\left(\frac{6g}{10}\right)$$

$$= \frac{18}{10}mg = 18 \times 2 = 36\text{ N}$$

Q24: A geyser heats water flowing at a rate of 2.0 kg per minute from 30° to $70^\circ C$. If geyser operates on a gas burner, the rate of combustion of fuel will be 42 $g\,\mathrm{min}^{-1}$

[Heat of combustion $= 8 \times 10^3 Jg^{-1}$, Specific heat of water $= 4.2 Jg^{-1\circ}C^{-1}$]

42 gm/min

$\frac{dm}{dt} = 2\,kg/min$

$\theta_1 = 30^\circ C$, $\theta_2 = 70^\circ C$

$Q = m.s.\Delta\theta$

$\frac{dQ}{dt} = \left(\frac{dm}{dt}\right)(s)\Delta\theta$

$\frac{dQ}{dt} = \left(\frac{2}{60}\right)(4.2)\times(40)$ — ①

$Q = mL$

$\frac{dQ}{dt} = \frac{dm}{dt}(L)$ — ②

$\left(\frac{2}{60}\right)(4.2)(40) = \frac{dm}{dt}(L)$

$\frac{dm}{dt} = \frac{2\times4.2\times40}{60\times8\times10^3}$

$= 0.7\,gm/min$

$= 42\,grm/min$

Q25: A heat engine operates with the cold reservoir at temperature 324K. The minimum temperature of the hot reservoir, if the heat engine takes 300 J heat from the hot reservoir and delivers 180 J heat to the cold reservoir per cycle, is _____ K.

540 K

$T_2 = 324\ K$

$Q_1 = 300\ J$

$Q_2 = 180\ J$

$$\frac{T_1}{T_2} = \frac{Q_1}{Q_2}$$

$$T_1 = \left(\frac{Q_1}{Q_2}\right)(T_2)$$

$$= \left(\frac{300}{180}\right) \times 324$$

$$= 540\ K$$

Rough work

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