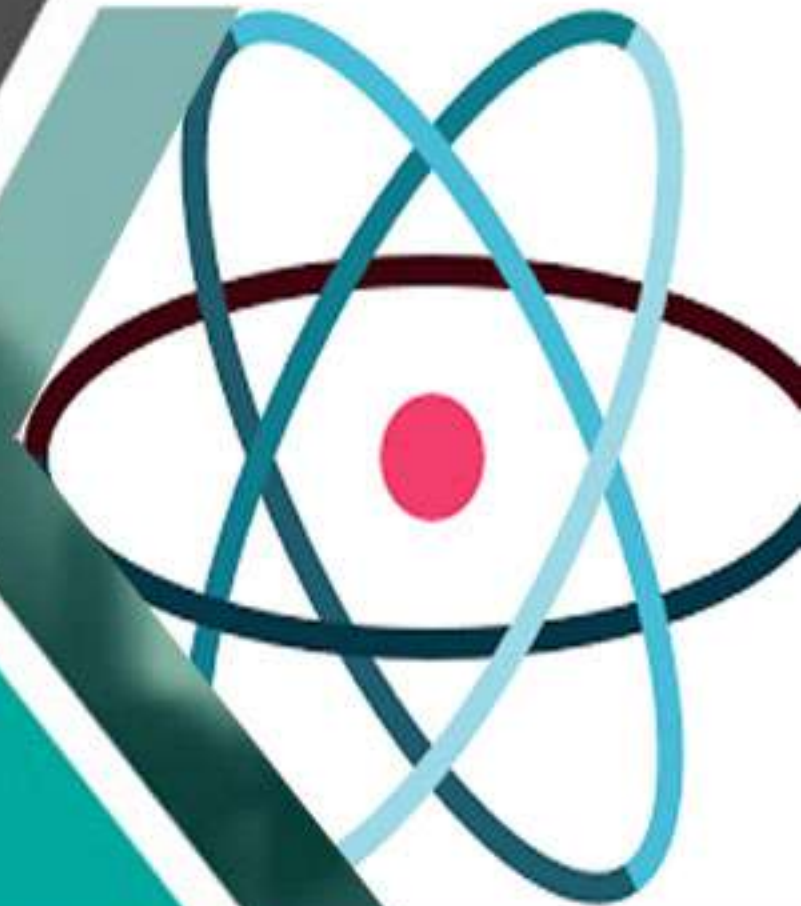


JNU PHYSICS

SOLVED SAMPLE PAPER



* DETAILED SOLUTIONS



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JNU PHYSICS MOCK TEST PAPER

- Attempt ALL the objective questions (Questions 1-25). Each of these questions carries four marks. 4/3 negative mark for each wrong answer.
- Pattern of questions : MCQs
- Total marks : 100
- Duration of test : 3 Hours

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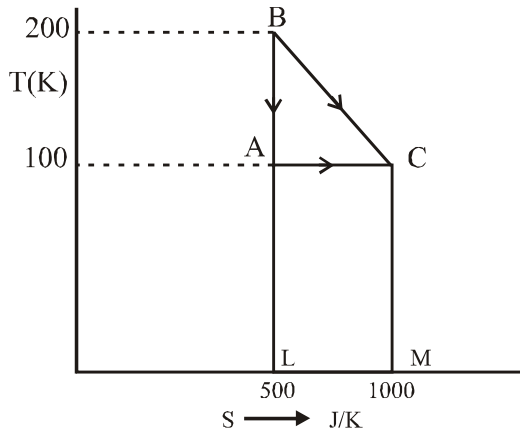
1. The half life of a radioactive substances is $T_{1/2} = 20$ days. The probability of decay of nucleus in 1 year is
 - (A) 3.7 %
 - (B) 7.3 %
 - (C) 0.037%
 - (D) 0.37%

2. What is the minimum attainable pressure of an ideal gas in the process given by $T = a + bV^2$, where a, b are constants and V is the Volume of the one mole of ideal gas?
 - (A) \sqrt{ab}
 - (B) $R\sqrt{ab}$
 - (C) $2R\sqrt{ab}$
 - (D) $\sqrt{\frac{a}{b}}$

(Where R is universal gas constant).

3. Three samples of the same gas A, B and C $\left(\gamma = \frac{3}{2}\right)$ have initially equal volume. Now the volume of each sample is doubled, the process is adiabatic for A; isobaric for B and isothermal for C if the final pressures are equals for all three samples, the ratios of their initial pressures are:
 - (A) $2\sqrt{2} : 2 : 1$
 - (B) $2\sqrt{2} : 1 : 2$
 - (C) $\sqrt{2} : 1 : 2$
 - (D) $2 : 1 : \sqrt{2}$

4. The efficiency of the reversible cycle shown in the given figure is:
 - (A) 16.7%
 - (B) 33.3%
 - (C) 50.0%
 - (D) 66.7%



5. An adiabatic vessel contains $n_1 = 3$ moles of a diatomic gas. Moment of inertia of each molecule is $I = 2.76 \times 10^{-46} \text{ kg m}^2$ and root mean square angular velocity is $\omega_0 = 5 \times 10^{12} \text{ rad/sec}$. Another adiabatic vessel contains $n_2 = 5$ mole of a monoatomic gas at temperature $T_0 = 470 \text{ K}$. Assuming gases to be ideal, calculate root mean square angular velocity of di-atomic molecules when the two vessels are connected by a thin non-conducting tube.
- Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J/molecule}$.
- (A) $6 \times 10^9 \text{ rad/sec}$ (B) $6 \times 10^{10} \text{ rad/sec}$
 (C) $6 \times 10^{11} \text{ rad/sec}$ (D) $6 \times 10^{12} \text{ rad/sec}$
6. Determine the p-v relation for monoatomic ideal gas undergoing an adiabatic process.
- (A) $PV^{2/3} = \text{constant}$ (B) $PV^{4/3} = \text{constant}$
 (C) $PV^{5/3} = \text{constant}$ (D) $PV^{7/3} = \text{constant}$
7. A cube is subjected to a uniform volume compression. If the side of the cube decreases by 2%, the bulk strain is:
- (A) 0.02 (B) 0.03 (C) 0.04 (D) 0.06
8. Calculate the inertia tensor for the system of four point masses 1 gm, 2 gm, 3 gm and 4 gm, located at the points (1,0,0), (1,1,0), (1,1,1) and (1, 1, -1) cm.

(A)
$$I = \begin{bmatrix} 16 & 9 & 1 \\ 9 & 17 & 1 \\ 1 & 1 & 19 \end{bmatrix}$$

$$(B) \quad I = \begin{bmatrix} -16 & 9 & 1 \\ 9 & -17 & 1 \\ 1 & 1 & -19 \end{bmatrix}$$

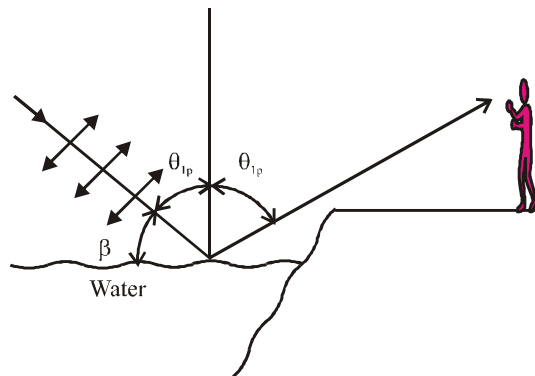
$$(C) \quad I = \begin{bmatrix} 16 & -9 & -1 \\ -9 & 17 & 1 \\ -1 & 1 & 19 \end{bmatrix}$$

$$(D) \quad I = \begin{bmatrix} 16 & -9 & 1 \\ -9 & 17 & 1 \\ 1 & 1 & 19 \end{bmatrix}$$

9. A pump draws water from a reservoir and sends it through a horizontal hose. Since the water starts at rest and is set into motion by the pump, the pump must deliver power P to the water when the flow rate is, even if fluid friction is negligible. A new pump is to be ordered which will pump water through the same system at rate $\Phi' = 2\Phi$. What must be the power P' of the new pump? Assume that friction is still negligible?
- (A) $2P$
 (B) $4P$
 (C) $8P$
 (D) $16P$
10. A parallel plate capacitor with area 0.30 m^2 and separation 5.5 m contains three dielectrics with interface normal to E and D as follows: $\epsilon r_1 = 3.0$, $d_1 = 1.0 \text{ mm}$; $\epsilon r_2 = 4.0$, $d_2 = 2.0 \text{ mm}$; $\epsilon r_3 = 6.0$, $d_3 = 2.5 \text{ mm}$. Find the capacitance.
- (A) 2.96 nF
 (B) 2.12 nF
 (C) 19.64 nF
 (D) 12.46 nF
11. A charged particle is deflected by two mutually perpendicular oscillating electric fields such that the displacement of the particle due to each one of them is given by $x = a \cos(\omega t)$ and $y = a \cos(\omega t + \pi/6)$ respectively. The trajectory followed by the charged particle is

- (A) a circle with equation $x^2 + y^2 = a^2$
 (B) a straight line with equation $y = \sqrt{3}x$
 (C) an ellipse with equation $x^2 + y^2 - xy = \frac{3}{4}a^2$
 (D) an ellipse with equation $x^2 + y^2 - \sqrt{3}xy = \frac{1}{4}a^2$

12. Two polaroids are aligned with their axes of transmission an angle of 45° . They are followed by a third Polaroid whose axis of transmission makes an angle of 90° with the first Polaroid. If all three are ideal, what fraction of the maximum possible light (if all Polaroids were at same angle) passes through all three?
- (A) 4
 (B) $\frac{1}{2}$
 (C) $\frac{1}{4}$
 (D) 2
13. At what angle β above the horizon is the sun when a person observing its rays reflected in water ($n_2 = 1.33$) finds them linearly polarized along the horizontal?



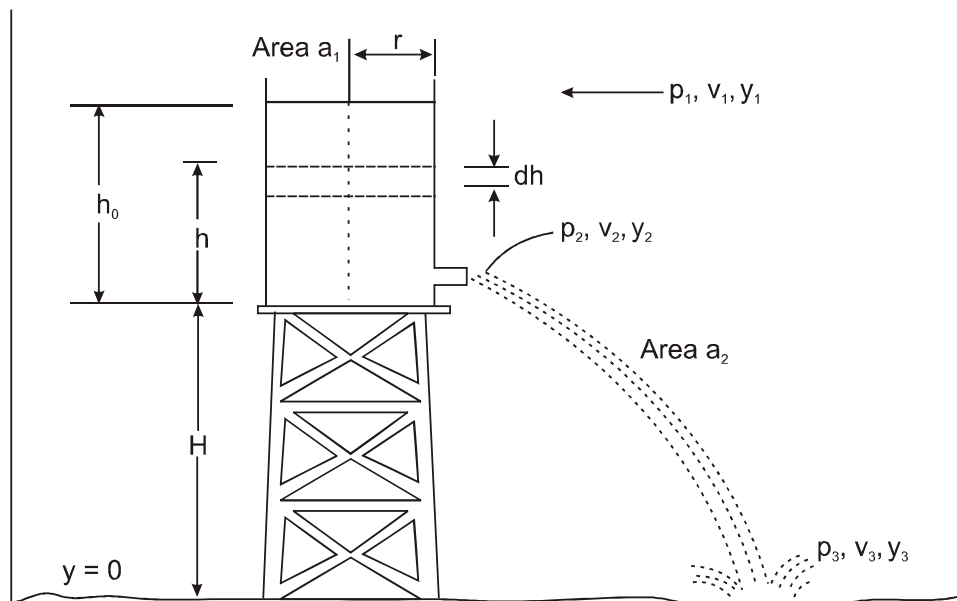
- (A) 53°
 (B) 37°
 (C) 33°
 (D) 57°

14. Given that the Curie temperature of a ferromagnet is 727°C , from this estimate the internal field.
- Given $\mu_B = 9.3 \times 10^{-21}$ erg/gauss
- (A) 15.05×10^6 Tesla
 (B) 15.05×10^6 Gauss
 (C) 15.05×10^{-6} Tesla
 (D) 15.05×10^{-6} Gauss
15. A sensor is exposed for 0.1 s to a 200 W lamp 10 m away. The sensor has an opening that is 20 mm in diameter. How many photons enter the sensor if the wavelength of the light is 600 nm? Assume that all the energy of the lamp is given off as light.
- (A) 1.53×10^{14} Photons/s
 (B) 1.53×10^{13} Photons/s
 (C) 1.53×10^{12} Photons/s
 (D) 1.53×10^{11} Photons/s
16. A system has N distinguishable particles. Each particle can occupy one of the two non-degenerate states with an energy difference of 0.1 eV. If the system is in thermal equilibrium at room temperature, the approximate fraction of particles in the higher energy state is
- (A) $\exp(-10)$
 (B) $\exp(-4)$
 (C) $\exp(-2)$
 (D) zero
17. A lattice is characterized by the following primitive vectors (in angstroms) : $\vec{a} = 2(\hat{i} + \hat{j})$,
 $\vec{b} = 2(\hat{j} + \hat{k})$, $\vec{c} = 2(\hat{k} + \hat{i})$. The reciprocal lattice corresponding to the above is
- (A) body centered cubic lattice with cube edge $\pi \text{ \AA}^{-1}$
 (B) body centered cubic lattice with cube edge $2\pi \text{ \AA}^{-1}$

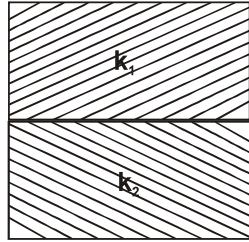
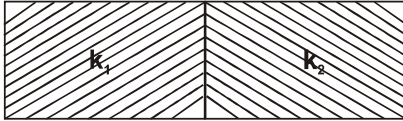
(C) face centered cubic lattice with cube edge $\pi \text{Å}^{-1}$

(D) face centered cubic lattice with cube edge $2\pi \text{Å}^{-1}$

18. The feedback ratio of an amplifier, which on application of a negative feedback, changes the voltage gain from -250 to -100 is
- (A) -0.250
 (B) -0.025
 (C) -0.060
 (D) -0.006
19. Water leaves a faucet with a downward velocity of 3.0 m/s . As the water falls below the faucet, it accelerates with acceleration g . The cross sectional area of water stream leaving the faucet is 1.0 cm^2 . What is the cross sectional area of the stream 0.50 m below the faucet?
- (A) 0.59 cm^2
 (B) 0.59 m^2
 (C) 0.69 cm^2
 (D) 0.69 m^2



20. A parallel plate capacitor is filled with two dielectrics of same dimensions but different dielectric constants K_1 and K_2 respectively as shown in the figure. Calculate its capacitance

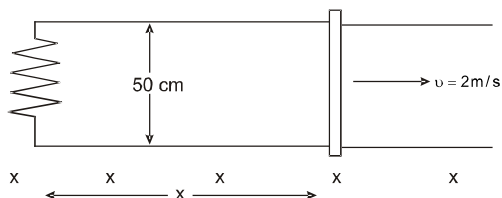


- (A) $\frac{\epsilon_0 A}{d} \left(\frac{K_1 K_2}{K_1 + K_2} \right)$
- (B) $\frac{\epsilon_0 A}{d} \left(\frac{K_1 + K_2}{K_1 K_2} \right)$
- (C) $\frac{2\epsilon_0 A}{d} \left(\frac{K_1 K_2}{K_1 + K_2} \right)$
- (D) $\frac{2\epsilon_0 A}{d} \left(\frac{K_1 + K_2}{K_1 K_2} \right)$
21. As shown in the fig. a metal rod makes contact with a partial circuit and completes the circuit. The circuit area is perpendicular to a magnetic field with $B = 0.15$ T. If the resistance of the total circuit is 3Ω , how large a force is needed to move the rod as indicated with a constant speed of 2 m/s ?

x x x x x x

$B = 0.15 \text{ T}$ (into page)

x x x x x x



x x x x x x

x x x x x x

- (A) $3.75 \times 10^{-3} \text{ N}$
- (B) $3.75 \times 10^{-4} \text{ N}$
- (C) $3.75 \times 10^{-5} \text{ N}$
- (D) $3.75 \times 10^{-6} \text{ N}$

22. A convex lens of focal length 12 cm is placed in contact with a plane mirror. If an object is placed 20 cm from the lens, where is the final image formed?

- (A) 8.6 cm to the left of the lens
- (B) 8.6 cm to the right of the lens
- (C) 30 cm to the right of the lens
- (D) 30 cm to the left of the lens

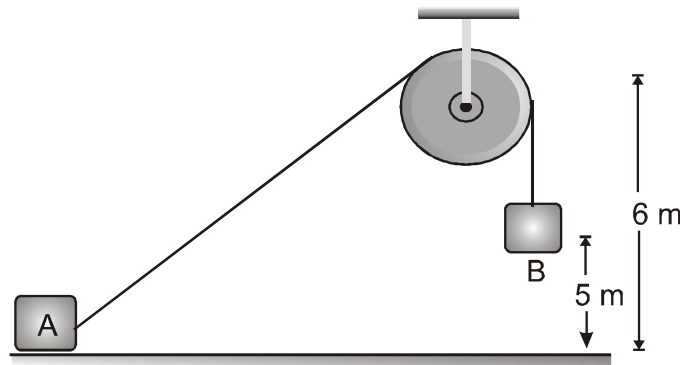
23. A grating having 15000 lines per inch produces spectra of a mercury arc. The green lines of the mercury spectrum have a wavelength of 5461. What is the angular separation between the first order green line and the second - order green line?

- (A) 18.8°
- (B) 40.2°
- (C) 21.4°
- (D) 22.7°

24. An unpolarised beam of 100 KeV neutrons (De Broglie wavelength 90 fm) collides with a stationary proton target. The range of interaction is about 1 fm ($= 10^{-15} \text{ m}$). Which of the following statements is correct?

- (A) Proton, antiproton, or pairs may be produced in the collision
- (B) The differential scattering cross-section will be approximately isotropic
- (C) The differential scattering cross-section will exhibit significant angular dependence
- (D) Energy of the scattered neutrons will be unchanged during collision

25. A block of mass m is held at rest on a smooth horizontal floor. A light frictionless, small pulley is fixed at a height of 6 m from the floor. A light inextensible string of length 16 m, connected with A passes over the pulley and another identical block B is hung from the string. Initial height of B is 5 m from the floor as shown in fig. When the system is released from rest, B starts to move vertically downwards and A slides on the floor towards right. If at an instant string makes an angle θ with horizontal. Calculate relation between velocity u of A and v of B.



- (A) $u = v \cos\theta$
- (B) $u = v \sin\theta$
- (C) $u = v \sec\theta$
- (D) $u = v \operatorname{cosec}\theta$

ANSWER KEY

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Answer	A	C	B	B	D	C	D	D	C	B	D	C	B	B	B	B	A	D	C	C
Question	21	22	23	24	25															
Answer	A	A	C	B	C															

HINTS AND SOLUTION

1.(A) The probability $P = \frac{\text{Number of nuclei decayed}}{\text{Total no. of nuclei}} = \frac{N_0(1 - e^{-\lambda t})}{N_0}$

$$\therefore P = 1 - e^{-\lambda t} = 1 - e^{-\left(\frac{\log_e 2}{T}\right)t} \therefore \lambda = \frac{\log_e 2}{T}$$

or $P = 1 - e^{-\log_e 2 \times \left(\frac{20}{365}\right)} = 1 - e^{-0.038} = 0.037 = 3.7\%$ So (A) is correct

2.(C) $T = a + bV^2$ for 1 mole gas $PV = RT \therefore T = \frac{PV}{R}$ or $\frac{PV}{R} = a + bV^2$

$$\therefore P = (a + bV^2) \frac{R}{V}$$

$$\therefore P = \frac{aR}{V} + \frac{V^2 Rb}{V} = \frac{aR}{V} + VbR. \text{ To find minimum pressure put } \frac{dP}{dV} = 0, \frac{-aR}{V^2} + Rb = 0$$

$$\therefore V^2 = \frac{a}{b}$$

Again differentiating eqnⁿ twice, we get $\frac{d^2P}{dV^2}$ is positive so P is minimum at $V^2 \therefore P_{\min}$

$$= \frac{aR}{\sqrt{a/b}} + bR\sqrt{\frac{a}{b}} = 2R\sqrt{ab}.$$

3.(B) Let the initial pressure of the three samples be P_A, P_B and P_C then $P_A(V)^{3/2} = (2V)^{3/2} P, P_B = P$ and $P_C(V) = P(2V)$

$$\Rightarrow P_A : P_B : P_C = (2)^{3/2} : 1 : 2 = 2\sqrt{2} : 1 : 2$$

4.(B) The path AB shows adiabatic compression
so temperature decrease and $ds = 0$
CA \rightarrow isothermal compression

$$dW = p dV = \frac{NkT}{V} dV$$

$$\text{Thus, } \frac{3}{2} Nk dT = -\frac{NkT}{V} dV$$

$$\text{or } \frac{dT}{T} + \frac{2}{3} \frac{dV}{V} = 0$$

$$\text{Integrating, in } T + \frac{3}{2} \ln V = \text{constant}$$

$$\text{or } TV^{2/3} = \text{constant}$$

Finally, substituting for T from the ideal gas law, $PV^{5/3} = \text{constant}$.

- 7.(D)** Let L be the length of each side of cube. Initial volume of cube = L^3 . when each side of cube decreases by 2% the new length = L'

$$L' = L - \frac{2L}{100} = \frac{98L}{100}$$

$$\text{New volume of cube} = L'^3 = \left(\frac{98L}{100}\right)^3$$

Change in volume =

$$L'^3 - \Delta V = L^3 - L'^3 = L^3 - \left(\frac{98L}{100}\right)^3 = L^3 \left[1 - \left(1 - \frac{2}{100}\right)^3\right]$$

$$\Delta V = L^3 \left[1 - \left(1 - \frac{6}{100} + \dots\right)\right] = L^3 \frac{6}{100} = \frac{6L^3}{100} \quad \text{Bulk strain } \frac{\Delta V}{V} = \frac{6L^3}{100L^3} = \frac{6}{100} = 0.06$$

8.(D) $I_{xx} = \sum_{i=1}^4 m_i (y_i^2 + z_i^2) = 1 \times 0 + 2 \times 1 + 3 \times 2 + 4 \times 2 = 16 \text{ gm-cm}^2$

Similarly, $I_{yy} = \sum_{i=1}^4 m_i (x_i^2 + z_i^2) = 17 \text{ gm-cm}^2$ $I_{zz} = \sum_{i=1}^4 m_i (x_i^2 + y_i^2) = 19 \text{ gm-cm}^2$

Also $I_{xy} = I_{yx} = -\sum_{i=1}^4 m_i x_i y_i = -[0 + 2 \times 1 \times 1 + 3 \times 1 \times 1 + 4 \times 1 \times 1] = -9 \text{ gm-cm}^2$

Similarly, $I_{xy} = I_{yx} = -\sum_{i=1}^4 m_i x_i z_i = 1 \text{ gm-cm}^2$ and $I_{yz} = I_{zy} = -\sum_{i=1}^4 m_i y_i z_i = 1 \text{ gm-cm}^2$

Thus the inertia tensor I is

$$I = \begin{pmatrix} 16 & -9 & 1 \\ -9 & 17 & 1 \\ 1 & 1 & 19 \end{pmatrix}$$

9.(C) By the work energy theorem,

$$\begin{aligned} P &= \frac{\text{KE imparted to the water}}{\text{time}} \\ &= \frac{\text{KE}}{\text{vol. water}} \times \frac{\text{vol. water}}{\text{time}} \propto v^2 \times v \\ &= v^3 \end{aligned}$$

The mass flux Φ is proportional to v so that $P \propto \Phi^3$. Thus $\Phi' = 2\Phi$, the new power $P' \propto (\Phi')^3 \Rightarrow P' \propto (2\Phi)^3 \propto 8\Phi^3$ $P' = 8P$.

10.(B) Each dielectric is treated as one capacitor which is a set of three capacitors in series

$$c_1 = \frac{\epsilon_0 \epsilon_r A}{d_1} = \frac{\epsilon_0 (3.0)(0.30)}{10^{-3}} = 7.96 \text{ nF}$$

Similarly, $c_2 = 5.31 \text{ nF}$ and $C_3 = 6.37 \text{ nF}$;

$$\frac{1}{c_{eq}} = \frac{1}{7.96 \times 10^{-9}} + \frac{1}{5.31 \times 10^{-9}} + \frac{1}{6.37 \times 10^{-9}} \quad \text{or} \quad c_{eq} = 2.12 \text{ nF}$$

11.(D) $\frac{x}{a} = \cos wt$ and $\frac{y}{a} = \cos(wt + \pi/6) = \cos wt \cos \frac{\pi}{6} - \sin wt \sin \frac{\pi}{6}$

$$\therefore \frac{y}{a} = \frac{x}{a} \frac{\sqrt{3}}{2} - \frac{1}{2} \sqrt{1 - \frac{x^2}{a^2}} \quad \therefore \left(\frac{y}{a} - \frac{x}{a} \frac{\sqrt{3}}{2} \right) = -\frac{1}{2} \sqrt{1 - \frac{x^2}{a^2}}$$

Squaring it.

$$\frac{3x^2}{4a^2} + \frac{y^2}{a^2} - \sqrt{3} \frac{xy}{a^2} = \frac{1}{4} \left(1 - \frac{x^2}{a^2} \right)$$

$$3x^2 + 4y^2 - 4 = \sqrt{3}xy \quad a^2 - x^2$$

$$4x^2 + 4y^2 - 4 = \sqrt{3}xy \quad a^2$$

$$\therefore x^2 + y^2 - \sqrt{3}xy = \frac{a^2}{4}$$

12.(C) The reduction factor for either of the last two Polaroids is $\cos^2 45^\circ = 1/2$; so the overall factor

$$\text{is } \left(\frac{1}{2}\right)^2 = \frac{1}{4}.$$

13.(B) In order for the reflected rays to be linearly polarized, the angle of incidence must be a Brewster's angle.

$$\tan \theta_{1p} = \frac{n_2}{n_1} = \frac{1.33}{1.00} \text{ or } \theta_{1p} \approx 53^\circ$$

$$\text{and } \beta = 90^\circ - \theta_{1p} = 37^\circ.$$

14.(B) For internal field (Weiss Field) H_e , the formula is

$$\begin{aligned} \mu_B H_e &= k \theta \\ H_e &= \frac{k\theta}{\mu_B} \begin{cases} \mu_B = 9.3 \times 10^{-21} \text{ erg/gauss} \\ \theta = 727^\circ\text{C} = 727 + 273 = 1000\text{K} \end{cases} \\ &= \frac{1.4 \times 10^{-16} \text{ erg/K} \times 1000\text{K}}{9.3 \times 10^{-21} \text{ erg Gauss}^{-1}} \\ &= \frac{14}{93} \times 10^8 = 1.505 \times 10^7 \\ &= 15.05 \times 10^6 \text{ Gauss} \end{aligned}$$

15.(B) The energy of a photon of the light is

$$\begin{aligned} E &= \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{600 \times 10^{-9}} \\ &= 3.3 \times 10^{-19} \text{ J} \end{aligned}$$

The lamp uses 200 W of power. The number of photons emitted per second is

$$n = \frac{200}{3.3 \times 10^{-19}} = 6.1 \times 10^{20} \text{ photons/s}$$

Since the radiations are spherically symmetrical, the numbers of photons entering the sensor per second are: n multiplied by the ratio of the aperture area to the area of a sphere of radius 10 m:

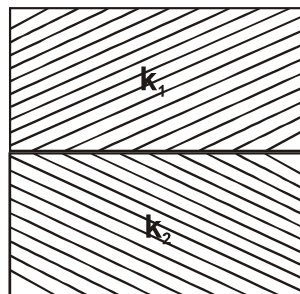
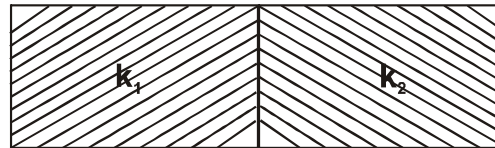
$$= .6 \times 10^{-2}$$

$$\beta = -0.006$$

Ans.

19.(C) We denote the initial speed by V_0 and the initial cross-sectional area by A_0 . After the freely falling stream has descended a distance h , its speed $v_1 = \sqrt{v_0^2 + 2gh}$. Under steady-flow conditions, the mass fluxes at the locations are equal : $\rho_0 v_0 A_0 = \rho_1 v_1 A_1$. Since the water is effectively incompressible, $\rho_0 = \rho_1$ and therefore $A_1 = (v_0 / v_1) A_0$. By inserting numerical values, we find $v_1 = \sqrt{(3.0)^2 + 2(9.8)(0.50)} = 4.34 \text{ m/s}$. Then $A_1 = (3.0 / 4.34) (1.0 \text{ cm}^2) = 0.69 \text{ cm}^2$.

20.(C) From figure the arrangement is simply two capacitors in parallel and each capacitor will have the area $A/2$



$$\text{Total capacitance, } C = C_1 + C_2 = \frac{\epsilon_0 A/2 \cdot K_1}{d} + \frac{\epsilon_0 A/2 \cdot K_2}{d} = \frac{\epsilon_0 A}{d} \left(\frac{K_1 + K_2}{2} \right)$$

The arrangement of following can be regarded as two capacitors in series. Each capacitor will be of area A and separation $d/2$. Therefore, total capacitance is given by the relation

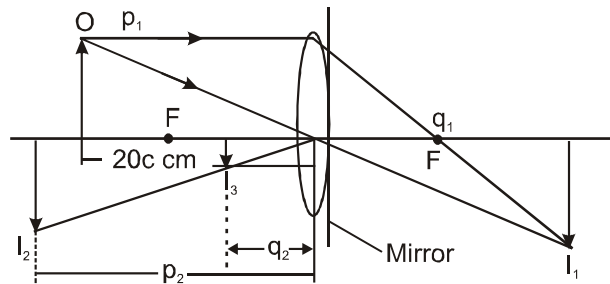
$$\begin{aligned} \frac{1}{C} &= \frac{1}{C_1} + \frac{1}{C_2} \\ &= \frac{d}{2} \left(\frac{1}{\epsilon_0 A k_1} + \frac{1}{\epsilon_0 A k_2} \right) \end{aligned}$$

22.(A) See fig. Because of the mirror, light goes through the lens twice. First we have

$$\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f} \qquad \frac{1}{20} + \frac{1}{q_1} = \frac{1}{12}$$

$$\frac{1}{q_1} = \frac{1}{12} - \frac{1}{20} = \frac{5-3}{60} = \frac{2}{60} \text{ and } q_1 = 30 \text{ cm.}$$

Image I_1 formed by the lens would be 30 cm behind the mirror location if the mirror is removed. After reflection in the mirror, the image of I_1 is at I_2 , 30 cm in front of the lens.



Since the light now goes to the left, I_2 acts as a virtual object for the lens and p_2 is negative.

Use the lens equation again.

$$\frac{1}{p_2} + \frac{1}{q_2} = \frac{1}{f} \qquad \frac{1}{-30} + \frac{1}{q_2} = \frac{1}{12}$$

$$\frac{1}{q_2} = \frac{1}{12} + \frac{1}{30} = \frac{5}{60} + \frac{2}{60} = \frac{7}{60}$$

$q_2 = 8.6 \text{ cm}$ to the left of the lens.

23.(C) Use the grating formula and solve for θ for both $n = 1$ and $n = 2$, with distances in meters:

$$n\lambda = d \sin \theta$$

$$5461 \times 10^{-10} = \frac{1}{(39.37)(15000)} \sin \theta_1$$

$$\text{or } 0.3225 = \sin \theta_1$$

$$\text{and } \theta_1 = 18.8^\circ \text{ first order}$$

Next, for $n = 2$

$$2(5461 \times 10^{-10}) = \frac{1}{(39.37)(15000)} \sin \theta_2$$

