PHYSICS

JEE and NEET Crash Course

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Problem Solving Class

(Calorimetry, Thermal Expansion and Heat Transfer)

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P-Q2651

The area of a hole of heat furnace is $\mathbf{10^{-4}\ m^2}$. It radiates $\mathbf{1.50} \times \mathbf{10^5}$ calories of heat per hour. If the emissivity of the furnace is **0.80**, then its temperature is (Stefan's constant = 5.6 × 10^{-8} J/m^{2}K^4):

(A) 1500 *K*

(B) 2000 *K*

(C) 2500 *K*

(D) 3000 *K*

1 hr = 60 × 60

1 cal = 4.2 J

$P_e = \sigma e A T^4$

$T^4 = \frac{1.5 \times 4.2 \times 10^5}{3600 \times 5.6 \times 10^{-8} \times 10^{-4} \times 0.8}$

$= \frac{15 \times 42 \times 10^{10} \times 10^5}{360 \times 56 \times 0.8} = \frac{21 \times 10^{16}}{12 \times 56 \times 8}$

$= \frac{7}{3^2 \times 56 \times 8} \times 10^{16} = \frac{1}{2^8} \times 10^{16}$

$T = \frac{1}{2^2} \times 10^4 = \frac{10000}{4}$

P-Q2651-Solution

Ans [C]

According to Stephen's Law **à** $E \propto T^4$ $where\ \sigma\ is\ called\ Stephen's\ Constant$

According to Stefen's law

$$E = \sigma \varepsilon A T^4$$

Power of radiation at temperature T by stefen's law

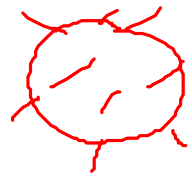
$$\frac{1.58 \times 10^5 \times 4.2}{60 \times 60}$$

$$= 5.6 \times 10^{-8} \times 10^{-4} \times 0.8 \times T^4$$

$$T \approx 2500 K$$

P-Q2652

Two spheres **P** and **Q** , of same colour having radii **8 cm** and **2cm** are maintained at temperatures **127°*C*** and **527°*C*** respectively. The ratio of **energy radiated** by P and Q is :



(A) 0.054 400 K 800 K (B) 0.0034

(C) 1 (D) 2

T → Kelvin

ΔT → Same in Kelvin or °C

$$P_e = \sigma e A T^4 \propto R^2 T^4$$

$$\frac{P_P}{P_Q} = \left(\frac{8}{2}\right)^2 \left(\frac{400}{800}\right)^4 = 16 \times \frac{1}{16} = 1$$

P-Q2652-Solution

Ans [C]

Total energy radiated from a body

$$Q = A\varepsilon\sigma T^4 t$$

$$\Rightarrow Q \propto AT^4 \propto r^2T^4 \quad (\because A = 4\pi r^2)$$

As they are made up of **same material** and have **same colour** so their emissivity and stefen's constant are same

$$\Rightarrow \frac{Q_P}{Q_Q} = \left(\frac{r_P}{r_Q}\right)^2 \left(\frac{T_P}{T_Q}\right)^4$$

$$= \left(\frac{8}{2}\right)^2 \left\{\frac{(273+127)}{(273+527)}\right\}^4 = 1$$

P-Q2653

A body cools from **60°C** to **50°C** in **10 minutes** when kept in air at **30°C** . In the next **10 minutes** its temperature will be :

(a) Below $40^{o}C$

(b) $40^{o}C$

(c) Above $40^{o}C$

(d) Cannot be predicted

Rate of cooling

$$-\frac{d\theta}{dt} \propto (\theta - \theta_0)$$

$50 \rightarrow 40^{o}C$ $t > 10$ min

$t = 10$ min

$> 40^{o}C$

P-Q2653-Solution

Ans [C]

According to newton's law of cooling rate of heat transfer **decreases** as temperature **decreases** .

if it falls by 10 °C in first 10 min then it will fall by less than 10°C in the next 10 minutes

P-Q2654

Hot water cools from **60°C** to **50°C** in the first **10 minutes** and to **42°C** in the next **10 min.**

The temperature of the surrounding is :

(A) 5 °C (B) 10 °C

(C) 15 °C (D) 20 °C

$$\frac{\Delta\theta}{\Delta t} = -K(\theta_{avg} - \theta_0) \Rightarrow \frac{\theta_f - \theta_i}{\Delta t} = -K\left(\frac{\theta_i + \theta_f}{2} - \theta_0\right)$$

$$\frac{50-60}{10} = -K(55 - \theta_0) \Rightarrow 1 = K(55 - \theta_0) \quad -(1)$$

$$\frac{42-50}{10} = -K(46 - \theta_0) \Rightarrow 0.8 = K(46 - \theta_0) \quad -(2)$$

$$(1) \div (2): \quad \frac{1}{0.8} = \frac{55 - \theta_0}{46 - \theta_0} = \frac{5}{4} = \frac{55 - \theta_0}{46 - \theta_0}$$

$$230 - 5\theta_0 = 220 - 4\theta_0$$

$$10 = \theta_0$$

P-Q2654-Solution

Ans [B]

$$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$$ ← According to newton's law of cooling

In the first case, $\frac{(60-50)}{10} = K\left[\frac{60+50}{2} - \theta_0\right]$

$$1 = K(55 - \theta)$$

In the second case, $\frac{(50-42)}{10} = K\left[\frac{50+42}{2} - \theta_0\right]$

$$0.8 = K(46 - \theta_0)$$

Dividing (i) by (ii), we get $\frac{1}{0.8} = \frac{55 - \theta_0}{46 - \theta_0}$

or $46 - \theta_0 = 44 - 0.8\theta_0 \Rightarrow \theta_0 = 10^o C$

P-Q2655

A bucket full of hot water cools from **75°C** to **70°C** in time T_1 , from **70°C** to **65°C** in time T_2 and from **65°C** to **60°C** in time T_3 , then :

(a) $T_1 = T_2 = T_3$

(b) $T_1 > T_2 > T_3$

(c) $T_1 < T_2 < T_3$

(d) $T_1 > T_2 < T_3$

Rate of cooling decreases as temp. of body decreases

P-Q2655-Solution

Ans [C]

According to Newton's law of cooling

Rate of cooling µ Mean temperature difference

$$\Rightarrow \frac{\text{Fall in temperature}}{\text{Time}} \propto \left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$$

$$\because \left(\frac{\theta_1+\theta_2}{2}\right)_1 > \left(\frac{\theta_1+\theta_2}{2}\right)_2 > \left(\frac{\theta_1+\theta_2}{2}\right)_3$$

$$\Rightarrow T_1 < T_2 < T_3$$

P-Q2656

Liquid is filled in a vessel which is kept in a room with temperature **20°C** (θ_0). When the temperature of the liquid is **80°C**, then it **loses** heat at the rate of **60 cal/sec**. . What will be the rate of loss of heat when the temperature of the liquid is **40°C.**

(A) 180 cal/sec (B) 40 cal/sec

(C) 30 cal/sec (D) 20 cal/sec

Rate of heat loss (P_1)

$$-\frac{dQ}{dt} \propto (\theta - \theta_0)$$

$$\frac{P_1}{P_2} = \frac{80-20}{40-20} = \frac{60}{20} = 3$$

$$\frac{60}{P_2} = 3 \Rightarrow P_2 = \frac{60}{3} = 20 \text{ cal/s}$$

P-Q2656-Solution

Ans [D]

Rate of loss of heat $\frac{\Delta Q}{t}$ ∝ temperature difference $\Delta\theta$

$$\frac{\left(\frac{\Delta Q}{t}\right)_1}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{\Delta\theta_2}{\Delta\theta_1}$$

$$\Rightarrow \frac{60}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{80-60}{40-20}$$

$$\Rightarrow \left(\frac{\Delta Q}{t}\right)_2 = \frac{20\ cal}{sec}$$

P-Q2601

How much heat is required to convert **8.0g** of ice at $-\mathbf{15}$℃ to steam at 100℃?

(given : $c_{ice} = 0.53 cal/g$-℃, $L_f = 80 cal/g$, $L_v = 539 cal/g$, $c_{water} = 1 cal/g$-℃

✓(A) 5816 cal

(B) 640 cal

(C) 5236 cal

(D) 4952 cal

8g ice, −15°C $\xrightarrow{ms\Delta T}$ 8g ice, 0°C $\xrightarrow{mL_f}$ 8g water, 0°C $\xrightarrow{ms_w\Delta T}$ 8g water, 100°C $\xrightarrow{mL_v}$ 8g steam, 100°C

$\Delta Q = 8g[0.53 \times 15 + 80 + 1 \times 100 + 539]$

$= 8[7.95 + 180 + 539] = 8 \times 728$

$= 5824$ cal

P-Q2601-Solution

Ans [A]

$$Q_1 = mc_{\text{ice}}(T_f - T_i) = (8.0)(0.53)[0-(-15)] = 63.6\,\text{cal}$$

Heat required for ice up to 0℃

$$Q_2 = mL_f = (8)(80) = 640\,\text{cal}$$

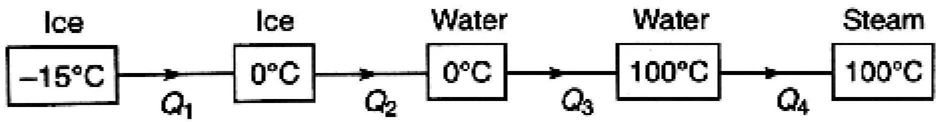
Latent heat required to convert into water

$$Q_3 = mc_{\text{water}}(T_f - T_i) = (8.0)(1.0)[100-0] = 800\,\text{cal}$$

Heat for water up to 100℃

$$Q_4 = mL_v = (8.0)(539) = 4312\,\text{cal}$$

Latent heat required for vaporization



∴ Net heat required

$$Q = Q_1 + Q_2 + Q_3 + Q_4 = 5815.6\,\text{cal}$$

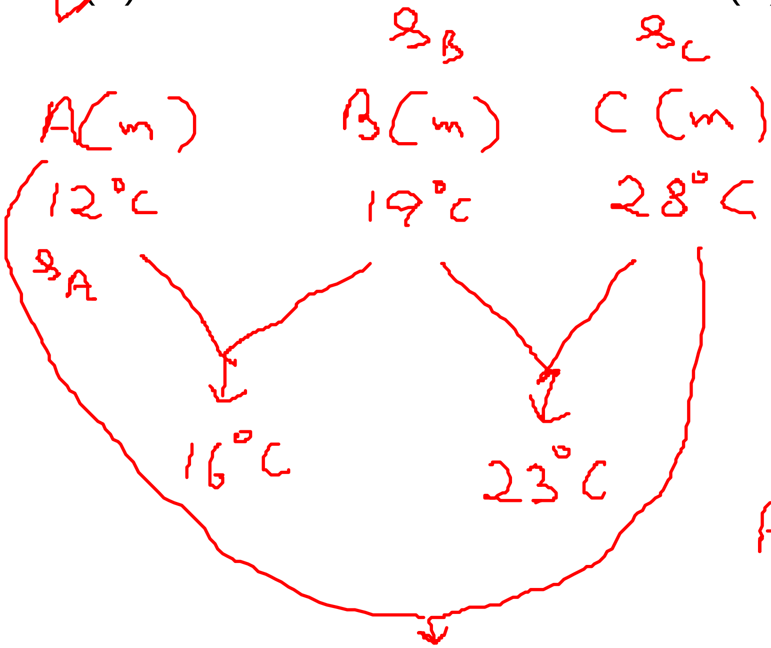
Total heat required

P-Q2603

The temperature of equal masses of three different liquids **A,B** and **C** are $\mathbf{12}$℃, $\mathbf{19}$℃ & $\mathbf{28}$℃ respectively . The temperature when **A** and **B** are mixed is $\mathbf{16}$℃ and when **B** and **C** are mixed is $\mathbf{23}$℃. What would be the temperature when **A** and **C** are mixed ?

(A) 28.53℃ (B) 19.34℃

(C) 20.26℃ (D) 24.67℃



$$T_m = \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2}$$

For A & B

$$16 = \frac{s_A \times 12 + s_B \times 19}{s_A + s_B}$$

$$16 s_A + 16 s_B = 12 s_A + 19 s_B$$

$$4 s_A = 3 s_B \Rightarrow s_A = \frac{3}{4} s_B$$

For B & C

$$23 s_B + 23 s_C = 19 s_B + 28 s_C$$

$$4 s_B = 5 s_C \Rightarrow s_C = \frac{4}{5} s_B$$

$$T_m = \frac{9 s_B + \frac{112}{5} s_B}{\frac{31}{20} s_B}$$

P-Q2603-Solution

Ans [C]

Heat balance

Heat balance for finding specific heat of liquids A and B

$$ms_A(16-12) = ms_B(19-16)$$ ← A and B mix

$$\Rightarrow \quad 4s_A = 3s_B \quad (1)$$

B and C mix — Heat balance for liquid B and C

$$ms_B(23-19) = ms_C(28-23)$$

$$\Rightarrow \quad 4s_B = 5s_C \quad (2)$$

A and C mix temperature change to $\boldsymbol{\theta}$

$$\therefore \quad ms_A(\theta-12) = ms_C(28-\theta)$$

From 1 and 2

$$\text{or} \quad \frac{3}{4}s_B(\theta-12) = \frac{4}{5}s_B(28-\theta)$$

$$\text{or} \quad 15(\theta-12) = 16(28-\theta)$$

$$\text{or} \quad 31\theta = 448 + 180$$

$$\Rightarrow \quad \theta = 20.26°C$$

P-Q2401

The temperature of an iron pieces is hated from $30℃$ $\boldsymbol{to}$ $90℃$. What is the change in its temperature on the kelvin scale ?

(A) 60K (B) 20K (C) 40K (D) 50K

Temp. change (ΔT) is same in Kelvin and celsius scale

373 - 273 = 100

100 - 0 = 100

P-Q2401-Solution

Ans [A]

$$\Delta T_C = 90^\circ\,C - 30^\circ\,C = 60^\circ\,C$$

Temperature difference in Celsius

$$\Delta T_F = \frac{9}{5}\Delta T_C = \frac{9}{5}(60^\circ\,C) = 108^\circ\,F$$

Relation btw T_F and T_c

$$\Delta T = \Delta T_C = 60\,K$$

P-Q2402

Find the coefficient of volume expansion for an ideal gas at constant pressure

(A) $\frac{2}{T}$ (B) $\frac{1}{2T}$ (C) $\frac{1}{T}$ (D) $\frac{2}{3T}$

$PV = nRT$

$V \propto T \quad — (1)$

$\Delta V \propto \Delta T \quad — (2)$

$(2) \div (1)$

$\frac{\Delta V}{V} = \frac{\Delta T}{T}$

$\Delta V = \gamma V \Delta T$

$\gamma = \frac{\Delta V}{V \Delta T}$

$\gamma = \frac{\Delta V}{V \Delta T} = \frac{\Delta V}{V \Delta T} = \frac{1}{T}$

$\gamma = \frac{1}{T}$

P-Q2402-Solution

Ans [C]

For an ideal gas

$$PV = nRT$$

$$P \cdot dV = nRdT$$

Change in volume due to temperature change

$$\frac{dV}{dT} = \frac{nR}{P}$$

$$\gamma = \frac{1}{V} \cdot \frac{dV}{dT} = \frac{nR}{PV} = \frac{nR}{nRT} = \frac{1}{T}$$

Relate volume expansion coefficient relation with equation

$$\gamma = \frac{1}{T}$$

P-Q2403

A seconds pendulum clock has a **steel wire** . The clock is calibrated at $\mathbf{20}$℃. How much time does the clock lose or gain in one week when the temperature is increased to $\mathbf{30}$℃?

$\boldsymbol{\alpha_{steel}} = \mathbf{1.2} \times \mathbf{10^{-5}} (℃)^{-\mathbf{1}}$

(A) 40.45s (B) 36.28s (C) 32.14s (D) 50.08s

$T = 2\pi\sqrt{\frac{l}{g}}$

$\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l}$

$\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta$

1 week

$\Delta T = \frac{1}{2}\alpha\Delta\theta \cdot T$

$= \frac{1}{2} \times 1.2 \times 10^{-5} \times 10 \times 7 \times 24 \times 3600$

$= 144 \times 252 \times 10^{-3}$

$=$

P-Q2403-Solution

Ans [B]

$$\Delta T = \frac{1}{2} T \alpha \Delta\theta$$

Change in time period due to temperature change

$$= \left(\frac{1}{2}\right)(2)(1.2 \times 10^{-5})(30^\circ - 20^\circ)$$

$$= 1.2 \times 10^{-4} \text{ s}$$

Now time period is

$$T' = T + \Delta T = (2 + 1.2 \times 10^{-4})$$

$$= 2.00012 \text{s}$$

New time period increase as temperature increase

Time lost in one week

$$\Delta t = \left(\frac{\Delta T}{T'}\right) t$$

Time lost in time **'t'**

$$= \frac{(1.2 \times 10^{-4})}{(2.00012)}(7 \times 24 \times 3600)$$

$$= 36.28 \text{s}$$

As time period increases then it taking more time hence loss in time

P-Q2404

At what temperature the **Fahrenheit and Celsius** scale of temperature give the same reading ?

(A) $-40℃$ (B) $-32℃$ (C) $20℃$ (D) $-54℃$

$$\frac{C}{100} = \frac{F-32}{180}$$

$$\frac{x}{100} = \frac{x-32}{180}$$

$$9x = 5x - 160$$

$$4x = -160$$

$$x = -40$$

$$-40°C = -40°F$$

P-Q2404-Solution

Ans [A]

$$\frac{C}{5} = \frac{F-32}{9} \qquad \Rightarrow \frac{9}{5}x = x - 32$$

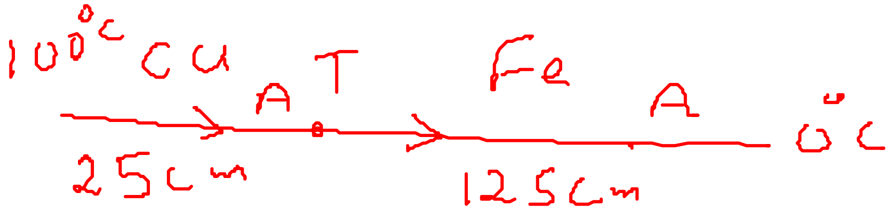
$$\Rightarrow \qquad \frac{4}{5}x = -32$$

$$\Rightarrow \qquad x = -\frac{5}{4} \times 32 = -40\ ^\circ\mathrm{C}$$

P-Question

A copper rod of length 25 cm and an iron rod of length 125 cm are joined together end to end. Both are of circular cross section with diameter 2 cm. The free ends of the copper and iron are maintained at 100^0C and 0^0C respectively. The surfaces of the bars are insulated thermally. The temperature of the junction is [Thermal conductivity of copper is 386.4 W/m-K and that of iron is 48.46 K]

1) 100^0C 2) 0^0C 3) 90^0C 4) 50^0C



$$\frac{K_{Cu} A (100 - T)}{25\ cm} = \frac{K_{Fe} A (T - 0)}{125\ cm}$$

$386.4 (100 - T) \times 5 = 48.46 (T)$

$4 (100 - T) = T$

$400 - 4T = T$

$400 = 5T$

$T = 80^0 C$

P-Solution

Ans [3]

$$\frac{100-\theta}{R_1} = \frac{\theta - 0}{R_2}$$

$$\frac{100-\theta}{\frac{L_1}{K_1 A_1}} = \frac{\theta - 0}{\frac{L_2}{K_2 A_2}} \quad (A_1 = A_2)$$

$$(100-\theta)\frac{K_1}{L_1} = \theta \frac{K_2}{L_2}$$

$$(100-\theta)\frac{386.4}{0.75} = \theta \times \frac{48.46}{1.25}$$

$$Þ \ \theta = 90^0 C$$

P-Question

A thermos flask contains 250 g of coffee 90^0C. To this 20 g of milk at 5^0C is added. After equilibrium is established, the temperature of the liquid is (Assume no heat loss to the thermos bottle. Take specific heat of coffee and milk as 1.00 cal/g^0C)

1) 3.23^0C 2) 3.17^0C 3) 83.7^0C 4) 37.8^0C

$$T_m = \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2} = \frac{250 \times 1 \times 90 + 20 \times 1 \times 5}{250 + 20}$$

$$= \frac{22500 + 100}{270} = \frac{22600}{270} \approx 84$$

P-Solution

Ans [3]

$$12.5\times1\times(90 - \theta) = 20\times1(\theta - 5)$$

$$12.5\times90 - 12.5\,\theta = 2\,\theta - 100$$

$$25\times90 - 25\,\theta = 2\,\theta - 10$$

$$2260 = 27\theta$$

$$\theta = \frac{2260}{27} = 83.7^0C$$

P-Question

Two perfect black bodies A_1 and A_2 made out of same material have diameter 2 cm and 16 cm respectively. ‘l ’ ‘l'_{max} and l''_{max}’ are the wavelengths corresponding to their maximum radiation of energy at a common temperature ‘l'_{max} and l''_{max}’ are related as

1) $16l'_{max} = 5l''_{max}$ 2) $l'_{max} = l''_{max}$ 3) $8l'_{max} = l''_{max}$ 4) $l'_{max} = 8l''_{max}$

$\lambda_m T$ = const

= b

P-Solution

Ans [2]

$\lambda_{max}T$ = constant

T is same

$\lambda'_{max} = \lambda''_{max}$

P-Question

A sphere at 600 K is losing heat due to radiation. At this temperature its rate of cooling is R. The rate of cooling of this sphere at 400 K is (temperature of surroundings is 200 K)

1) $\frac{8}{27}R$ **2)** $\frac{8}{26}R$ **3) 7R** **4)** $\frac{3}{16}R$ ✓

For Newton's Law

$T - T_0 << T$ or T_0

$R = -\frac{dQ}{dt} \propto (T^4 - T_0^4)$

$\frac{R}{R'} = \frac{[600^4 - 200^4]}{[400^4 - 200^4]} = \frac{[1296 - 16] \times 10^8}{[256 - 16] \times 10^8}$

$\frac{R}{R'} = \frac{1280}{240} = \frac{16}{3} \Rightarrow R' = \frac{3R}{16}$

P-Solution

Ans [4]

$$\frac{dQ}{dt} \propto \left(T^4 - T_0^4\right)$$

$$R \propto \left(600^4 - 200^4\right)$$

$$R \propto (1296 - 16) \times 10^8$$

$$R \propto 1280 \times 10^8 \ldots .(1)$$

$$R' \propto \left(400^4 - 200^4\right)$$

$$R' \propto (256 - 16) \times 10^8$$

$$R' \propto 240 \times 10^8 \ldots ..(2)$$

$\frac{(2)}{(1)}$ Þ $\frac{R'}{R} = \frac{240}{1280}$

$$R' = \frac{24}{128} R = \frac{3}{16} R$$