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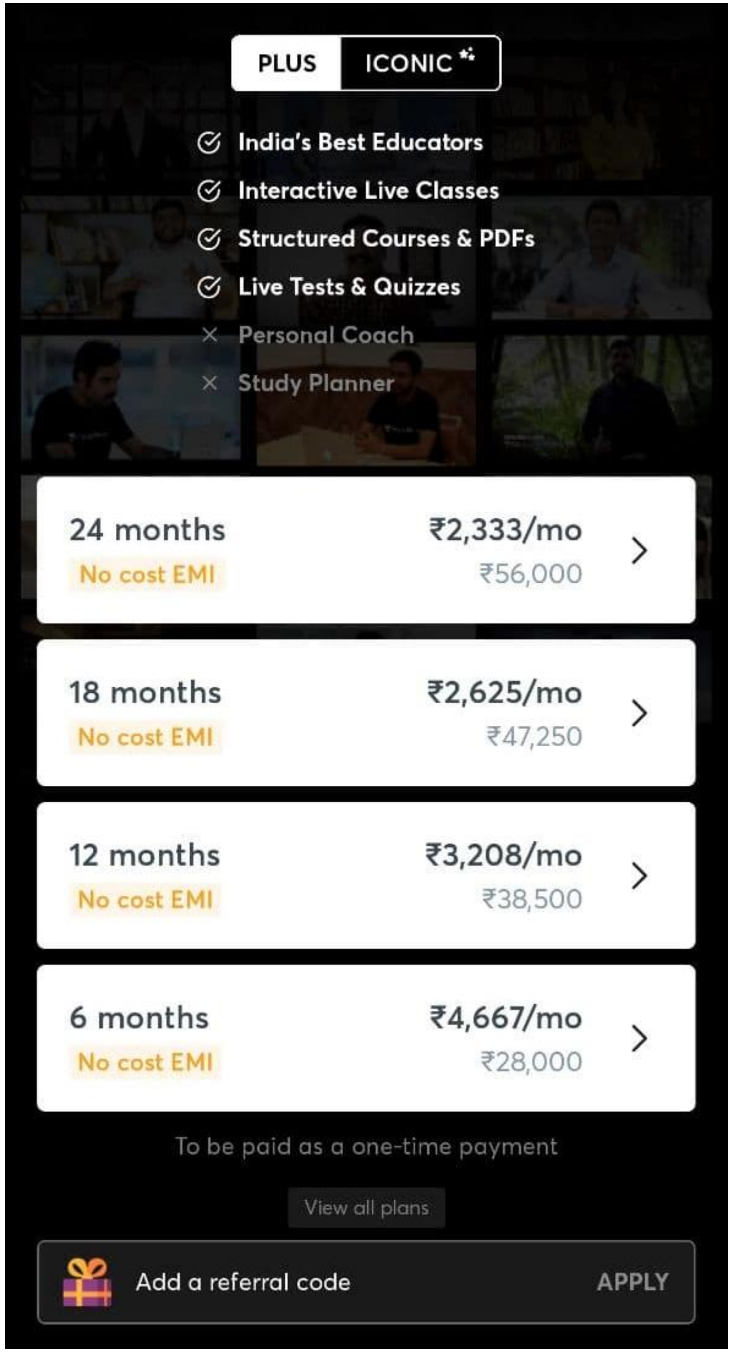

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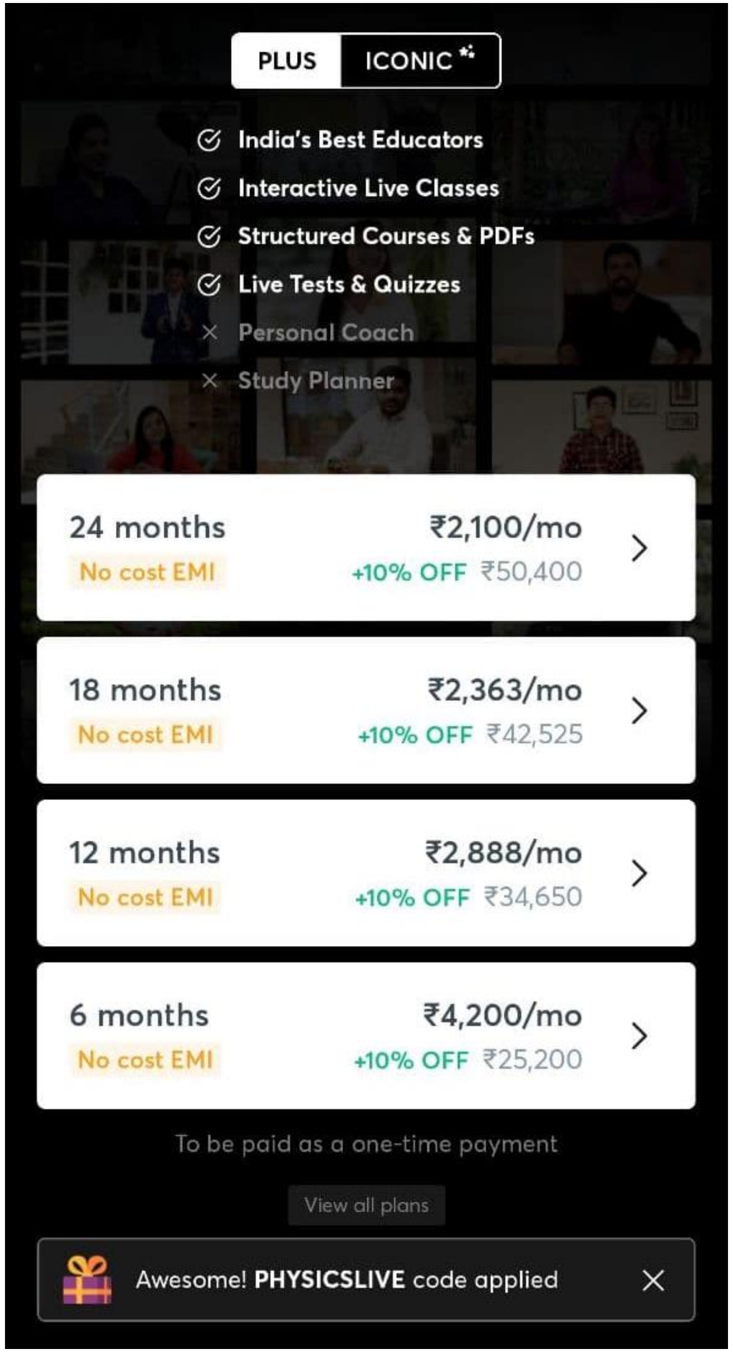

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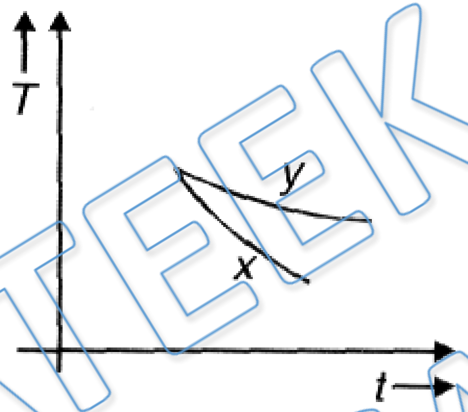
JEE Main & Advanced, NSEP, INPhO, IPhO Physics DPP

DPP- 3 Heat Transfer: Radiation, electromagnetic spectrum, Blackbody, Stefan's Law

By Physicsaholics Team

Q) The graph shown in diagram represents the variation of temperature T of bodies x and y having same surface area with time (t) due to emission of radiation. Find correct relation between emissivity and absorptive power of two bodies



(a) $e_x > e_y$ and $a_x < a_y$ (b) $e_x < e_y$ and $a_x > a_y$
(c) $e_x > e_y$ and $a_x > a_y$ (d) $e_x < e_y$ and $a_x < a_y$

Ans. c

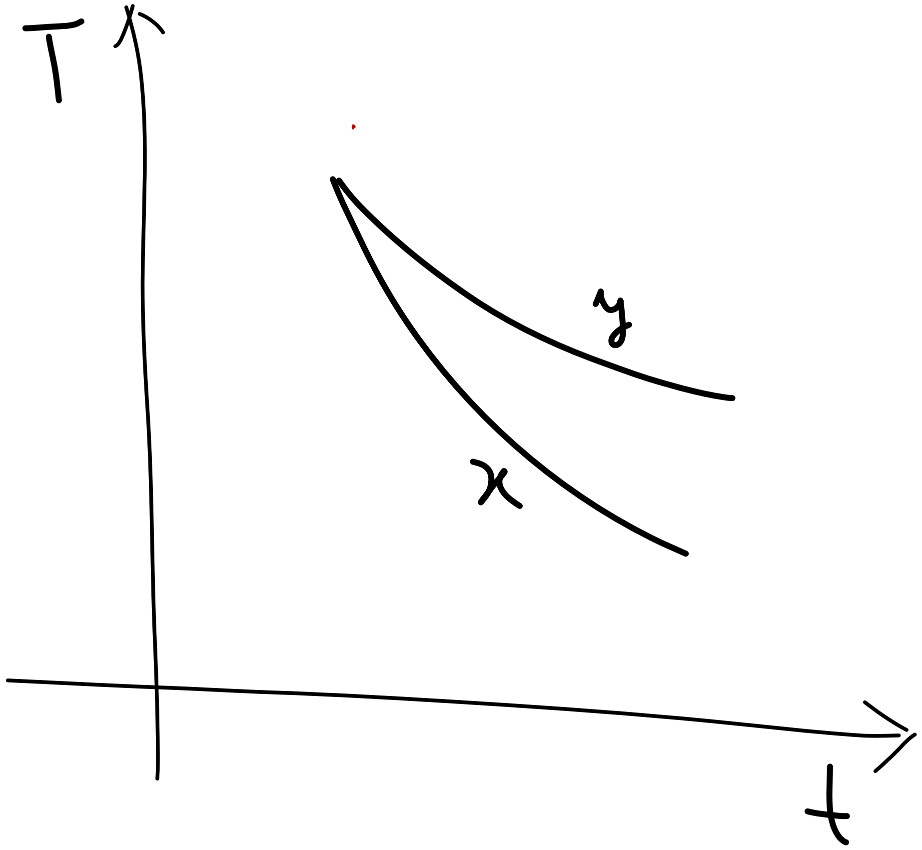
$$-\frac{dT}{dt} \propto -\frac{dQ}{dt} = e\sigma A(T^4 - T_0^4)$$

Since rate of fall of temperature is greater for x,

$$e_x > e_y$$

Since $e = a$

$$a_x > a_y$$



Ans (c)

Q) An ideal black body at room is thrown into furnace it is observed that

(a)Initially it is darkest body and at later times the brightest
(b)It is darkest body at all times
(c)It cannot be distinguished at all times
(d)Initially it is darkest body and at later times it cannot be distinguished

Ans. a

Initially it is darkest as its temperature is lower.

finally it is brightest because at same temperature.

black body radiates more power per unit surface area than others.

Ans(a)

Q) Three discs A, B and C having radii 2 m, 4 m and 6 m respectively are coated with carbon black on their outer surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm respectively. The power radiated by them are Q_A, Q_B and Q_C respectively

(a) Q_A is maximum (b) Q_B is maximum
(c) Q_C is maximum (d) $Q_A = Q_B = Q_C$

Ans. b

$\lambda \rightarrow$ wavelength corresponding to maximumum intensity

$$\lambda T = b$$

Power radiated $Q \propto AT^4 \propto r^2 T^4 \propto \frac{r^2}{\lambda^4}$

for A $\rightarrow$ $\frac{r^2}{\lambda^4} = \frac{4}{81 \times 10^8}$

for B $\rightarrow$ $\frac{r^2}{\lambda^4} = \frac{16}{256 \times 10^8} = \frac{4}{64 \times 10^8}$

for C $\rightarrow$ $\frac{r^2}{\lambda^4} = \frac{36}{625 \times 10^8} = \frac{4}{69 \times 10^8}$

$\Rightarrow \quad Q_B > Q_C > Q_A$

Ans(b)

Q) A solid copper sphere (density p and specific heat capacity C) of radius r at an initial temperature 200 K is suspended inside a chamber whose walls are at almost 0 K. The time required (in μs) for temperature of sphere to drop to 100 K is

(a) $\frac{72\rho rc}{7\sigma}$

(b) $\frac{7\rho rc}{72\sigma}$

(c) $\frac{27\rho rc}{7\sigma}$

(d) $\frac{7\rho rc}{27\sigma}$

Ans. b

at sphere temperature T

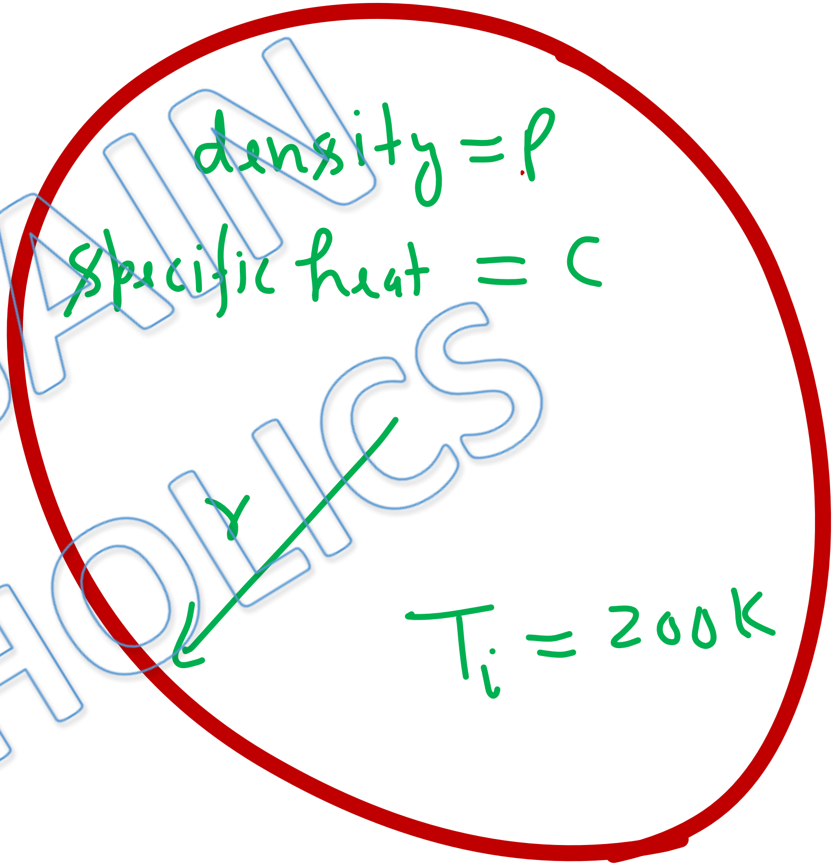
$$\frac{dQ}{dt} = -\sigma\, 4\pi r^2 (T^4 - 0^4)$$

$$mc\frac{dT}{dt} = -4\pi r^2 \sigma\, T^4$$

$$\Rightarrow \int_{200}^{100} \frac{dT}{T^4} = -\frac{4\pi r^2 \sigma}{c \cdot \frac{4}{3}\pi r^3 \rho}\int dt$$

$$\Rightarrow \left[\frac{1}{(100)^3} - \frac{1}{(200)^3}\right] \times \frac{1}{3} = \frac{3\sigma}{c\rho r}\, t$$

$$\Rightarrow t = \frac{7}{72}\,\frac{\rho r c}{\sigma} \times 10^{-6} = \frac{7\rho r c}{72\sigma}\ \mu\,\text{Sec.}$$



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Ans(b)

Q) Maximum spectral radiancy of black body corresponds to wavelength λ . If temperature is now changed so that maximum spectral radiancy now corresponds to $\frac{3\lambda}{4}$ .Then

(a) New temperature is 4/3 times the old temperature

(b) New temperature is 3/4 times the old temperature

(c) Power radiated by body changes by factor 256/81

(d) Power radiated by body changes by factor 81/256

Ans. a,c

According to wien's Law $\lambda_m \times T = b$

$\Rightarrow \lambda_1 T_1 = \lambda_2 T_2 \Rightarrow \lambda T = \frac{3\lambda}{4} T' \Rightarrow T' = \frac{4T}{3}$

According to stefan's Law $\rightarrow$

Power radiated $\propto T^4$

$\Rightarrow$ Power radiated changes by a factor of $\left(\frac{4}{3}\right)^4 = \frac{256}{81}$

Ans (a, c)

Q) A black body is at temperature of 2880 K. The energy of radiation emitted by this object between wavelength 4990 Å and 5000 Å is U_1; between 9990 Å and 10000 Å is U_2 and between 14990 Å and 15000 Å is U_3. The Wein's constant is $b = 2.88 \times 10^{-3}$ mK , Then

(a) $U_2 > U_1$
(b) $U_2 > U_3$
(c) $U_1 = U_3 < U_2$
(d) $U_1 < U_2 < U_3$

Ans. a.b

$$\lambda_m T = b$$

$$\Rightarrow \quad \lambda_m = \frac{2.88 \times 10^{-3}}{2880} = 10^{-6} m = 10000 \, A^{o}$$

$\Rightarrow$ U_2 is greater than U_1 & U_3

Ans (a,b)

Q) Explanations of phenomena's in column-ll is explained by laws given in column-l.

	Column I		Column II
(A)	Why days are hot and nights are cold in deserts	(P)	Wein's displacement law
(B)	Why blackened platinum wire when heated gradually appears red and then blue	(q)	Planck's law
(C)	Variation in spectral intensity with temperature in distribution of energy in black body spectrum	(r)	Kirchhoff's law
(D)	Determination of some stars being hotter than others	(s)	Stefan's law

Ans. A(r), B(p), C(q), D(p)

A) Sand is good absorber & good emitter of heat.
(Kirchoff's Law)

B) As the temperature increases, wavelength corresponding to maximum intensity decreases. (wien's Law)

C) Spectral emissive power Vs λ relation is given by Planck.

D) Temperature of star is determine by equation $\lambda_m T = b$
(wiens Law)

(Q) Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies radiate energy at the same rate. The wavelength λ_B, corresponding to the maximum spectral radiancy in the radiation from B, is shifted from the wavelength corresponding to the maximum spectral radiancy in the radiation from A by 1.00 μm. If the temperature of A is 5802 K,

(a) the temperature of B is 1934 K
(b) $\lambda_B = 1.5\mu m$
(c) the temperature of B is 11604 K
(d) the temperature of B is 2901 K

Ans. a,b

$$\lambda_B = \lambda_A + 1\,\mu m \quad --(1)$$

$$(e\sigma A T^4)_A = (e\sigma A T^4)_B$$

Wien's Constant

$$\Rightarrow \quad .01\,\sigma A\left(\frac{b}{\lambda_A}\right)^4 = .81\,\sigma A\left(\frac{b}{\lambda_B}\right)^4$$

$$\Rightarrow \quad \left(\frac{\lambda_B}{\lambda_A}\right)^4 = 81 = 3^4 \quad \Rightarrow \lambda_B = 3\lambda_A$$

$$\Rightarrow \quad 2\lambda_A = 1\,\mu m \Rightarrow \lambda_A = .5\,\mu m$$

$$\lambda_B = 1.5\,\mu m \quad \Rightarrow T_b = \frac{2.88\times10^{-3}}{1.5\times10^{-6}} = 1934\,K$$

Ans (a, b)

(Q) A 100 Watt bulb has tungsten filament of total length 1.0 m and radius 4×10^{-5}m. The emissivity of the filament is 0.8 and $\sigma = 6.0 \times 10^{-8} W/m^2\text{-}K^4$. Calculate the temperature of the filament when the bulb is operating at correct wattage.

(a) 1605 K

(b) 1000 K

(c) 900 K

(d) 3000K

Ans. a

Electrical power consumed = Power radiated

$$\Rightarrow \quad 100 = e\sigma A T^4$$

$$\Rightarrow \quad 100 = .8 \times 6 \times 10^{-8} \times 2\pi(4 \times 10^{-5}) \times 1 \, T^4$$

$$\Rightarrow \quad T^4 = \frac{100}{4.8 \times 2\pi \times 4 \times 10^{-13}}$$

$$\Rightarrow \quad T = 1605\,K$$

Ans (a)

Q) A metal piece loses 200 J heat per second by radiation when its temperature is 1400 K, and the temperature of surrounding is 300 K. Calculate the rate of loss of heat when the temperature of the metal piece is 800 K.

(a) 21 J/sec

(b) 115 J/sec

(c) 86 J/sec

(d) 155 J/sec

Ans. a

Rate of heat loss $= e\sigma A(T^4 - T_0^4)$

$$200 = e\sigma A\left((1400)^4 - (300)^4\right)$$

$$u = e\sigma A\left((800)^4 - (300)^4\right)$$

$$\Rightarrow \frac{u}{200} = \frac{8^4 - 3^4}{14^4 - 3^4} = \frac{4096 - 81}{38416 - 81}$$

$$\Rightarrow u = 21 \text{ J/Sec}$$

Ans(a)

Q) A polished metal with rough black spot on it is heated to about 1400 K and quickly taken to dark room. Which one of the following statements is true?

(a) Spot will appear brighter than plate
(b) Spot will appear darker than plate
(c) Spot and plate will be equally bright
(d) Spot and plate will not be visible in dark

Ans. a

Spot will appear brighter than plate because

$e_{blackbody} = 1$ but $e_{Metal} < 1$

Ans(a)

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Chalo Niklo