Paper-2

JEE Advanced, 2016

Part I: Physics

Read the instructions carefully:

General:

1. This sealed booklet is your Question Paper. Do not break the seal till you are instructed to do so.
2. The question paper CODE is printed on the left hand top corner of this sheet and the right hand top corner of the back cover of this booklet.
3. Use the Optical Response Sheet (ORS) provided separately for answering the questions.
4. The paper CODE is printed on its left part as well as the right part of the ORS. Ensure that both these codes are identical and same as that on the question paper booklet. If not, contact the invigilator.
5. Blank spaces are provided within this booklet for rough work.
6. Write your name and roll number in the space provided on the back cover of this booklet.
7. After breaking the seal of the booklet at 2:00 pm, verify that the booklet contains 36 pages and that all the 54 questions along with the options are legible. If not, contact the invigilator for replacement of the booklet.
8. You are allowed to take away the Question Paper at the end of the examination.

Optical Response Sheet

9. The ORS (top sheet) will be provided with an attached Candidate's Sheet (bottom sheet). The Candidate's Sheet is a carbon – less copy of the ORS.
10. Darken the appropriate bubbles on the ORS by applying sufficient pressure. This will leave an impression at the corresponding place on the Candidate's Sheet.
11. The ORS will be collected by the invigilator at the end of the examination.
12. You will be allowed to take away the Candidate's Sheet at the end of the examination.
13. Do not tamper with of mutilate the ORS. Do not use the ORS for rough work.

14. Write your name, roll number and code of the examination center, and sign with pen in the space provided for this purpose on the ORS. Do not write any of these details anywhere else on the ORS. Darken the appropriate bubble under each digit of your roll number.

Darken the Bubbles on the ORS

15. Use a Black Ball Point Pen to darken the bubbles on the ORS.

16. Darken the bubble ⬭ completely.

17. The correct way of darkening a bubble is as: ⬬

18. The ORS is machine – gradable. Ensure that the bubbles are darkened in the correct way.

19. Darken the bubbles only if you are sure of the answer. There is no way to erase or “un–darken” a darkened bubble.

PART-I : PHYSICS

SECTION–1 : (Maximum Marks : 18)

- This section contains **SIX** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :

Full Marks : +3 If only the bubble corresponding to the correct option is darkened.

Zero Marks : 0 If none of the bubbles is darkened.

Negative Marks : –1 In all other cases.

1. The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by $E = \frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$

The measured masses of the neutron, ${}_1^1H$, ${}_7^{15}N$ and ${}_8^{15}O$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u respectively. Given that the radii of both the ${}_7^{15}N$ and ${}_8^{15}O$ nuclei are same, 1u = 931.5 MeV/c^2 (c is the speed of light) and $\frac{e^2}{(4\pi\varepsilon_0)}$ = 1.44 MeV fm. Assuming that the difference between the binding energies of ${}_7^{15}N$ and ${}_8^{15}O$ is purely due to the electrostatic energy, the radius of either of the nuclei is ($1\text{fm} = 10^{-15}\text{m}$)

(A) 2.85 fm (B) 3.03 fm (C) 3.42 fm (D) 3.80 fm

Ans. **(C)**

Sol. Electrostatic energy = $BE_N - BE_O$

$= [[7M_H + 8M_n - M_N] - [8M_H + 7M_n - M_O]] \times C^2$

$= [-M_H + M_n + M_O - M_N]C^2$

$= [-1.007825 + 1.008665 + 15.003065 - 15.000109] \times 931.5$

$= +3.5359$ MeV

$$\Delta E = \frac{3}{5} \times \frac{1.44 \times 8 \times 7}{R} - \frac{3}{5} \times \frac{1.44 \times 7 \times 6}{R} = 3.5359$$

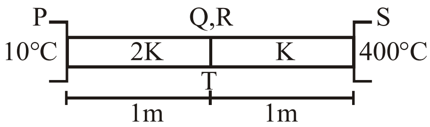
$$R = \frac{3 \times 1.44 \times 14}{5 \times 3.5359} = 3.42\text{fm}$$

2. The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1m at 10°C. Now the end P is maintained at 10°C, while the end S is heated and maintained at 400°C. The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is $1.2 \times 10^{-5}\ K^{-1}$, the change in length of the wire PQ is

(A) 0.78 mm (B) 0.90 mm (C) 1.56 mm (D) 2.34 mm

Ans. (A)

Sol.



Heat flow from P to Q

$$\frac{dQ}{dt} = \frac{2KA(T-10)}{1}$$

Heat flow from Q to S

$$\frac{dQ}{dt} = \frac{KA(400-T)}{1}$$

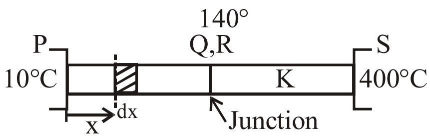
At steady state heat flow is same in whole combination

$$\frac{2KA(T-10)}{1} = KA(400\text{-}T)$$

$2T - 20 = 400–T$

$3T = 420$

$T = 140°$



Temp of junction is 140°C

Temp at a distance x from end P

is $T_x = (130x + 10°)$

Change in length dx is dy

$dy = \alpha dx(T_x - 10)$

$$\int_0^{\Delta y} dy = \int_0^1 \alpha dx(130x + 10 - 10)$$

$$\Delta y = \left[\frac{\alpha x^2}{2} \times 130\right]_0^1$$

$\Delta y = 1.2 \times 10^{-5} \times 65$

$\Delta y = 78.0 \times 10^{-5}$ m = 0.78 mm

3. An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratory. Tests revealed that the radiation was 64 times more than the permissible level required for safe operation of the laboratory. What is the minimum number of days after which the laboratory can be considered safe for use?

(A) 64 (B) 90 (C) 108 (D) 120

Ans. (C)

Sol. Let the permissible level have activity of $A_{permissible}$

Thus, initially

$A_0 = 64\ A_{permissible}$ [Given]

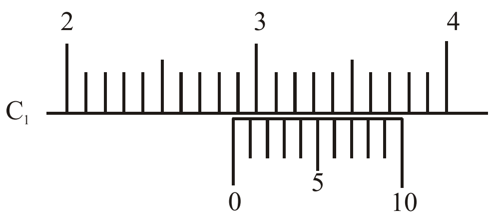
Let number of days required be t.

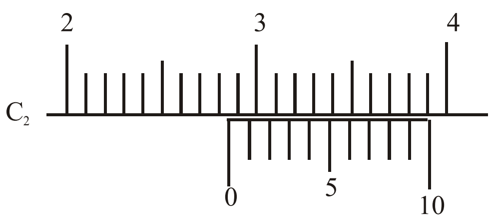
$$\therefore \frac{A_0}{2^{t/t_{1/2}}} = A_{permissible}$$

$$\Rightarrow \frac{64A_{permissible}}{2^{t/18}} = A_{permissible}$$

$\therefore$ t = 108 days

4. There are two vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2 respectively, are





(A) 2.87 and 2.86 (B) 2.87 and 2.87 (C) 2.87 and 2.83 (D) 2.85 and 2.82

Ans. **(C)**

Sol. For caliper C_1

10 VSD = 9MSD

LC = 1MSD – 1VSD

LC = 0.01 cm

Measured value = Main scale reading + vernier scale reading

= (2.8 + 7 × 0.01) cm

= 2.87 cm

For Caliper C_2

10 VSD = 11 MSD

LC = 0.01 cm

Measured value = {2.8 + (10–7) × 0.01}cm

= 2.83 cm

5. A gas is enclosed in a cylinder with a movable frictionless piston. Its initial thermodynamic state at pressure $P_i = 10^5$ Pa and volume $V_i = 10^{-3}$ m^3 changes to a final state at $P_f = \left(\frac{1}{32}\right) \times 10^5 \text{Pa}$ and $V_f = 8 \times 10^{-3}$ m^3 in an adiabatic quasi-static process, such that P^3V^5 = constant. Consider another thermodynamic process that brings the system from the same initial state to the same final state in two steps: an isobaric expansion at P_i followed by an isochoric (isovolumetric) process at volumes V_f. The amount of heat supplied to the system in the two step process is approximately

(A) 112 J (B) 294 J (C) 588 J (D) 813 J

Ans. **(C)**

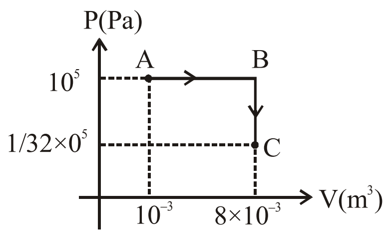
Sol. In adiabatic process

P^3V^5 = constant

$\Rightarrow PV^{5/3}$ = constant

$\Rightarrow \gamma = \frac{5}{3} \Rightarrow C_V = \frac{3}{2}R$ and $C_P = \frac{5}{2}R$

In another process



$\Delta Q = nC_P\Delta T + nC_V\Delta T$

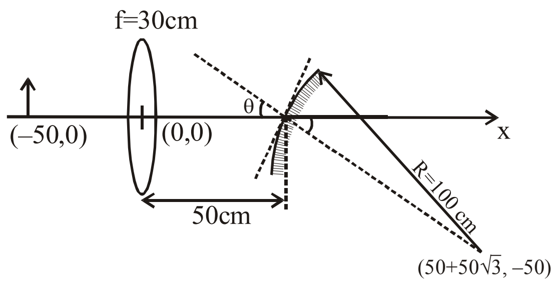
$= \frac{5}{2}nR(T_B - T_A) + \frac{3}{2}nR(T_C - T_B)$

$\Delta Q = \frac{5}{2}(P_BV_B - P_AV_A) + \frac{3}{2}(P_CV_C - P_BV_B)$

Putting values

$\Delta Q = 587.5 \text{ J} \approx 588\text{J}$

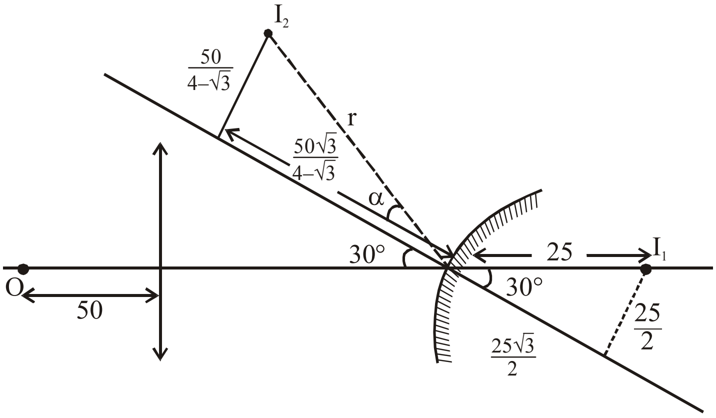
6. A small object is placed 50 cm to the left of thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle $\theta = 30°$ to the axis of the lens, as shown in the figure. If the origin of the coordinate system is taken to be at the centre of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are :



(A) $(25, 25\sqrt{3})$ (B) $\left(\frac{125}{3}, \frac{25}{\sqrt{3}}\right)$ (C) $(50 - 25\sqrt{3}, 25)$ (D) (0, 0)

Ans. (A)

Sol.



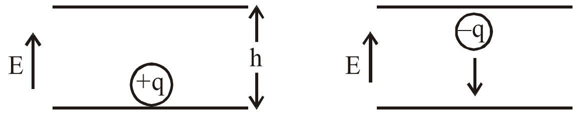
PHYSICS

18. The average current in the steady state registered by the ammeter in the circuit will be :

(A) Proportional to $V_0^{1/2}$ (B) Proportional to V_0^2

(C) Proportional to the potential V_0 (D) Zero

Ans. (B)

Sol. 

$$h = \frac{1}{2}at^2 \qquad [\text{as } u = 0]$$

$$\sqrt{\frac{2hm}{qE}} = \text{time} \Rightarrow \text{time} = \sqrt{\frac{2m}{q\Delta V}}$$

$$E = \frac{V_0}{h}$$

$$\text{<current>} = \frac{\text{charge}}{\text{time}} = \frac{q\sqrt{qV_0}}{\sqrt{2mh^2}}$$

$$q \propto V_0$$

$$< I > \propto V_0^2$$