Physics

TARGET : JEE 2013

SCORE

JEE (Advanced)

Home Assignment # 03

ALLEN CAREER INSTITUTE
KOTA (RAJASTHAN)
Path to Success

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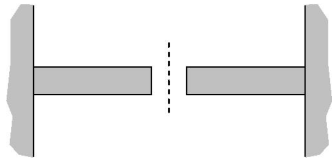
HEAT & THERMODYNAMICS

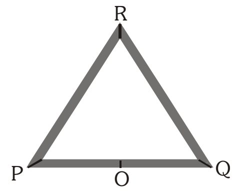
EXERCISE # (O)

1. The figure shows two thin rods, one made of aluminum [$\alpha = 23 \times 10^{-6}$ $(C°)^{-1}$] and the other of steel [$\alpha = 12 \times 10^{-6}$ $(C°)^{-1}$]. Each rod has the same length and the same initial temperature. They are attached at one end to two separate immovable walls. Temperature of both the rods is increased by the same amount, until the gap between the rods vanishes. Where do the rods meet when the gap vanishes?



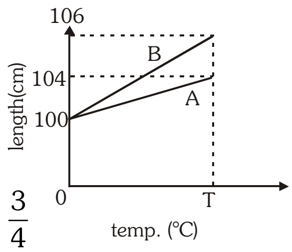
(A) The rods meet exactly at the midpoint.
(B) The rods meet to the right of the midpoint .
(C) The rods meet to the left of the midpoint.
(D) Information insufficient

2. Three rods of equal length ℓ are joined to form an equilateral triangle PQR. O is the mid point of PQ. Distance OR remains same for small change in temperature. Coefficient of linear expansion for PR and RQ is same, i.e., α_2 but that for PQ is α_1. Then–



(A) $\alpha_2 = 3\alpha_1$ (B) $\alpha_2 = 4\alpha_1$ (C) $\alpha_1 = 3\alpha_2$ (D) $\alpha_1 = 4\alpha_2$

3. The variation of lengths of two metal rods A and B with change in temperature are shown in figure. The ratio of $\frac{\alpha_A}{\alpha_B}$ is



(A) $\frac{3}{2}$ (B) $\frac{2}{3}$ (C) $\frac{4}{3}$ (D) $\frac{3}{4}$

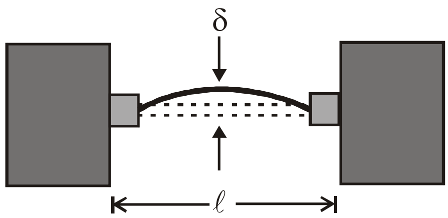
4. A long, thin metal bar of length ℓ is clamped rigidly at its ends at temperature t_0. When the temperature t is increased, the expanding bar will bow out, as shown below. If the bowing in not too large, a fair first approximation to the shape of the bar is two equal straight segments in the form of a wide V. What is the arch δ of the bow as a function of t? (This is the distance between the corner of the V and the straight line that represents the form of the bar at t_0.)

(A) $\delta = (\ell/2)\sqrt{2\alpha(t-t_0)}$

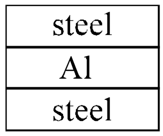
(B) $\delta = (\ell)\sqrt{\alpha(t-t_0)}$

(C) $\delta = (\ell/2)\sqrt{\alpha(t-t_0)}$

(D) $\delta = (\ell)\sqrt{2\alpha(t-t_0)}$

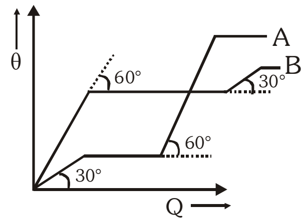


5. Arrangement of three metallic rods riveted to each other is as shown in figure. α_{Al} is the coefficient of linear expansion for aluminium and α_S (when $\alpha_{Al} > \alpha_S$) for steel. The arrangement is heated, then



(A) Tensile stress is developed in the aluminium rod.
(B) Compressive stress is developed in the aluminium rod
(C) No stress is developed in the aluminium rod
(D) Data is incomplete

6. The temperature (θ) versus heat transfer (Q) plot for two substances A and B is given in the figure. If some quantity of substance A in liquid phase at temperature 30°C is mixed with substance B in liquid phase at 20°C then the temperature of the mixture will be (Given that boiling points for substance A and B is more than 30°C)



(A) 22.5°C (B) 27.5°C (C) 25°C (D) 20°C

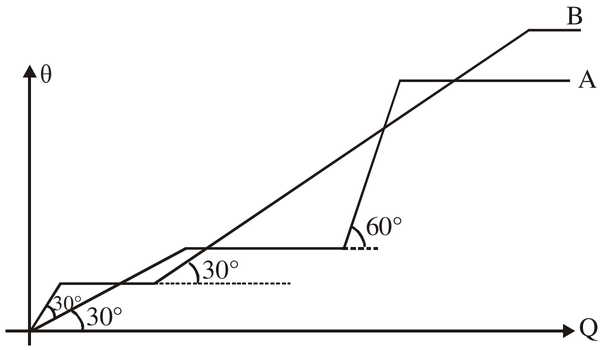
7. A certain amount of ice is given heat at constant rate x cal/s. The heat is supplied for 7 minute. For the first one minute temperature rises uniformly with time, and then it becomes constant for the next four minute and after that temperature again rises uniformly for last two minutes. [Latent heat of ice = 336×10^3 J/kg and specific heat of water = 4200 J/kg – K

(A) temperature at the end of 3 min. is 30°C (B) Temperature at the end of 3 min. is 10°C
(C) temperature at the end of 7 min. is 40°C (D) temperature at the end of 7 min. is 100°C

8. Work done in converting one gram of ice at -10°C into steam at 100°C is (1 cal = 4.2 J) (Specific heat of ice = 0.5 cal/g°C, specific heat of water = 1 cal/g^{0}C, Latent heat of fusion = 80 ca/g; Latent heat of vaporisation = 540 cal/g)

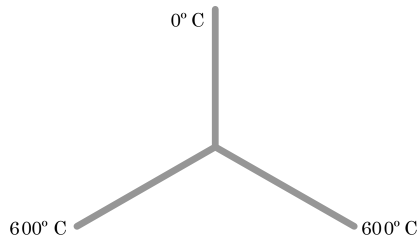
(A) 3045 J (B) 6056 J (C) 721 J (D) 616 J

9. The temperature (θ) versus heat transfer (Q) plot for two substances A and B is given in the figure. If some quantity of substance A in liquid phase at temperature 30°C is mixed with substance B at 20°C then the temperature of the mixture will be. (Given that boiling point for substance A is more than 30°C and freezing point less than 20°C).



(A) 22.5°C (B) 27.5°C (C) 25°C (D) 20°C

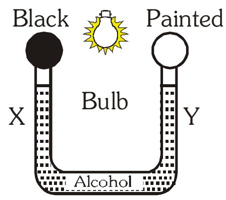
10. Three identical rods made of the same material have been joined as shown in the figure. The free ends of the rods are maintained at temperatures 0º C, 600º C and 600º C as shown in the figure. The temperature at the junction of the three rods is



(A) 200º C (B) 300º C

(C) 400º C (D) 500º C

11. The following figure shows two air-filled bulbs connected by a U-tube partly filled with alcohol. What happens to the levels of alcohol in the limbs X and Y when an electric bulb placed midway between the bulbs is lighted-



(A) The level of alcohol in limb X falls while that in limb Y rises

(B) The level of alcohol in limb X rises while that in limb Y falls

(C) The level of alcohol falls in both limbs

(D) There is no change in the levels of alcohol in the two limbs

12. A copper sphere is suspended in an evacuated chamber maintained at 300 K. The sphere is mantained at a constant temperature of 500 K by heating it electrically. A total of 300 W of electric power is needed to do it. When **half** of the surface of the copper sphere is completely blackened, 600W is needed to maintain the same temperature of the sphere. Calculate the emissivity of copper.

(A) $e = \frac{1}{3}$ (B) $e = \frac{2}{3}$ (C) $e = \frac{1}{2}$ (D) $e = \frac{1}{6}$

13. One mole of an ideal gas (whose adiabatic constant is γ) undergoes the process $P = \alpha T^{1/2}$, where α is constant then find the molar specific heat of the gas

(A) $\left(\frac{\gamma-1}{\gamma+1}\right)\frac{R}{2}$ (B) $\left(\frac{\gamma-1}{\gamma+1}\right)^2 R$ (C) $\left(\frac{\gamma+1}{\gamma-1}\right)\frac{R}{2}$ (D) $\left(\frac{\gamma+1}{\gamma}\right)R$

14. A copper rod of length ℓ_1 and an iron rod of length ℓ_2 are always maintained at the same common temperature T. If the difference $(\ell_2 - \ell_1)$ is 15 cm and is independent of the value of T, the ℓ_1 and ℓ_2 have the values (given the linear coefficient of expansion for copper and iron are $2.0 \times 10^{-6}\,C^{-1}$ and $1.0 \times 10^{-6}\,C^{-1}$ respectively) :-

(A) ℓ_1 = 15 cm, ℓ_2 = 30 cm (B) ℓ_1 = 30 cm, ℓ_2 = 15 cm

(C) ℓ_1 = 10 cm, ℓ_2 = 25 cm (D) ℓ_1 = 25 cm, ℓ_2 = 10 cm

15. The total kinetic energy of translatory motion of all the molecules of 5 litres of nitrogen exerting a pressure P is 3000 J.

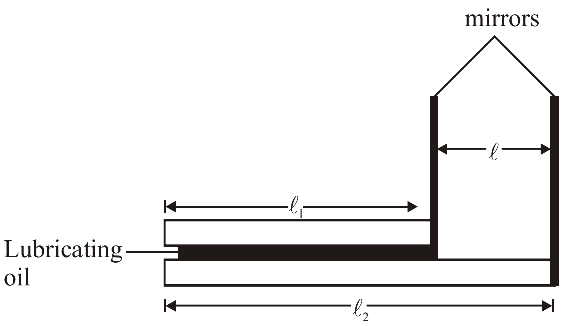
(A) The total K.E. of 10 litres of N_2 at a pressure of 2P is 3000 J

(B) The total K.E. of 10 litres of He at a pressure of 2P is 3000 J

(C) The total K.E. of 10 litres of O_2 at a pressure of 2P is 20000 J

(D) The total K.E. of 10 litres of Ne at a pressure of 2P is 12000 J

16. An optical engineering firm needs to ensure that the separation between two mirrors is unaffected by temperature changes. The mirrors are attached to the ends of two bars of different materials that are welded together at one end as shown in figure. The surfaces of the bars in contact are lubricated. The distance ℓ does not change with temperature change. ℓ_1 and ℓ_2 are the length of the bars α_1 and α_2 are the respective thermal coefficients of temperature. Which of the following options is/are correct :



(A) $\ell_1 = \dfrac{\ell\alpha_2}{\alpha_1 - \alpha_2}$ (B) $\ell_2 = \dfrac{\ell\alpha_1}{\alpha_2 - \alpha_1}$ (C) $\alpha_1\ell_1 = \alpha_2\ell_2$ (D) $\alpha_1\ell_2 = \alpha_2\ell_1$

17. Four rods A, B, C, D of same length and material but of different radii r, $r\sqrt{2}$, $r\sqrt{3}$ and 2r respectively are held between two rigid walls. The temperature of all rods is increased by same amount. If the rods do not bend, then

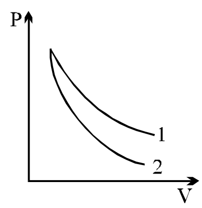
(A) the stress in the rods are in the ratio 1 : 2 : 3 : 4.

(B) the force on the rods exerted by the wall are in the ratio 1 : 2 : 3 : 4.

(C) the energy stored in the rods due to elasticity are in the ratio 1 : 2 : 3 : 4.

(D) the strains produced in the rods are in the ratio 1 : 2 : 3 : 4.

18. P-V plots for two gases during adiabatic processes are shown in the figure. Plots 1 and 2 should correspond respectively to



(A) He and O_2

(B) O_2 and He

(C) He and Ar

(D) O_2 and N_2

19. A container holds 10^{26} molecules/m^3, each of mass 3×10^{-27} kg. Assume that 1/6 of the molecules move with velocity 2000 m/s directly towards one wall of the container while the remaining 5/6 of the molecules move either away from the wall or in perpendicular direction, and all collisions of the molecules with the wall are elastic

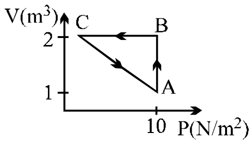
(A) Number of molecules hitting 1 m^2 of the wall every second is 3.33×10^{28}.

(B) Number of molecules hitting 1 m^2 of the wall every second is 2×10^{29}.

(C) Pressure exerted on the wall by molecules is 24×10^5Pa.

(D) Pressure exerted on the wall by molecules is 4×10^5Pa.

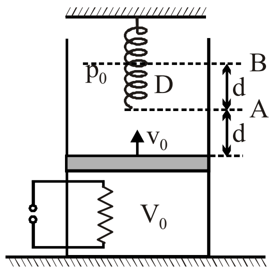
20. An ideal gas is taken through the cycle A → B → C → A, as shown in the figure. If the net heat supplied to the gas in the cycle is 5J, the work done by the gas in the process C → A is **[JEE(Scr)2002]**



(A) –5J (B) –10 J (C) –15 J (D) –20 J

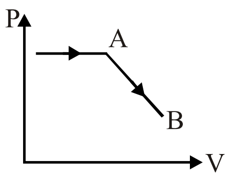
Paragraph for question nos. 21 to 23

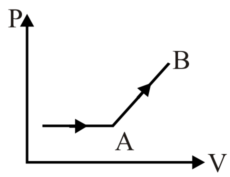
A mass less piston, which can move without friction, closes a sample of Helium in a vertical, thermally insulated cylinder, which is closed at its bottom, and the cross-section of which is $A = 2\ dm^2$. Above the piston there is a fixed stand to which an unstretched spring of spring constant 2000 N/m is attached, whose bottom end is at a distance of 2dm from the piston when the volume of the gas is $V_0 = 8dm^3$. The external pressure is $p_0 = 10^5$ Pa, $g = 10\ m/s^2$. The gas confined in the cylinder is heated with an electric heating element. ($1dm = 10^{-1}$ m)

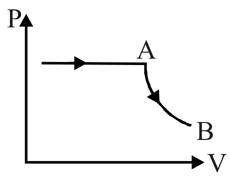


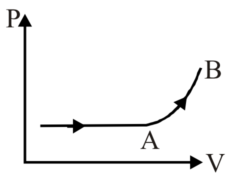
21. How much heat is supplied by the element till it reaches the spring :
(A) zero (B) 600 J (C) 8000 J (D) 1000 J

22. How will process look like on a PV diagram

(A) 

(B) 

(C) 

(D) 

23. What is the ratio of work done by gas in moving the piston from initial position to A, and from there to B

(A) $\frac{10}{11}$ (B) $\frac{11}{10}$ (C) $\frac{5}{3}$ (D) $\frac{3}{5}$

Paragraph for Question No. 24 to 26

You are program director in ISRO (Indian Space Research Organisation) to conduct a feasibility study into the SDI (Strategic Defence Initiative) missile defence system. You are to consider the viability of a ground based laser defence against ICBM's, which will use powerful CO_2 lasers to bore holes in the incoming missiles, thus destroying them. The lasers have an output power of 50W in a beam diameter of 1 mm. The laser beam is fired at the missile when it is 10 km away and the beam loses 3% of its intensity for every kilometre travelled. The outer skin of the missile is aluminium that is 3 cm thick. When the laser fires the skin temperatures of the missile is – 50°C and must be heated to its boiling point at 2500°C. The density of aluminium is 2.4 g/cm^3 and heat capacity is 0.9 J/g°C.

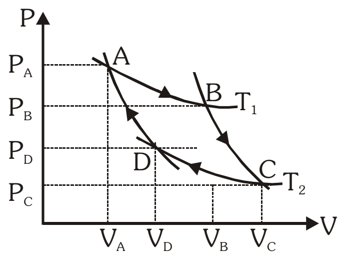
24. The amount of heat required to reach the outer skin of aluminium to its boiling point is
(A) 129.7 J (B) 140.7 J (C) 196.4 J (D) 554.7 J

25. The power of laser beam when it strikes missile surface is (Take $(0.97)^{10} = 0.738$)
(A) 50W (B) 24.8 W (C) 36.9 W (D) None of these

26. How long will it take the laser to burn through the outer skin of the missile, thus destroying it? Assume that all of the laser power that reaches the missile goes into heating the 1 mm diameter spot.
(A) 3.5 s (B) 3.2 s (C) 2.4 s (D) 7.1 s

Paragraph for Question No. 27 to 29

In the following P-V diagram, two adiabatics cut two isothermals at T_1 and T_2 . 2 moles of an ideal diatomic gas is taken through the cyclic process ABCDA.



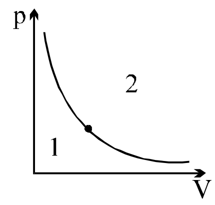
27. In which process heat is absorbed by the gas.
(A) DA (B) BC (C) AB (D) CD

28. The volumes at different points A,B,C & D are satisfy the following relation
(A) $V_AV_B = V_CV_D$ (B) $V_AV_C = V_BV_D$ (C) $V_AV_D = V_BV_C$ (D) $V_AV_C^2 = V_BV_D^2$

29. If Q_1 is heat absorbed and Q_2 is heat rejected in one cycle then-
(A) $Q_1T_1 = Q_2T_2$ (B) $Q_1T_1^2 = Q_2T_2^2$ (C) $Q_1T_2^2 = Q_2T_1^2$ (D) $Q_1T_2 = Q_2T_1$

Paragraph for Question No. 30 & 31

The dot in figure represents the initial state of a gas. An adiabatic divides the p-V diagram into regions 1 and 2 as shown.



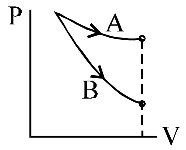
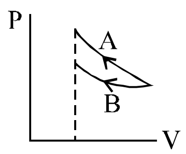
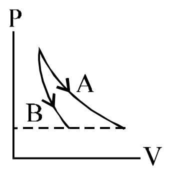
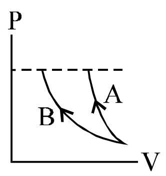
30. For which of the following processes, the corresponding heat supplied to the system Q is positive

(A) the gas moves up along the adiabatic,
(B) it moves down along the adiabatic,
(C) it moves to anywhere in region 1,
(D) it moves to anywhere in region 2.

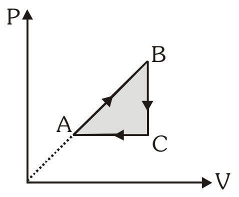
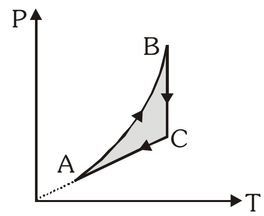
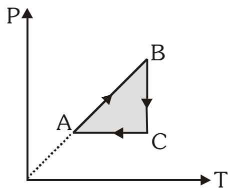
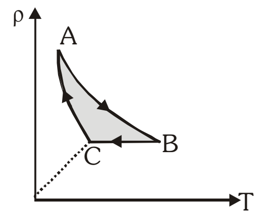
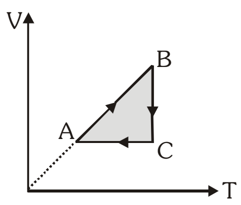
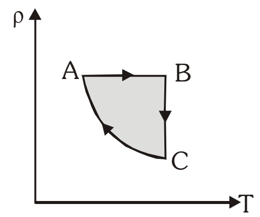
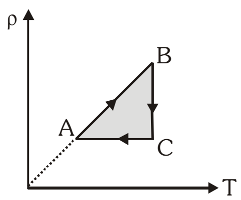
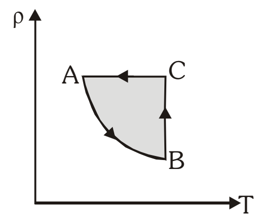
31. As the gas moves down along the adiabatic, the temperature

(A) increases
(B) decreases
(C) remains constant
(D) variation depends on type of gas

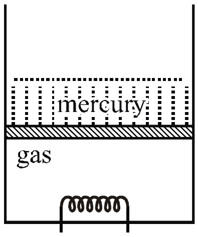
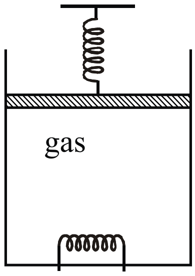
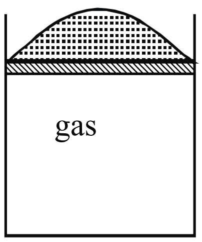
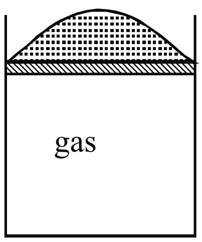
32. An ideal gas undergoes two processes A and B. One of these is isothermal and the other is adiabatic.

Column-I	**Column-II**
(A) 	(P) Heat supplied during curve A is positive
(B) 	(Q) Work done by gas in both processes positive
(C) 	(R) Internal energy increases in adiabatic process
(D) 	(S) Temperature of gas in process B is constant

33. Match the graph for an ideal monoatomic gas in different process for constant mass of gas (ρ = density of gas)

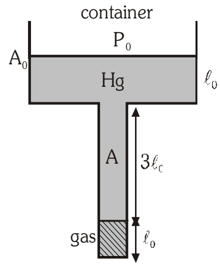
Column I	**Column II**
(A) 	(P) 
(B) 	(Q) 
(C) 	(R) 
(D) 	(S) 

34. Column I shows certain thermodynamic systems and column II represents thermodynamic properties.

Column I		Column II
(A) An ideal gas is filled in a thermally insulated cylindrical vessel of height h which is enclosed by a massless thermally insulating piston. Mercury is filled above the piston as shown. Now gas is slowly supplied heat. Mercury does not spill.		(P) Internal energy of the gas is increasing.
(B) A thermally insulated cylindrical vessel is enclosed by a light piston. The piston is connected to ceiling by an ideal spring as shown in figure. Spring is initially relaxed and then heat is supplied slowly to the ideal gas in the vessel. The system is kept in open atmosphere.		(Q) Pressure of the gas is increasing.
(C) A thermally insulated cylindrical vessel is enclosed by a light thermally insulated piston. Some sand is kept on top of piston as shown in figure. The system is kept in open atmosphere. Now sand grains are removed slowly one by one.		(R) Temperature of the gas is decreasing.
(D) A good conducting cylindrical vessel is enclosed by a light thermally insulated piston. Some sand is kept on top of piston as shown in figure. The system is kept in open atmosphere. Now sand grains are added slowly one by one.		(S) Work done by gas is positive. (T) The process is neither isobaric, isochoric, isothermic or adiabatic.

EXERCISE # (S)

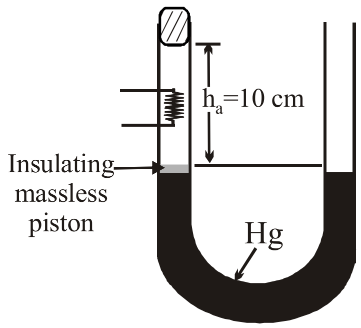
1. A container having base area A_0. Contains mercury upto a height ℓ_0. At its bottom a thin tube of length $4\ell_0$ and cross-section area A (A<<A_0) having lower end closed is attached. Initially the length of mercury in tube is $3\ell_0$. In remaining part 2 mole of a gas at temperature T is closed as shown in figure. Determine the work done (in joule) by gas if all mercury is displaced from tube by heating slowly the gas in the rear end of the tube by means of a heater. (Given : density of mercury = ρ, atmospheric pressure $P_0 = 2\ell_0\rho g$, C_V of gas = 3/2 R, A= (3/ρ)m^2, ℓ_0 = (1/9) m, all units in S.I.)



2. One mole of a monoatomic gas is enclosed in a cylinder and occupies a volume of 4 liter at a pressure 100 N/m^2. It is subjected to a process $T = \alpha V^2$, where α is a positive constant, V is volume of the gas and T is Kelvin temperature. Find the work-done by gas (in joule) in increasing the volume of gas to six times initial volume.

3. A liquid of volumetric thermal expansion coefficient 200×10^{-6} /°C and bulk modulus = 1.2×10^9 Pa is filled in a spherical tank of negligible heat expansion coefficient. Its radius is 25 cm and wall thickness is 2 mm. When the temperature of the liquid is raised by 20 °C, find the tensile stress developed (in MPa) in the wall of the tank?

4. A U tube, made of heat-insulating material, is shown in figure. One limb is closed by a non-conducting cork, the temperature is T_0 = 300 K. a × 10^2 J heat is required to be given by the coil so that the air rises to a temperature T = 510 K. The thermal expansion of mercury is negligible. Then the value of 'a' (choose nearest integer value of 'a'). Neglect the heat flow through the mercury. [Take : Area of the tube as 0.1 m^2, P_{atm} = 75 cm of Hg,



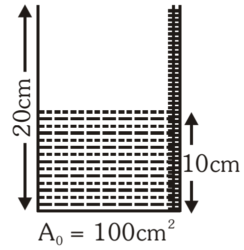
$R = \frac{25}{3}$ and density of mercury $\rho_{Hg} = 13.6 \times 10^3$ kg/m^3].

5. One mole of an ideal gas with heat capacity at constant pressure C_p undergoes the process $T = T_0 + \alpha V$, where T_0 and α are constants. Find:
(a) heat capacity of the gas as a function of its volume;
(b) the amount of heat transferred to the gas, if its volume increased from V_1 to V_2.

6. An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat S of the container varies with absolute temperature T according the empirical relations = A + BT, where A = 100 cal/kg-K and B = 2×10^{-2} cal/kg-K^2. If the final temperature of the container is 27°C, determine the mass of the container. (Latent heat of fusion for water = 8×10^4 cal/kg. Specific heat of water = 10^3 cal/kg-K)

7. A 5m long cylindrical steel wire of radius 2×10^{-3} m is suspended vertically from a rigid support and carries a bob of mass 100 kg at the other end. If the bob gets snapped, calculate the change in temperature of the wire ignoring radiation losses.)For the steel wire: Young's modulus = 2.1×10^{11} Pa; Density = 7860 kg/m^3; Specific heat = 420 J/kg-K)

8. At 20°C a liquid is filled upto 10 cm height in a container of glass of length 20 cm and cross– sectional area 100 cm^2 .Scale is marked on the surface of container. This scale gives correct reading at 20°C. Find the volume of liquid (in cc), actual height of liquid (in cm) and reading of scale (in cm) at 40°C (Given $\gamma_L = 5 \times 10^{-5}$ K^{-1}, $\alpha_g = 1 \times 10^{-5}$ °C^{-1}.)

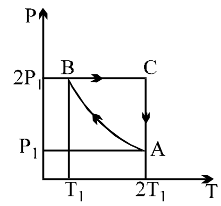


9. Two moles of an ideal monatomic gas is taken through a cycle ABCA as shown in the P-T diagram. During the process AB, pressure and temperature of the gas vary such that PT = constant. If T_1 = 300 K, calculate:

(a) the work done on the gas in the process AB and

(b) the heat absorbed or released by the gas in each of the processes.

Give answers in terms of the gas constant R.



10. A monoatomic ideal gas of two moles is taken through a cyclic process starting from A as shown in the figure. The volume ratio are $\frac{V_B}{V_A}=2$ and $\frac{V_D}{V_A}=4$. If the temperature T_A at A is 27°C.

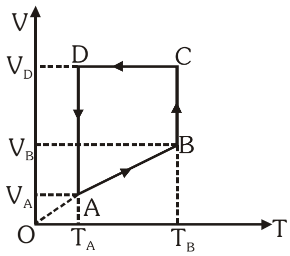
Calculate :

(i) The temperature of the gas at point B.

(ii) Heat absorbed or released by the gas in each process.

(iii) The total work done by the gas during the complete cycle.

Express your answer in terms of the gas constant R.



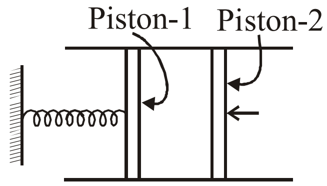
11. A cubical box of side 1 meter contains helium gas (atomic weight 4) at a pressure of 100 N/m^2. During an observation time of 1 second, an atom travelling with the root mean square speed parallel to one of the edges of the cube, was found to make 500 hits with a particular wall, without any collision with other atoms. Take R = $25/3$ J/mol-K and k = 1.38×10^{-23} J/K. **[JEE'2002]**

(a) Evaluate the temperature of the gas ;

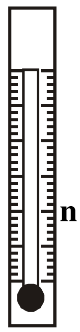
(b) Evaluate the average kinetic energy per atom

(c) Evaluate the total mass of helium gas in the box.

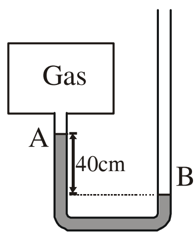
12. A long container has air enclosed inside at room temperature and atmospheric pressure (10^5 pa). It has a volume of 20,000 cc. The area of cross section is 100 cm^2 and force constant of spring is k_{spring} = 1000N/m. We push the right piston isothermally and slowly till it reaches the original position of the left piston which is movable. What is the final length of air column in cm. Assume that spring is initially relaxed.



13. A thermometer has a spherical bulb of volume 1 cm^3 having 1 cm^3 of mercury. A long cylindrical capillary tube is connected to spherical bulb. Volumetric coefficient of expansion of mercury is $1.8 \times 10^{-4}\ K^{-1}$; cross-section area of capillary is $1.8 \times 10^{-4}\ cm^2$. Ignoring expansion of glass, how far apart (in cm) on the stem are marks indicating 1K temperature change.



14. Figure shows an ideal gas. Its pressure, volume & temperature are P_0, V_0 & T_0 respectively. Thin U-tube contains mercury. It was observed that there was a difference of 40 cm in the level of mercury column in two limbs. Now the gas is heated to temperature 1.5 T_0 and simultaneously mercury was added in limb B to maintain the level of mercury in limb A at its original position. Find the new difference in the level of mercury in limb A & B (in cm). [Take : P_{atm} = 76 cm of Hg]

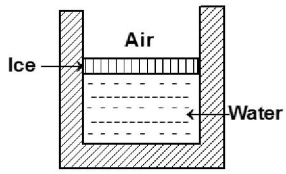


15. A metal block is placed in a room which is at 10°C for long time. Now it is heated by an electric heater of power 500 W till its temperature becomes 50°C. Its initial rate of rise of temperature is 2.5°C/sec. The heater is switched off and now a heater of 100W is required to maintain the temperature of the block at 50°C. The heat radiated per second when the block was 30°C is given as α watt. Find the value of $\left(\frac{\alpha}{10}\right)$. (Assume Newtons Law of cooling to be valid)

16. Find the efficiency of a cycle consisting of two isochoric and two adiabatic line, if the volume of the ideal gas changes n = 10 times within the cycle. The working substance is nitrogen.

17. A rod of negligible heat capacity has length 40 cm, area of cross-section 1.0 cm^2 and thermal conductivity 100 W/m-°C. The temperature of one end is maintained at 0°C and that of the other end is slowly and linearly varied from 0°C to 60°C in 10 minutes. Assuming no loss of heat through the sides, find the total heat transmitted through the rod in these 10 minutes (in J).

18. A tank of water is placed in the open in cold weather until a 5.0 cm thick slab of ice forms on its surface. The air above the ice is at -10^0C. Calculate the rate of formation of ice in centimeters per hour on the bottom surface of the slab. Take thermal conductivity, density and heat of fusion of ice to be 0.0040 cal/cm^{0}C, 0.92 g/cc and 80 cal/g respectively. Assume that no heat enters or leaves the water through the walls of the tank.



19. A small sphere (emissivity = 0.9, radius = r_1) is located at the centre of a spherical asbestos shell (thickness = 5.0 cm, outer radius = r_2). The thickness of the shell is small compared to the inner and outer radii of the shell. The temperature of the small sphere is 800 K, while the temperature of the inner surface of the shell is 600 K. The temperature of small sphere is maintained constant. Assuming that $\frac{r_2}{r_1} = 10.0$ and ignoring any air inside the shell, find the temperature (in K) of the outer surface of the shell. Take : $K_{asbestos}$ = 0.085W/m°C, $\sigma = \frac{17}{3} \times 10^{-8} W/m^2k^4$

ANSWER KEY

EXERCISE # (O)

1. Ans. (C) **2. Ans. (D)** **3. Ans. (B)** **4. Ans. (A)** **5. Ans. (B)**

6. Ans. (A) **7. Ans. (C)** **8. Ans. (A)** **9. Ans. (A)** **10. Ans. (C)**

11. Ans. (A) **12. Ans. (A)** **13. Ans. (C)** **14. Ans. (A)** **15. Ans. (C, D)**

16. Ans. (A, C) **17. Ans. B, C** **18. Ans. (B)** **19. Ans. (A, D)**

20. Ans. (A) **21. Ans. (D)** **22. Ans. (B)** **23. Ans. (A)**

24. Ans. (A) **25. Ans. (C)** **26. Ans. (A)** **27. Ans. (C)**

28. Ans. (B) **29.Ans. (D)** **30. Ans. (D)** **31. Ans. (B)**

32. Ans. (A) → (P,Q) ; (B) → (R,S) ; (C) → (P,Q) ; (D) → (R,S)

33. Ans. (A) → (Q); (B) → (R); (C) → (S); (D) → (P)

34. Ans. (A) → (P,S) ; (B) → (P,Q,S,T) ; (C) → (R,S) ; (D) → (Q)

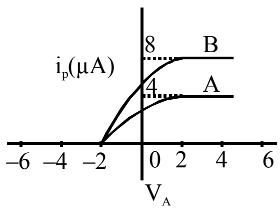
EXERCISE # (S)

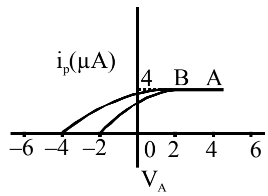
1. **Ans. 5**
2. **Ans. 7**
3. **Ans. 300**
4. **Ans. 023**
5. **Ans:** (a) $C = C_p + RT_0/\alpha V$; (b) $Q = \alpha C_p(V_2-V_1) + RT_0\, ln(V_2/V_1)$
6. **Ans.** 0.5 kg
7. **Ans.** 0.00457°C
8. **Ans. 1001 cc,** 10.006 cm, 10.004 cm
9. **Ans** (a) 1200 R, (b) Q_{AB} = – 2100 R, Q_{BC} = 1500 R, Q_{CA} = 1200 Rln2
10. **Ans** (a) 600 K (b) 1500 R, 1200 Rln2, – 900R, – 1200 Rln2 (c) 600 R
11. **Ans.** 160 K, 3.3×10^{-21} J, 0.3 gm
12. **Ans. 0100**
13. **Ans. 1**
14. **Ans. 22**
15. **Ans. 5**
16. **Ans: 60%**
17. **Ans. 450**
18. **Ans: 0.39cm/h**
19. **Ans. 0516**

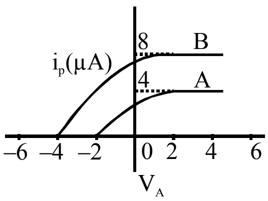
MODERN PHYSICS

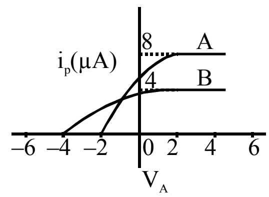
EXERCISE # (O)

1. In a photoelectric effect experiment, photons of energy 5 eV are incident on the photo-cathode of work function 3 eV. For photon intensity $I_A = 10^{15}\ m^{-2}s^{-1}$, saturation current of 4.0 μA is obtained. Sketch the variation of photocurrent i_p against the anode voltage V_a for photon intensity I_A (curve A) and $I_B = 2 \times 10^{15}\ m^{-2}\ s^{-1}$ (curve B) will be:

(A) 

(B) 

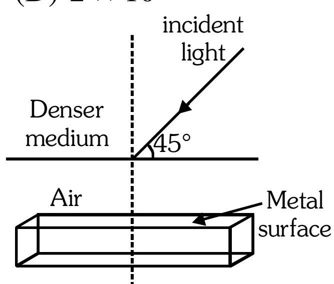
(C) 

(D) 

2. A beam of light has two wavelengths 3100 Å and 4133 Å with a total intensity of 12.8 W/m^2 equally distributed between the two wavelengths. The beam falls normally on an area of a clean metallic surface of work function 3.1 eV. Assume that there is no loss of energy by reflection and that each energetically capable photon ejects one electron. How many electrons will emit per second from the face area ?

(A) 2×10^{19} (B) 10^{19} (C) 10^{18} (D) 2×10^{18}

3. Light comprising three wavelength 310, 455, 620 nm is incident on a surface separating two media at an angle of 45° and given refractive index for 455 nm light is √2. If a metal plate of work function 1.2 eV is placed in this medium then maximum kinetic energy of the electron emitted from metallic plate is



(A) 0.8 eV (B) 2.8 eV
(C) 1.8 eV (D) 1.5 eV

4. In a photoelectric experiment, the collector plate is at 2.0V with respect to the emitter plate made of copper φ = 4.5eV). The emitter is illuminated by a source of monochromatic light of wavelength 200nm.

(A) the minimum kinetic energy of the photoelectrons reaching the collector is 0.
(B) the maximum kinetic energy of the photoelectrons reaching the collector is 3.7eV.
(C) if the polarity of the battery is reversed then answer to part A will be 0.
(D) if the polarity of the battery is reversed then answer to part B will be 1.7eV.

5. The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect

(A) n = 3 to 1 (B) n = 3 to 2

(C) n = 2 to 1 (D) n = 4 to 1

6. Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to

(A) 9/(5R) (B) 36/(5R) (C) 18/(5R) (D) 4/R [JEE' 2000 (Scr)]

7. According to Bohr model, magnetic field at the centre (at the nucleus) of a hydrogen atom due to the motion of the electron in n^{th} orbit is proportional to

(A) $1/n^3$ (B) $1/n^5$ (C) n^5 (D) n^3

8. Two hydrogen atoms are in excited state with electrons residing in n = 2. First one is moving towards left and emits a photon of energy E_1 towards right. Second one is moving towards left with same speed and emits a photon of energy E_2 towards left. Taking recoil of nucleus into account during emission process

(A) $E_1 > E_2$ (B) $E_1 < E_2$ (C) $E_1 = E_2$ (D) information insufficient

9. Frequency of the K_α X–ray for the element calcium (Ca, Z = 20) is 8.95×10^{17} Hz. Frequency of K_α X–ray for element cadmium (Cd, Z = 48) will be

(A) 5.46×10^{18} Hz (B) 6.31×10^{18} Hz (C) 5.71×10^{17} Hz (D) 6.31×10^{17} Hz

10. The K shell ionization energies for cobalt, copper and molybdenum are 7.8, 9.0 and 20.1 keV respectively. If an X–ray tube operates at 15 kV with any of the above metals as targets, then

(A) characteristics X–rays of K series will be emitted only from cobalt

(B) characteristic X–rays of K series will be emitted only from copper and cobalt

(C) characteristic X–rays of K series will be emitted only from cobalt, copper and molybdenum

(D) the shortest wavelength of continuous X–rays emitted is the same for the three metals

11. In a Coolidge tube experiment, the minimum wavelength of the continuous X-ray spectrum is equal to 66.3 pm, then

(A) electrons accelerate through a potential difference of 12.75 kV in the Coolidge tube

(B) electrons accelerate through a potential difference of 18.75 kV in the Coolidge tube

(C) de-Broglie wavelength of the electrons reaching the anticathode is of the order of 10μm.

(D) de-Broglie wavelength of the electrons reaching the anticathode is 0.01Å.

12. The energy, the magnitude of linear momentum and orbital radius of an electron in a hydrogen atom corresponding to the quantum number n are E, p and r respectively. Then according to Bohr's theory of hydrogen atom

(A) Epr is proportional to $\frac{1}{n}$ (B) $\frac{p}{E}$ is proportional to n

(C) Er is constant for all orbits (D) pr is proportional to n

13. A particular hydrogen like atom has its ground state binding "energy 122.4eV. Its is in ground state. Then:

(A) Its atomic number is 3

(B) An electron of 90eV can excite it.

(C) An electron of kinetic energy nearly 91.8eV can be brought to almost rest by this atom.

(D) An electron of kinetic energy 2.6eV may emerge from the atom when electron of kinetic energy 125eV collides with this atom.

14. Consider the following nuclear reactions and select the correct statements from the options that follow.

Reaction I : $n \rightarrow p + e^- + \bar{\nu}$ **Reaction II :** $p \rightarrow n + e^+ + \nu$

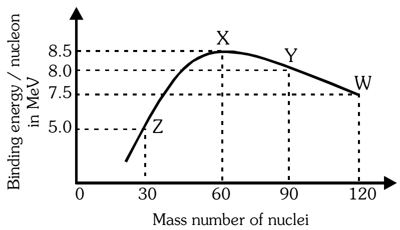
(A) Free neutron has higher mass than proton, therefore reaction I is possible

(B) Free proton has less mass than neutron, therefore reaction II is not possible

(C) Inside a nucleus, both decays (reaction I and II) are possible

(D) Inside a nucleus, reaction I is not possible but reaction II is possible.

15. Binding energy per nucleon versus mass number curve for nuclei is shown in figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is

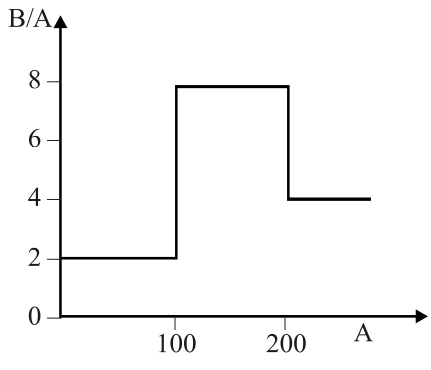


(A) $X \rightarrow 2Z$ (B) $W \rightarrow Y + Z$

(C) $W \rightarrow 2X$ (D) $Y \rightarrow X + Z$

16. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below : [JEE 2008]

Figure :



(A) Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy

(B) Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy

(C) Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments

(D) Fission of a nucleus lying in the mass range of $200 < A < 260$ will release energy when broken into two equal fragments

17. Select the fusion reaction

(i) $_7N^{14} + {}_1H^1 \rightarrow {}_8O^{15}$ + 7.3 MeV

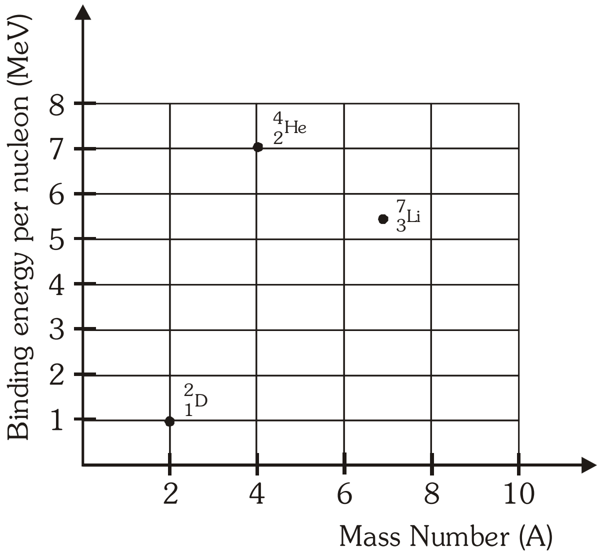
(ii) $_{92}U^{235} + {}_0n^1 \rightarrow X_e^{190} + {}_{38}S_1^{34} + {}_0n^1 + r + 200$ MeV

(iii) $_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} + 2$MeV

(iv) $_6C^{13} + {}_1N^1 \rightarrow {}_6C^{17} + 4.3$ MeV

(A) (iii), (iv) (B) (i), (ii) (C) (i), (iii) (D) (ii), (iv)

18. The positions of $_1^2D, {}_2^4He$ and $_3^7Li$ are shown on the binding energy curve as shown in figure.



The energy released in the fusion reaction. $_1^2D + {}_3^7Li \rightarrow 2\,{}_2^4He + {}_0^1n$

(A) 20 MeV (B) 16 MeV (C) 8 MeV (D) 1.6 MeV

19. The binding energy per nucleon for C^{12} is 7.68 MeV and that for C^{13} is 7.5 MeV. The energy required to remove a neutron from C^{13} is

(A) 5.34 MeV (B) 5.5 MeV (C) 9.5 MeV (D) 9.34 MeV

20. Match the entries of column–I with the entries of column–II :-

	Column-I		**Column-II**
(I)	Mass defect	(P)	Participating nuclei are small
(II)	Nuclear fission	(Q)	Participating nuclei are large
(III)	Nuclear fusion	(R)	$E = \Delta mc^2$

Then choose the correct matching.

(A) (i) →(R) ; (ii) →(QR) ; (iii) →(PR) (B) (i) →(R) ; (ii) →(PR) ; (iii) →(QR)

(C) (i) →(R) ; (ii) →(Q) ; (iii) →(P) (D) (i) →(R) ; (ii) →(P) ; (iii) →(Q)

21. Imagine a Young's double slit interference experiment performed with waves associated with fast moving electrons produced from an electron gun. The distance between successive maxima will decrease maximum if

(A) the accelerating voltage in the electron gun is decreased

(B) the accelerating voltage is increased and the distance of the screen from the slits is decreased

(C) the distance of the screen from the slits is increased.

(D) the distance between the slits is decreased.

22. Tritium ($_1^3H$), an isotope of hydrogen with a half life of 12.3 year, is produced in the upper atmosphere by cosmic rays and is intimately mixed with the hydrogen in air. In order to determine the age of a bottle of wine found in an ancient cave, the tritium in the wine is measured and found to be 6.9% of that found in new wine. How old is the wine in bottle?

(A) 59.20 years (B) 47.5 years (C) 37.5 years (D) 53.2 years

23. An unstable nucleus decays in three different modes, each mode having a different half life $T_1, T_2, T_3 (T_1 >> T_2 >> T_3)$. The overall half–life of a sample will be given by–

(A) $T \approx T_1$ (B) $T \approx T_3$ (C) $T \approx \frac{T_1 + T_2 + T_3}{3}$ (D) $T \approx T_2$

24. The half-life of substance X is 45 years, and it decomposes to substance Y. A sample from a meteorite was taken which contained 2% of X and 14% of Y by quantity of substance. If substance Y is not normally found on a meteorite, what is the approximate age of the meteorite?

(A) 270 years (B) 135 years (C) 90 years (D) 45 years

25. The decay constant of a radio active substance is 0.173 $(\text{years})^{-1}$. Therefore :

(A) Nearly 63% of the radioactive substance will decay in (1/0.173) year.

(B) half life of the radio active substance is (1/0.173) year.

(C) one -forth of the radioactive substance will be left after nearly 8 years.

(D) all the above statements are true.

26. A radioactive sample decays by β-emission. In first two seconds 'n' β-particles are emitted and in next 2 seconds, '0.25n' β-particles are emitted. The half life of radioactive nuclei is

(A) 2 sec (B) 4 sec (C) 1 sec (D) None of these

Paragraph for Question No. 27 & 28

Few atomic masses are given

$$^{238}_{92}U = 238.05079u,\ ^{4}_{2}He = 4.00260u,\ ^{234}_{90}Th = 234.04363u$$

$$^{1}_{1}H = 1.007834,\ ^{237}_{91}Pa = 237.065121u.$$

Answer the following questions on the basis of above data.

27. Calculate the energy released during the α–decay of $^{238}_{92}U$.

(A) Q = 4.25 MeV (B) Q = 8.5 MeV (C) Q = 3.25 MeV (D) None of these

28. Spontaneous emission of a proton from $^{238}_{92}U$ is

(A) possible (B) impossible (C) can't say (D) none of these

Paragraph for Question No. 29 to 31

One of the most amazing principle in modern physics is the Heisenberg uncertainty principle. According to it. It is not possible to make a simultaneous determination of the position and the momentum of a particle with unlimited precision. The same is applicable for energy and time coordinate of a particle.

$\Delta P.\Delta x = \frac{h}{2\pi} = \Delta E.\Delta t$. where : ΔP = uncertainty in momentum; Δx = uncertainty in position; Δt = uncertainty in time, ΔE = uncertainty in energy

[Given $\frac{h}{2\pi}$ = t = 1.05×10^{-34} J sec $\approx 6.60 \times 10^{-16}$ eV- s.

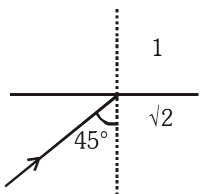
29. The minimum velocity of a billiard ball (m = 100 g) confined to a billiard table of dimension 1 m is :-

(A) 10^{-32} m/sec (B) 10^{-33} m/sec (C) 10^{-34} m/sec (D) 10^{-31} m/sec

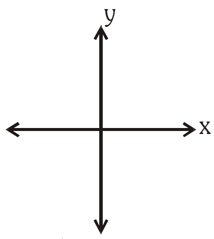
30. A particle has a rest energy of 750 MeV and life time of 4.4×10^{-24} sec. The fraction of energy uncertainty to rest energy is equal to :-

(A) zero (B) 150 (C) 0.20 (D) Infinite

31. Assuming laws of refraction to be strictly valid, a ray incident at 45° from a medium having refractive index of $\sqrt{2}$ to air (λ_{ray} = 5500 Å)



c > $\Delta x = \infty$



d> $\Delta y = \infty$

(A) $\Delta x = 0$ (B) $\Delta y = 0$ (C) $\Delta x = \infty$ (D) $\Delta y = \infty$

Paragraph for Question No. 32 to 34

Polonium (P_0^{210}) emits $_2\alpha^4$ particles and is converted into lead ($_{82}Pb^{206}$). This reaction is used for producing electric power in a space mission: P_0^{210} has half life of 138.6 days. (Given masses of the nuclei) P_0^{210} = 209.98264 amu, Pb^{206}= 205.97440, $_2\alpha^4$ = 4.00260 amu)

32. Assuming an efficiency of 10% of the thermoelectric machine, how much P_0^{210} is required to produce 1.2×10^7 J of electric energy per day at the end of 693 days?

(A) 1.0 gm (B) 2.0 gm (C) 3.0 gm (D) 0.5 gm

33. What is the initial amount of P_0^{210} ?

(A) 16 gm (B) 8 gm (C) 32 gm (D) 64 gm

34. Find the initial activity of the material.

(A) 4.57×10^{21} per day (B) 3.57×10^{21} per day

(C) 2.28×10^{21} per day (D) 1.785×10^{21} per day

Paragraph for Question Nos. 35 to 37

We have two radioactive nuclei A and B. Both convert into a stable nucleus C. Nucleus A converts into C after emitting two α-particles and three β-particles. Nucleus B converts into C after emitting one α-particle and five β-particles. At time t = 0, nuclei of A are $4N_0$ and that of B are N_0. Half-life of A (into the conversion of C) is 1 min and that of B is 2 min. Initially number of nuclei of C are zero.

35. If atomic numbers and mass numbers of A and B are Z_1, Z_2, A_1 and A_2 respectively. Then :-

(A) $Z_1 - Z_2 = 6$ (B) $A_1 - A_2 = 4$

(C) both (A) and (B) are correct (D) both (A) and (B) are wrong

36. What are number of nuclei of C, when number of nuclei of A and B are equal ?

(A) $2N_0$ (B) $3\ N_0$ (C) $\frac{9N_0}{2}$ (D) $\frac{5N_0}{2}$

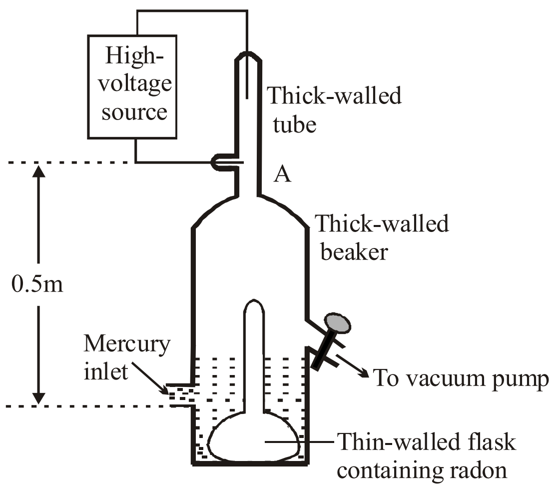
37. At what time, rate of disintegrations of A and B are equal ?

(A) 4 min (B) 6 min (C) 8 min (D) 2 min

Paragraph for Question No. 38 to 40

The Rutherford - Royds experiment : The following experiment dates from 1909. The apparatus is shown below. The thin - walled glass flask, containing radon (an α emitter), is placed inside the thick-walled glass apparatus. The apparatus is evacuated, and the valve to the vacuum pump is then closed. After a week, additional mercury is added to the apparatus until the liquid level reaches the bottom of the tube. A high-voltage discharge is then passed through the tube, and the light emitted is observed with a spectrometer. The flask emits α-particles when Radon decays according to equation

$$^{222}_{86}Rn \longrightarrow ^{218}_{84}Po + ^{4}_{2}He$$



with a half life of 3.5 days. The flask contained 222 mg of radioactive Radon. We can assume that half of the α-particles emitted accumulate in the empty space above mercury. The volume of tube is 1 litre. Take density of mercury as 13.6 gm/cc. Assume that α-particles can combine with 1 stray electron or 2 stay electrons to form Helium gas, or singly ionized Helium in ground state.

(Take : Atmospheric pressure 10^5 Pa, temperature = 27°C, R = 25/3 J/mol-K)

38. How many moles of Helium gas is present in the capillary tube?

(A) 0.75 mole (B) 0.68 moles (C) 0.5 mole (D) 0.375 mole

39. What is the pressure at point A?

(A) 0.32 atm (B) 9.375 atm (C) 3.25 atm (D) 18.75 atm

40. What should be the minimum voltage of the discharge to obtain spectra emitted by singly ionized Helium gas ?

(A) 10.2 V (B) 13.6 V (C) 40.8 V (D) 54.4 V

41. Column I shows possible inferences on events given in column II.

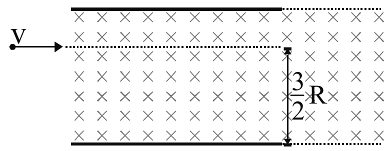
Column I	**Column II**
(A) Not possible	(P) Conversion of a free proton to a neutron.
(B) Possible	(Q) A neutron with kinetic energy 15 eV is incident on a stationary hydrogen atom in ground state such that excitation of H atom occurs.
(C) Release of energy	(R) Conversion of a neutron to proton outside nucleus.
(D) A chargeless particle carrying momentum is emitted.	(S) A nuclei emits electromagnetic radiation without emitting α or β particles.
	(T) A thermal particle causing fission of nucleus.

42. In each situation of column–I a physical quantity related to orbiting electron in a hydrogen like atom is given. The terms 'Z' and 'n' given in column–II have usual meaning in Bohr's theory. Match the quantities in column–I with the terms they depend on in column–II :-

Column-I	**Column-II**
(A) Frequency of orbiting electron	(P) Is directly proportional to Z^2
(B) Angular momentum of orbiting electron	(Q) Is directly proportional to n
(C) Magnetic moment of orbiting electron	(R) Is inversely proportional to n^3
(D) The average current due to orbiting of electron	(S) Is independent of Z
	(T) None of these

EXERCISE # (S)

1. Light from a discharge tube containing hydrogen atoms falls on a piece of sodium due to the transition of electron from 4th orbit to 2nd orbit. Work function of sodium is 1.83 eV. The fastest moving photoelectron is allowed to enter in a magnetic field,



which is perpendicular to the direction of motion of photoelectron as shown in figure. Find distance (in μm) covered by the electron in the magnetic field. [B = 1 Tesla, $\pi^2 = 10$, mass of electron $= 9 \times 10^{-31}$ Kg]

where R is the radius of the path that the most energetic electron takes in the presence of applied magnetic field.

2. Suppose the potential energy between an electron and a proton at a distance r is $-\frac{Ke^2}{3r^3}$. The velocity of orbital motion of the electron is given as, $\frac{\alpha}{\beta}\left(\frac{n^3h^3}{\pi^3m^2ke^2}\right)$. Then find the value of $\alpha + \beta$.

3. The shortest wavelength of the Brakcet sereis of a hydrogen-like atom (atomic number =z) is the same as the shortest wavelength of the Balmer series of hydrogen atom. Find the value of z .

4. A radionuclide with disintegration constant λ is produced in a reactor at a constant rate α nuclei per sec. During each decay energy E_0 is released. 20% of this energy is utilised in increasing the temperature of water. Find the increase in temperature of m mass of water in time t. Specific heat of water is S. Assume that there is no loss of energy through water surface.

5. In certain experiment it has been found that the ratio of the decay current in a L-R circuit to the activity of a radioactive sample remains constant with time. The time constant of L-R circuit is 3 sec, find the average life (in second) of radioactive sample.

6. In a slow reaction, heat is being evolved at a rate about 10mW in a liquid. If the heat were being generated by the decay of ^{32}P, a radioactive isotope of phosphorus that has half-life of 14 days and emits only beta-particles with a mean energy of 700KeV, estimate the number of ^{32}P atoms in the liquid. Express your answer in form of $A \times 10^{17}$ and fill *5A* in OMR sheet. [Take : $\ln 2 = 0.675$]

ANSWER KEY

EXERCISE # (O)

1. Ans. (A)	2. Ans. (B)	3. Ans. (A)	4. Ans. (B)
5. Ans. (A)	6. Ans. (C)	7. Ans. (B)	8. Ans. (B)
9. Ans. (A)	10. Ans. (B,D)	11. Ans. (B)	12. Ans. (A,B,C,D)
13. Ans. (A, C, D)	14. Ans. (A,B,C)	15. Ans. (C)	16. Ans. (B, D)
17. Ans. (C)	18. Ans. (B)	19. Ans. (A)	20. Ans. (A)
21. Ans. (B)	22. Ans. (B)	23. Ans. (B)	24. Ans. (B)
25. Ans. (A, C)	26. Ans. (C)	27. Ans. (A)	28. Ans. (B)
29. Ans. (B)	30. Ans. (C)	31. Ans. (D)	32. Ans.(A)
33. Ans.(C)	34. Ans.(A)	35. Ans. (B)	36. Ans. (C)
37. Ans. (B)	38. Ans. (A)	39. Ans. (D)	40. Ans. (C)

41. Ans. (A) $\rightarrow$ (P,Q) ; (B) $\rightarrow$ (R,S,T) ; (C) $\rightarrow$ (R,S,T) ; (D) $\rightarrow$ (R,S,T)

42. Ans. (A) $\rightarrow$ (P,R) ; (B) $\rightarrow$ (Q,S) ; (C) $\rightarrow$ (Q,S) ; (D) $\rightarrow$ (P,R)

EXERCISE # (S)

1. Ans. 6 2. Ans. 9 3. Ans. 2

4. Ans. $\Delta T = \dfrac{0.2E_0\left[\alpha\ \ t-\dfrac{\alpha}{\lambda}(1-e^{-\lambda t})\right]}{m\ \ S}$ 5. Ans. 3 6. Ans. 8