JEE MAIN 2021

PAPER-1 (B.E. / B.TECH)

QUESTIONS & SOLUTIONS

18 March, 2021 SHIFT-2

03:00 pm to 06:00 pm

Duration : 3 Hours Max. Marks : 300

SUBJECT - PHYSICS

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JEE(MAIN) 2021 (18 MARCH ATTEMPT) SHIFT-2
PHYSICS
SECTION-A

1. Which of the following statements are correct?

(A) Electric monopoles do not exist whereas magnetic monopoles exist.

(B) Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and confined.

(C) Magnetic field lines are completely confined within a toroid.

(D) Magnetic field lines inside a bar magnet are not parallel.

(E) $\chi = -1$ is the condition for a perfect diamagnetic material, where χ is its magnetic susceptibility.

Choose the correct answer from the options given below :

(1) (C) and (E) only
(2) (B) and (D) only
(3) (A) and (B) only
(4) (B) and (C) onlyϕ

Official Ans. by NTA (1)

Sol. Theoretical.

2. An object of mass m_1 collides with another object of mass m_2, which is at rest. After the collision the objects move with equal speeds in opposite direction. The ratio of the masses $m_2 : m_1$ is :

(1) 3 : 1
(2) 2 : 1
(3) 1 : 2
(4) 1 : 1

Official Ans. by NTA (1)

Sol. Using linear momentum conservation

$P_i = m_1u + m_2(0) = P_f = m_1v - m_2v$

$m_1u = (-m_1 + m_2)v$

$e = 1 = \frac{2v}{u} = 1$

$u = 2v$

$m_1 \times 2v = (m_2 - m_1)v$

$2m_1 = m_2 - m_1$

$3m_1 = m_2$

$\frac{m_1}{m_2} = \frac{1}{3}$

3. For an adiabatic expansion of an ideal gas, the fractional change in its pressure is equal to (where γ is the ratio of specific heats):

(1) $-\gamma\frac{dV}{V}$ (2) $-\gamma\frac{V}{dV}$ (3) $-\frac{1}{\gamma}\frac{dV}{V}$ (4) $\frac{dV}{V}$

Official Ans. by NTA (1)

Sol. $PV^{\gamma} = \text{constant}$

$\ell nP + \gamma\ell nV = \text{constant}$

$\frac{dP}{P}+\gamma\frac{dv}{v}=0$; $\frac{dP}{P}=-\gamma\frac{dv}{v}$

4. A proton and an α-particle, having kinetic energies K_p and K_α, respectively, enter into a magnetic field at right angles.

The ratio of the radii of trajectory of proton to that of α-particle is 2 : 1. The ratio of $K_p : K_\alpha$ is :

(1) 1 : 8 (2) 8 : 1 (3) 1 : 4 (4) 4 : 1

Official Ans. by NTA (4)

Sol. $R = \frac{\sqrt{2mK.E.}}{qB}$

$\frac{R_p}{R_\alpha}=2=\sqrt{\frac{m\times k_p}{q^2}}\times\sqrt{\frac{4q^2}{4mk_\alpha}} \Rightarrow \frac{k_p}{k_\alpha}=4$

5. A plane electromagnetic wave propagating along y-direction can have the following pair of electric field $(\vec{E})$ and magnetic field $(\vec{B})$ components.

(1) E_y, B_y or E_z, B_z (2) E_y, B_x or E_x, B_y

(3) E_x, B_z or E_z, B_x (4) E_x, B_y or E_y, B_x

Official Ans. by NTA (3)

Sol. $\hat{E}\times\hat{B}=\hat{C}$

i.e $\hat{E}\times\hat{B}$ points in the direction of propagation of EM wave.

6. Consider a uniform wire of mass M and length L. It is bent into a semicircle. Its moment of inertia about a line perpendicular to the plane of the wire passing through the centre is :

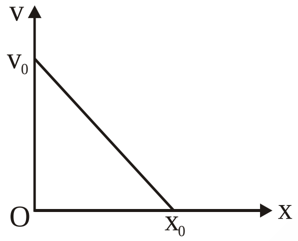
(1) $\frac{1}{4}\frac{ML^2}{\pi^2}$ (2) $\frac{2}{5}\frac{ML^2}{\pi^2}$ (3) $\frac{ML^2}{\pi^2}$ (4) $\frac{1}{2}\frac{ML^2}{\pi^2}$

Official Ans. by NTA (3)

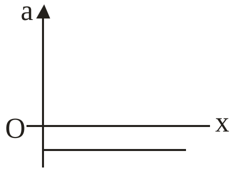
Sol. $L = \pi R$, $R = \frac{L}{\pi}$

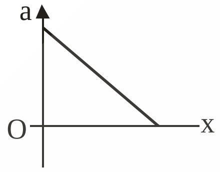
Moment of inertia $= mR^2 = \frac{mL^2}{\pi^2}$

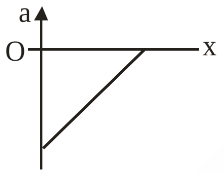
7. The velocity-displacement graph of a particle is shown in the figure.

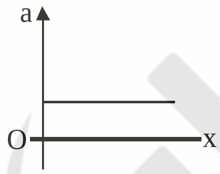


The acceleration-displacement graph of the same particle is represented by :

(1)


(2)


(3)


(4)


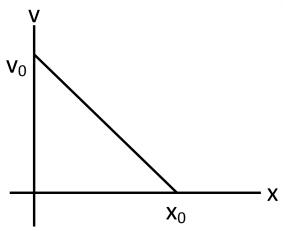
Official Ans. by NTA (3)

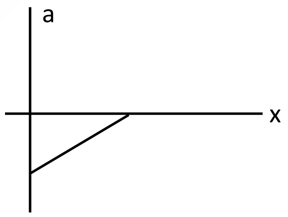
Sol. $\frac{v}{v_0}+\frac{x}{x_0}=1$

$\frac{a}{v_0}=-\frac{v_0}{x_0}v$

$\frac{a}{v_0}=-\frac{v_0^2}{x_0}\left(1-\frac{x}{x_0}\right)$

$a=-\frac{v_0^3}{x_0}\left(1-\frac{x}{x_0}\right)$





8. The correct relation between α (ratio of collector current to emitter current) and β (ratio of collector current to base current) of a transistor is :

(1) $\beta = \frac{\alpha}{1+\alpha}$ (2) $\alpha = \frac{\beta}{1-\alpha}$ (3) $\beta = \frac{1}{1-\alpha}$ (4) $\alpha = \frac{\beta}{1+\beta}$

Official Ans. by NTA (4)

Sol. $\alpha = \frac{I_C}{I_E}$, $\beta = \frac{I_C}{I_B}$

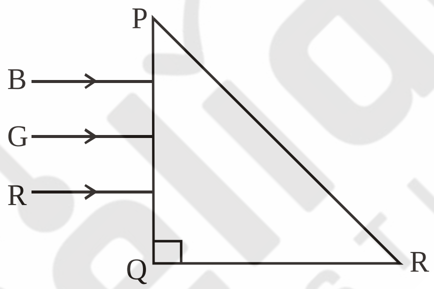
$I_E = I_B + I_C$

$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$

$\frac{1}{\alpha} = \frac{1}{\beta} + 1$

$\alpha = \frac{\beta}{1+\beta}$

9. Three rays of light, namely red (R), green (G) and blue (B) are incident on the face PQ of a right angled prism PQR as shown in figure.



The refractive indices of the material of the prism for red, green and blue wavelength are 1.27, 1.42 and 1.49 respectively. The colour of the ray(s) emerging out of the face PR is :

(1) green (2) red (3) blue and green (4) blue

Official Ans. by NTA (2)

Sol. For T.I.R

$i = 45^o$

$i > C$ $n > \sqrt{2}$

$45° > C$ $n > 1.414$

$\frac{1}{\sqrt{2}} > \frac{1}{n}$

So only red ray will come out.

10. If the angular velocity of earth's spin is increased such that the bodies at the equator start floating, the duration of the day would be approximately :

(Take : $g = 10\ ms^{-2}$, the radius of earth, $R = 6400 \times 10^3$ m, Take $\pi = 3.14$)

(1) 60 minutes (2) does not change

(3) 1200 minutes (4) 84 minutes

Official Ans. by NTA (4)

Sol. effective gravity at

equator $g_{eff} = (g - R_e\omega^2) = 0$

$$\omega = \sqrt{\frac{g}{R_e}}$$

so time period

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R_e}{g}} = 84.6 \text{ min}$$

≈ 84

11. The decay of a proton to neutron is :

(1) not possible as proton mass is less than the neutron mass

(2) possible only inside the nucleus

(3) not possible but neutron to proton conversion is possible

(4) always possible as it is associated only with β^+ decay

Official Ans. by NTA (2)

Sol. Theory (k-Capture)

12. In a series LCR circuit, the inductive reactance (X_L) is 10 Ω and the capacitive reactance (X_C) is 4 Ω. The resistance (R) in the circuit is 6 Ω. The power factor of the circuit is :

(1) $\frac{1}{2}$ (2) $\frac{1}{2\sqrt{2}}$ (3) $\frac{1}{\sqrt{2}}$ (4) $\frac{\sqrt{3}}{2}$

Official Ans. by NTA (3)

Sol. power factor

$$\text{Cos } \phi = \frac{R}{z}$$

$$= \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$= \frac{6}{\sqrt{6^2 + (10-4)^2}} = \frac{1}{\sqrt{2}}$$

13. The angular momentum of a planet of mass M moving around the sun in an elliptical orbit is $\vec{L}$. The magnitude of the areal velocity of the planet is :

(1) $\frac{4L}{M}$ (2) $\frac{L}{M}$ (3) $\frac{2L}{M}$ (4) $\frac{L}{2M}$

Official Ans. by NTA (4)

Sol. Theoretical.

14. The function of time representing a simple harmonic motion with a period of $\frac{\pi}{\omega}$ is :

(1) $\sin(\omega t) + \cos(\omega t)$ (2) $\cos(\omega t) + \cos(2\omega t) + \cos(3\omega t)$

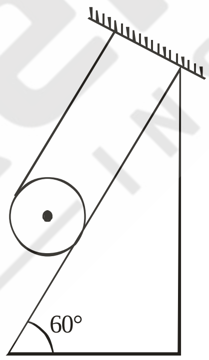
(3) $\sin^2(\omega t)$ (4) $3\cos\left(\frac{\pi}{4} - 2\omega t\right)$

Official Ans. by NTA (4)

Sol. 2 and 3 option represent SHM of time period π/ω as angular frequency is 2ω.

If the above equations represent displacement from mean position then only 3 is correct but if they represent position then 2 and 3 both will be correct.

15. A solid cylinder of mass m is wrapped with an inextensible light string and, is placed on a rough inclined plane as shown in the figure. The frictional force acting between the cylinder and the inclined plane is :

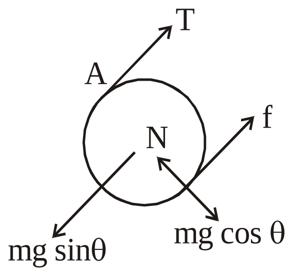


[The coefficient of static friction, μ_s, is 0.4]

(1) $\frac{7}{2}mg$ (2) 5 mg

(3) $\frac{mg}{5}$ (4) 0

Official Ans. by NTA (3)

Sol. 

$T_A = 0$, so mg sinθ × R = f × 2 R

$f = \frac{mg\sin\theta}{2}$

$f = \sqrt{3}\frac{mg}{4}$

but $f_{max} = 0.4$ mg cos 60° = 0.2 mg

16. The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance R, inductance L is connected to a battery, is :

(1) $\frac{L}{R}\ell n5$ (2) infinite (3) $\frac{L}{R}\ell n2$ (4) $\frac{L}{R}\ell n10$

Official Ans. by NTA (3)

Sol. $U = \frac{1}{2}LI^2$

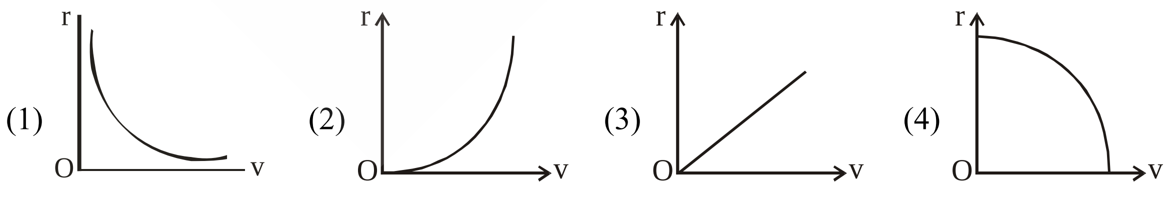
$\frac{1}{2}LI^2 = \frac{1}{4}LI_0^2$

$I = \frac{I_0}{2} = I_0\,(1 - e^{-t/\tau})$

$t = I\ell n2 = \frac{L}{R}\ell n2$

17. A particle of mass m moves in a circular orbit under the central potential field, $U(r) = \frac{-C}{r}$, where C is a positive constant.

The correct radius – velocity graph of the particle's motion is :



Official Ans. by NTA (1)

Sol. $U = -\frac{c}{r}$

$F = -\frac{du}{dr} = \frac{c}{r^2}$

$$\frac{mv^2}{r} = \frac{c}{r^2}$$

$$v = \sqrt{\frac{2c}{mr}}$$

$$v \propto \frac{1}{\sqrt{r}}$$

18. An ideal gas in a cylinder is separated by a piston in such a way that the entropy of one part is S_1 and that of the other part is S_2. Given that $S_1 > S_2$. If the piston is removed then the total entropy of the system will be :

(1) $S_1 \times S_2$ (2) $S_1 - S_2$ (3) $\frac{S_1}{S_2}$ (4) $S_1 + S_2$

Official Ans. by NTA (4)

Sol. $S_1 = \frac{f}{2} n_1 R$ $S_2 = \frac{f}{2} n_2 R$

$S = \frac{f}{2}(n_1 + n_2)R \Rightarrow \quad S = S_1 + S_2$

19. Consider a sample of oxygen behaving like an ideal gas. At 300 K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be :
(Molecular weight of oxygen is 32 g/mol; R = 8.3 J K^{-1} mol^{-1})

(1) $\sqrt{\frac{3}{3}}$ (2) $\sqrt{\frac{8}{3}}$ (3) $\sqrt{\frac{3\pi}{8}}$ (4) $\sqrt{\frac{8\pi}{3}}$

Official Ans. by NTA (3)

Sol. $v_{RMS} = \sqrt{\frac{3RT}{M}}$

& $v_{avg} = \sqrt{\frac{8RT}{\pi M}}$

$\therefore \frac{v_{RMS}}{v_{avg}} = \sqrt{\frac{3\pi}{8}}$

20. The speed of electrons in a scanning electron microscope is 1×10^7 ms^{-1}. If the protons having the same speed are used instead of electrons, then the resolving power of scanning proton microscope will be changed by a factor of:

(1) 1837 (2) $\frac{1}{1837}$ (3) $\sqrt{1837}$ (4) $\frac{1}{\sqrt{1837}}$

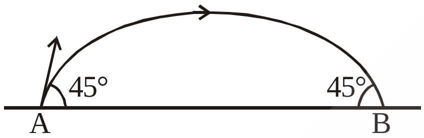
Official Ans. by NTA (1)

Sol. $RP \propto \frac{1}{\lambda}$

$\lambda \propto \frac{1}{m}$ (speed remains same)

SECTION-B

1. The projectile motion of a particle of mass 5 g is shown in the figure.



The initial velocity of the particle is $5\sqrt{2}$ ms^{-1} and the air resistance is assumed to be negligible. The magnitude of the change in momentum between the points A and B is $x \times 10^{-2}$ kgms^{-1}. The value of x, to the nearest integer, is _______.

Official Ans. by NTA (5)

Sol. $\vec{P}_i = m(5\sqrt{2}\cos 45^o\,\hat{i} + 5\sqrt{2}\sin 45^o\,\hat{j})$

$\vec{P}_f = m(5\sqrt{2}\cos 45^o\,\hat{i} - 5\sqrt{2}\sin 45^o\,\hat{j})$

$\Delta\vec{P} = \vec{P}_f - \vec{P}_i = -2m \times 5\sqrt{2} \times \frac{1}{\sqrt{2}}\hat{j}$

$= -10 \times 5 \times 10^{-3}$ kg m/s

$|\overrightarrow{\Delta P}| = 5 \times 10^{-2}$ kg m/s

2. A ball of mass 4 kg, moving with a velocity of 10 ms^{-1}, collides with a spring of length 8 m and force constant 100 Nm^{-1}. The length of the compressed spring is x m. The value of x, to the nearest integer, is_____.

Official Ans. by NTA (6)

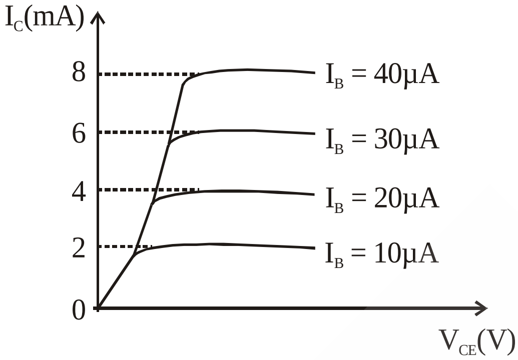
Sol. $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$\frac{1}{2}4 \times 10^2 = \frac{1}{2} \times 100\,x^2$

x = 2m.

so length of compressed spring is 6 m.

3. The typical output characteristics curve for a transistor working in the common-emitter configuration is shown in the figure.

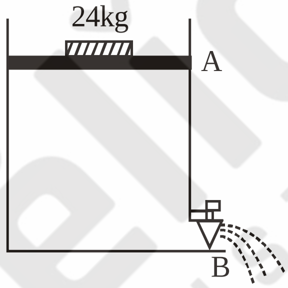


The estimated current gain from the figure is

Official Ans. by NTA (200)

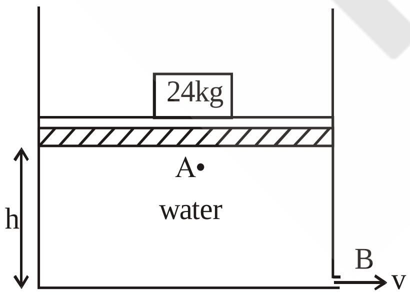
Sol. $\beta = \frac{I_C}{I_B} = \frac{6\times10^{-3}}{30\times10^{-6}} = 200$

4. Consider a water tank as shown in the figure. It's cross-sectional area is 0.4 m^2. The tank has an opening B near the bottom whose cross-section area is 1 cm^2. A load of 24 kg is applied on the water at the top when the height of the water level is 40 cm above the bottom, the velocity of water coming out the opening B is v ms^{-1}. The value of v, to the nearest integer, is___. [Take value of g to be 10 ms^{-2}]



Official Ans. by NTA (3)

Sol. Applying Bernoulli's equation at A and B.



$$P_{atm} + \frac{mg}{A} + \rho gh + \frac{1}{2}\rho V^2 = P_{atm} + \frac{1}{2}\rho v^2$$

$V \to 0$

$$\frac{mg}{A} + \rho gh = \frac{1}{2}\rho v^2$$

$$\frac{24\times10}{0.4}+1000\times10\times0.4=\frac{100}{2}v^2$$

$v \simeq 3$ m/s.

5. A TV transmission tower antenna is at a height of 20 m. Suppose that the receiving antenna is at.
(i) ground level
(ii) a height of 5 m.
The increase in antenna range in case (ii) relative to case (i) is n%.
The value of n, to the nearest integer, is .

Official Ans. by NTA (50)

Sol. % change = $\left(\frac{\sqrt{2\times20R}-\sqrt{2\times5R}}{\sqrt{2\times20R}}\right)\times100$

= 50%

n = 50

6. The radius of a sphere is measured to be (7.50 ± 0.85) cm. Suppose the percentage error in its volume is x. The value of x, to the nearest x, is_______.

Official Ans. by NTA (34)

Sol. V = volume = $\frac{4}{3}\pi r^3$

$$\ell nv=\ell n\left(\frac{4\pi}{3}\right)+\ell nr$$

$$\frac{dv}{v}=\frac{3dr}{4}$$

Percentage error in volume = $\frac{3\Delta r}{r}\times100$

$$=\frac{3\times0.85}{7.5}\times100=34\%$$

7. An infinite number of point charges, each carrying 1 μC charge, are placed along the y-axis at y = 1 m, 2 m, 4 m, 8 m................. The total force on a 1 C point charge, placed at the origin, is x × 10^3 N. The value of x, to the nearest integer, is________.

[Take $\frac{1}{4\pi\in_0}$ = 9 × 10^9 Nm^2/C^2]

Official Ans. by NTA (12)

Sol. $F=\frac{kq_1q_2}{r_1^2}+\frac{kq_1q_2'}{r_2^2}+\frac{kq_1q_2''}{r_3^2}+.......$

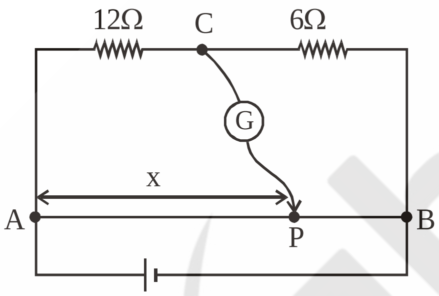
$$=9\times10^9\times10^{-6}\left[1+\left(\frac{1}{2}\right)^2+\left(\frac{1}{2^2}\right)^2+\left(\frac{1}{2^3}\right)^2+....\left(\frac{1}{2^\infty}\right)^2\right]$$

$$= 9 \times 10^9 \times 10^{-6} \left[\frac{1}{1-\frac{1}{4}} \right]$$

$$= 9 \times 10^3 \times \frac{4}{3}$$

$$= 12 \times 10^3 \text{ N}$$

8. Consider a 72 cm long wire AB as shown in the figure. The galvanometer jockey is placed at P on AB at a distance x cm from A. The galvanometer shows zero deflection.



The value of x, to the nearest integer, is

Official Ans. by NTA (48)

Sol. $\frac{12}{x} = \frac{6}{(72-x)}$

$12 \times 72 - 12x = 6x$

$x = \frac{12 \times 72}{18}$

$x = 48$ cm

9. Two wires of same length and thickness having specific resistances 6Ω cm and 3Ω cm respectively are connected in parallel. The effective resistivity is ρ Ω cm. The value of ρ, to the nearest integer, is_____.
Official Ans. by NTA (4)

Sol. $R_0 = \frac{\rho\ell}{A}$

$$R_{eq} = \frac{R_1R_2}{R_1+R_2} \Rightarrow \frac{\frac{3\times\ell}{A}\times\frac{6\times\ell}{A}}{\frac{3\ell}{A}\times\frac{6\ell}{A}} \Rightarrow \frac{2\ell}{A}$$

By comparing R_{eq} with $\frac{\rho_{eq}\ell}{2A}$

$\rho_{eq} = 4$

10. A galaxy is moving away from the earth at a speed of 286 kms^{-1}. The shift in the wavelength of a red line at 630 nm is $x \times 10^{-10}$ m. The value of x, to the nearest integer, is_____.

[Take the value of speed of light c, as 3×10^8 ms^{-1}]

Official Ans. by NTA (6)

Sol. $\upsilon' = \upsilon\sqrt{\frac{1+v/c}{1-v/c}}$

v <<< c thus

$\lambda' = \lambda\left(1+\frac{v}{c}\right)$

$\lambda' = \lambda = \frac{\lambda v}{c}$

$\frac{630\times10^{-9}\times286\times10^{3}}{3\times10^{8}} = 210 \times 286 \times 10^{-14} = 6 \times 10^{-10}$

x = 6