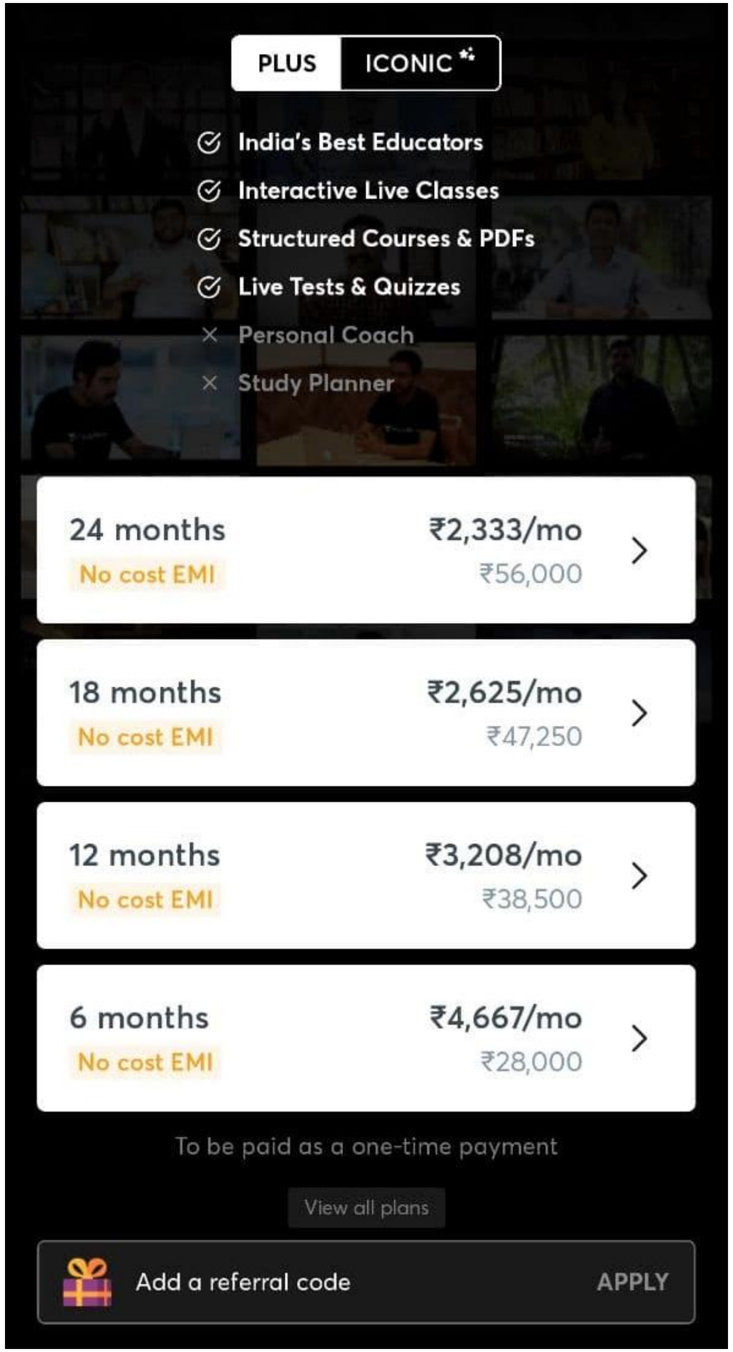
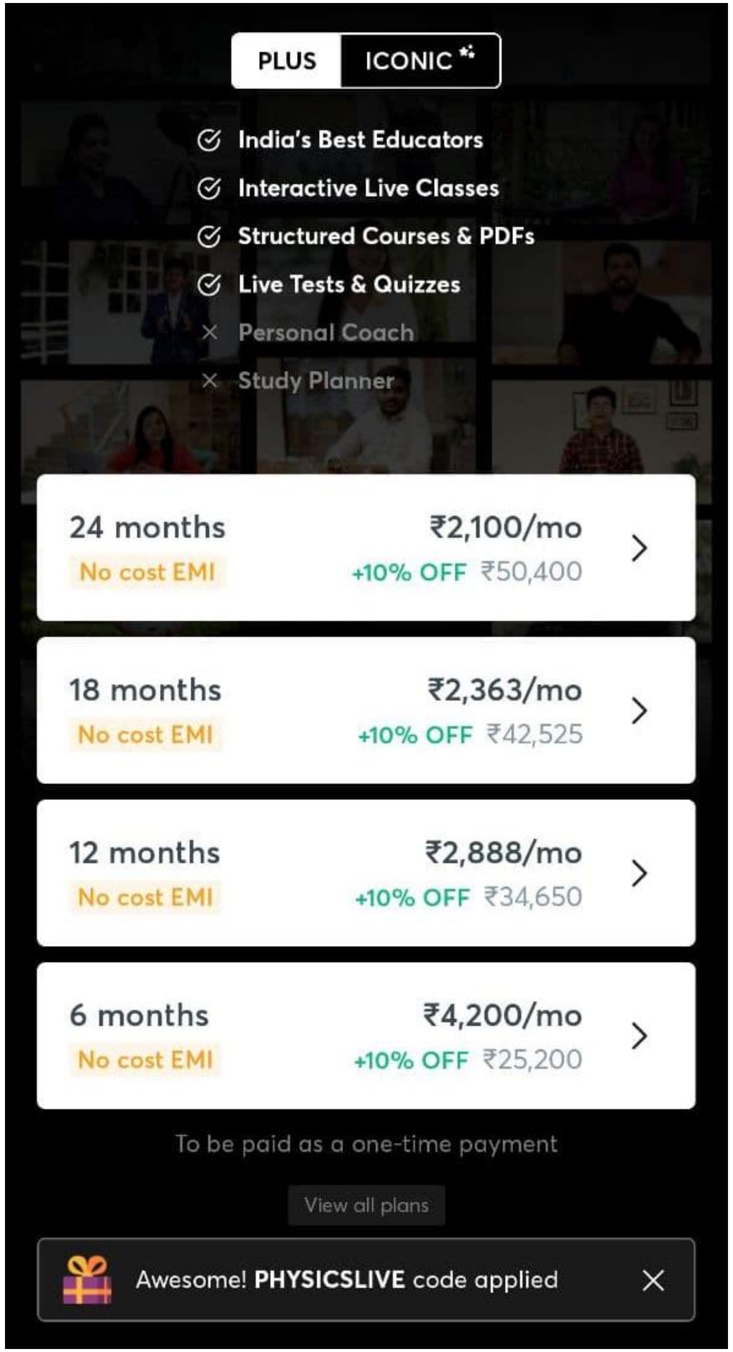
SIR PRATEEK JAIN

. Founder @Physicsaholics
. Top Physics Faculty on Unacademy (IIT JEE & NEET)
. 8+ years of teaching experience in top institutes
like FIITJEE (Delhi, Indore) , CP (KOTA) etc.
. Produced multiple Top ranks.
. Research work with HC Verma sir at
IIT Kanpur
. Interviewed by International media.



PHYSICSLIVE



Use code PHYSICSLIVE to get 10% OFF on Unacademy PLUS.

For Video Solution of this DPP, Click on below link

Video Solution on Website:- https://physicsaholics.com/home/courseDetails/68

Video Solution on YouTube:- https://youtu.be/EirLXuNXWbk

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

DPP- 4 Heat Transfer: Newton's law of cooling, solar constant

By Physicsaholics Team

Passage

The body radiates energy or cools down to surrounding depends on the temperature of the surrounding. It says that the rate of heat loss to the surrounding at higher temperature is more than that of the body at lower temperature. To perform that we take a metal ball of mass 1 kg is heated by means of a 20 W heater in a room at 20ºC. The temperature of the ball rises continuously but the rate of increase in temperature decreases continuously and finally it becomes zero, when the temperature of the ball reaches to 50ºC. Corresponding to above observation answer the following questions

Q) Find the rate of loss of heat to the surrounding when the ball is at 50ºC.

(A) 10 W (B) 15 W

(C) 20 W (D) 25 W

Ans. c

At $T = 50^\circ C$

$$\frac{dT}{dt} = 0 \Rightarrow \frac{dQ}{dt} = 0$$

Power loss to surrounding = Power gain by heater

$= 20W$

Ans(c)

Q) Using Newtons law of cooling , find rate of heat loss to the surrounding when ball is at 30^0C ?

(A) $\frac{10}{3}W$

(B) $\frac{20}{3}W$

(C) $\frac{30}{3}W$

(D) $\frac{40}{3}W$

Ans. b

Rate of heat loss $\propto$ temperature difference with surrounding

$$\frac{\text{Rate of heat loss at } 30^\circ}{\text{,, ,, ,, ,, ,, } 50^\circ} = \frac{30-20}{50-20} = \frac{1\cancel{0}}{3\cancel{0}}$$

$$\text{Rate of heat loss at } 30^\circ C = \frac{1}{3} \times 20 = \frac{20}{3}\text{ Watt}$$

Ans (b)

Q) Assume that the temperature of the ball rises uniformly from 20ºC to 30ºC in 5 minutes find the total loss of heat to the surrounding during this period –

(A) 250 J (B) 500 J

(C) 750 J (D) 1000 J

Ans. d

from $20^\circ C$ to $30^\circ C$, average temperature of body $= 25^\circ C$

$$\frac{\text{Rate of Heat loss at } 25^\circ C}{\text{,, ,, ,, } 50^\circ C} = \frac{25-20}{50-20} = \frac{5}{30} = \frac{1}{6}$$

$$\text{Rate of Heat loss at } 25^\circ C = \frac{20}{6} = \frac{10}{3}$$

$$\text{Heat loss in 5 minutes} = \frac{10}{\cancel{3}} \times 5 \times \cancel{60}^{\,20}$$

$$= 1000\ J$$

Ans (d)

Q) Find the specific heat capacity of the metal

(A) 500 J/kg-K
(B) 1000 J/kg-K
(C) 1500 J/kg-K
(D) 2000 J/kg-K

Ans. a

Heat supplied by heater in 5 minutes $= 20 \times 5 \times 60$
$= 6000\ J$

Heat loss to surrounding $= 1000\ J$.

net heat absorbed $= 6000 - 1000 = 5000\ J$

$$\Delta Q = m s \Delta T$$

$$s = \frac{5000}{1 \times 10} = 500\ J/kg^\circ C = 500\ J/kg\,K$$

Ans(a)

Q) An object is cooled from 75°C to 65°C in 2 minutes in room at 30°C. The time taken to cool the same object from 55°C to 45°C in the same room is

(a) 5 minute
(b) 3 minute
(c) 4 minute
(d) 2 minute

Ans. c

$$\frac{\Delta T}{\Delta t} = CA\left(T - T_0\right)$$

$$\Rightarrow \quad \frac{75-65}{2} = CA\left(\frac{75+65}{2} - 30\right)$$

$$\Rightarrow \quad \frac{55-45}{\Delta t} = CA\left(\frac{55+45}{2} - 30\right)$$

$$\Rightarrow \quad \frac{\Delta t}{2} = \frac{70-30}{50-30} = \frac{40}{20} = 2$$

$$\Rightarrow \quad \Delta t = 4 \text{ minute}$$

Ans(c)

Q) A planet having surface temperature T has solar constant S. An angle θ is subtended by the sun at planet then

(a) $S \propto T^2$

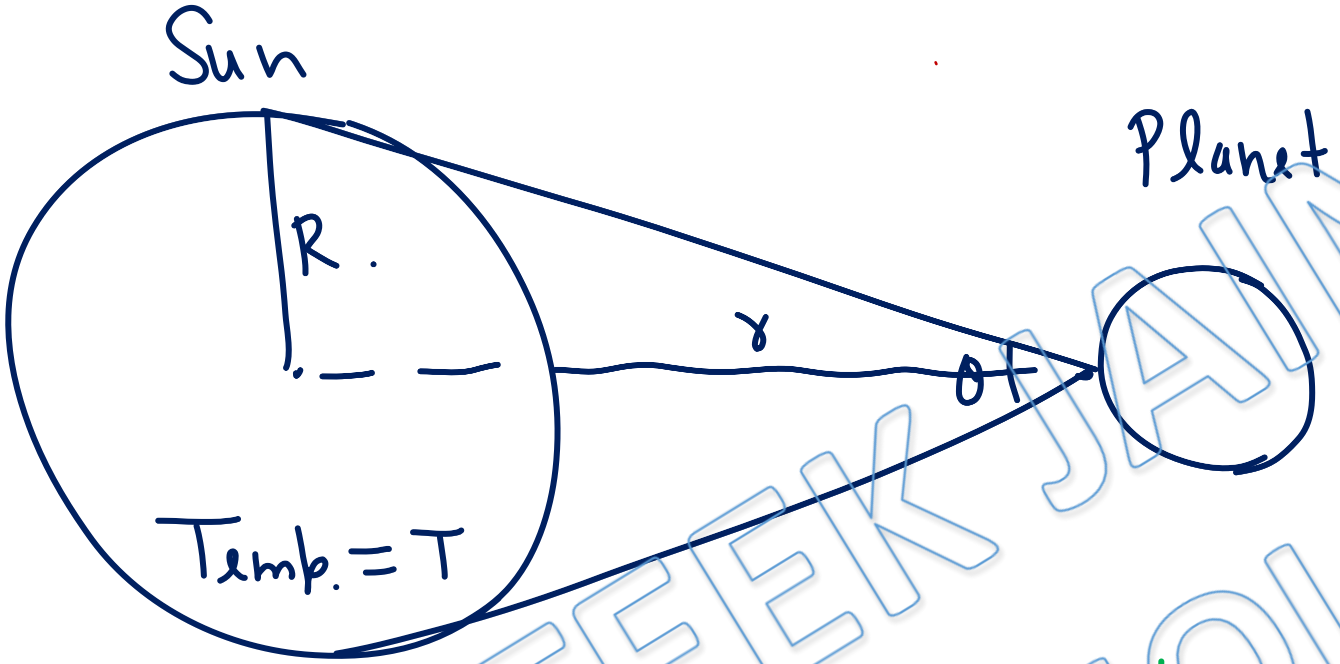
(b) $S \propto T$

(c) $S \propto \theta^0$

(d) $S \propto \theta^2$

Ans. d

23)



Power emitted by Sun $= \sigma 4\pi R^2 T^4$

Intensity at planet $= \dfrac{\sigma . 4\pi R^2 T^4}{4\pi r^2} = \sigma \left(\dfrac{R}{r}\right)^2 T^4$

$= \sigma . 4\theta^2 T^4$

$S \propto \theta^2$ & $S \propto T^4$

Ans(d)

Q) Four spheres A, B, C and D of different metals but of same radius are kept at same temperature. The ratio of their densities and specific heats are 2 : 3 : 5 : 1 and 3 : 6 : 2 : 4. Which sphere will show the fastest rate of cooling (initially):

(a) A
(b) B
(c) C
(d) D

Ans. d

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

$$\Rightarrow \quad -ms\frac{dT}{dt} = e\sigma A\left(T^4 - T_0^4\right)$$

$$\Rightarrow \quad -\frac{dT}{dt} = \frac{e\sigma 4\pi R^2}{s\,\rho \cdot \frac{4}{3}\pi R^3}\left(T^4 - T_0^4\right) \propto \frac{1}{\rho s}$$

for A $\rightarrow$ $\rho s = 2 \times 3 = 6$

for B $\rightarrow$ $\rho s = 3 \times 6 = 18$

for C $\rightarrow$ $\rho s = 5 \times 2 = 10$

for D $\rightarrow$ $\rho s = 1 \times 4 = 4$

Q) A body cools from 50°C to 40°C in 5 minutes. The surrounding temperature is 20°C. In what further time (in minutes) will it cool to 30°C?

(a) 5
(b) 15/2
(c) 25/3
(d) 10

Ans. c

$$-\frac{\Delta\theta}{\Delta t} = CA\,(T - T_0)$$

$$\Rightarrow \quad \frac{50-40}{5} = CA\left(\frac{50+40}{2} - 20\right)$$

$$\Rightarrow \quad \frac{40-30}{\Delta t} = CA\left(\frac{40+30}{2} - 20\right)$$

$$\Rightarrow \quad \frac{\Delta t}{5} = \frac{45-20}{35-20} = \frac{25}{15} = 5/3$$

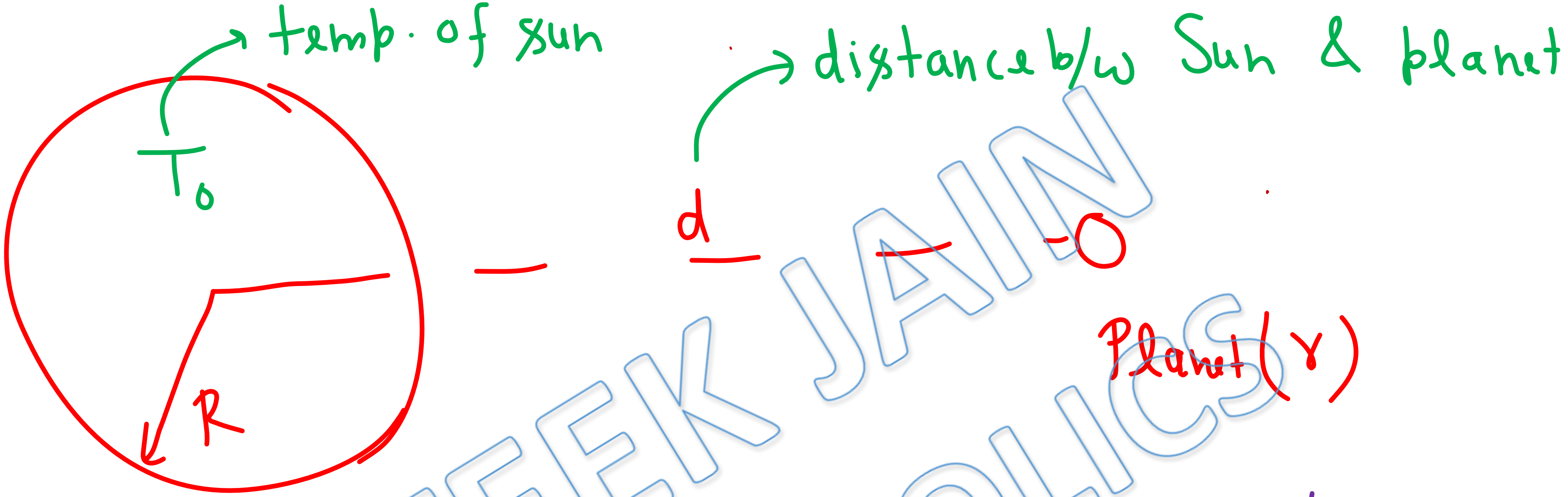
$$\Rightarrow \quad \Delta t = \frac{25}{3} \text{ minute}$$

Ans(c)

Q) A planet is at an average distance d from the sun, and its average surface temperature is T. Assume that the planet receives energy only from the sun, and loses energy only through radiation from its surface. Neglect atmospheric effects. If $T \propto d^{-n}$, the value of n is

(a) 2
(b) 1
(c) 1/2
(d) 1/4

Ans. c



Power of sun $= e\sigma\, 4\pi R^2 T_0^4$

Intensity at surface of planet $= \dfrac{e\sigma \times 4\pi R^2 T_0^4}{4\pi d^2}$

Power absorbed by planet $= \dfrac{e\sigma R^2 T_0^4}{d^2} \times \pi r^2$

Energy radiated by planet $= e' \sigma 4\pi r^2 T^4$

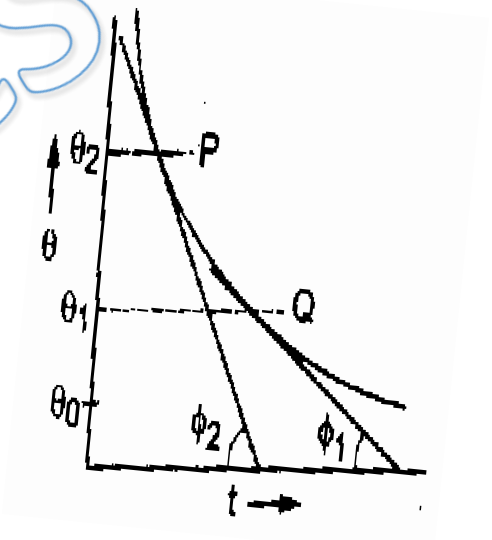
$$\Rightarrow \quad e' \sigma 4\pi r^2 T^4 = \frac{e \sigma R^2 T_0^4}{d^2} \times \pi r^2$$

$$\Rightarrow \quad T^4 \propto \frac{1}{d^2}$$

$$T \propto \frac{1}{\sqrt{d}}$$

Ans(c)

Q) A body cools in a surrounding which is at a constant temperature of θ_0. Assume that it obeys Newton's law of cooling. Its temperature θ is plotted against time t. Tangents are drawn to the curve at the points $P(\theta = \theta_1)$ and $Q(\theta = \theta_2)$. These tangents meet the time axis at angles of ϕ_2 and ϕ_1, as shown.



(a) $\frac{\tan\varphi_2}{\tan\varphi_1} = \frac{\theta_1-\theta_0}{\theta_2-\theta_0}$ (b) $\frac{\tan\varphi_2}{\tan\varphi_1} = \frac{\theta_2-\theta_0}{\theta_1-\theta_0}$

(c) $\frac{\tan\varphi_1}{\tan\varphi_2} = \frac{\theta_1}{\theta_2}$ (d) $\frac{\tan\varphi_1}{\tan\varphi_2} = \frac{\theta_2}{\theta_1}$

Ans. b

In temperature (θ) - t graph Slope $= \frac{d\theta}{dt}$

$$\frac{d\theta}{dt} = -bA(\theta - \theta_0) = -\tan\phi$$

$\phi \rightarrow$ angle of tangent with -ve t axis.

$$\Rightarrow \quad \tan\phi = bA(\theta - \theta_0)$$

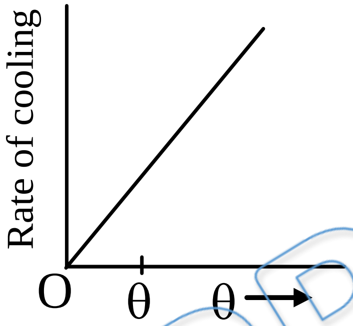
$$\Rightarrow \quad \tan\phi_1 = bA(\theta_1 - \theta_0)$$

$$\tan\phi_2 = bA(\theta_2 - \theta_0)$$

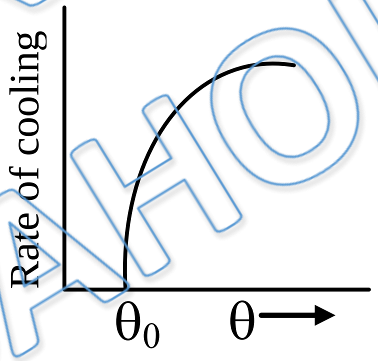
$$\Rightarrow \frac{\tan\phi_1}{\tan\phi_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$$

Q) If the temperature of a body (θ) is slightly more than the temperature of the surrounding (θ_0), then the rate of cooling is correctly represented by –

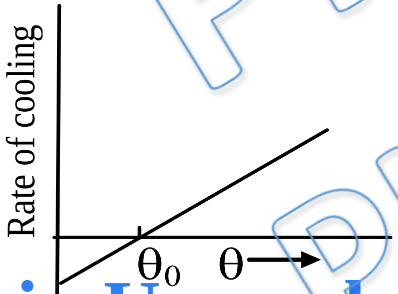
(A)



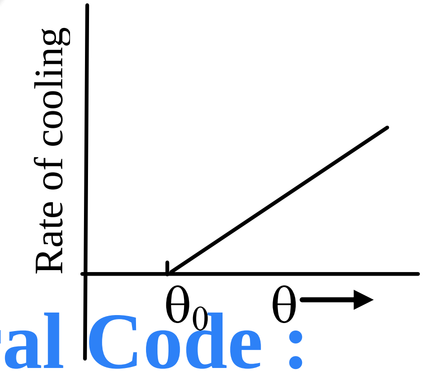
(B)



(C)



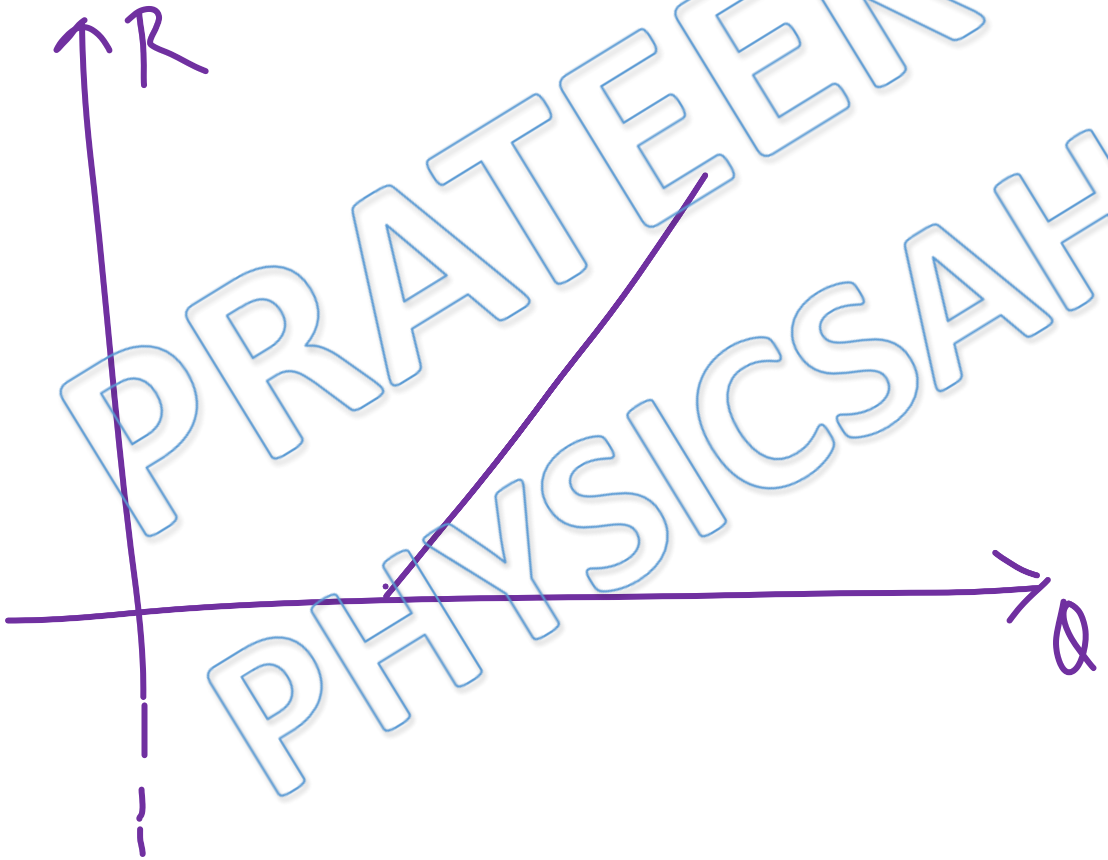
(d)



Ans. d

$$R = -\frac{d\theta}{dt} = bA(\theta - \theta_0)$$

$$\Rightarrow R = bA\theta - bA\theta_0$$



Ans(d)

Q) Two identical spheres A and B are suspended in an air chamber which is maintained at a temperature of 50^0C. Find the ratio of heat lost per sec from the surface of A to that of B, if A and B are at temperature 60^0 and 55^0C respectively.

Ans. 2

Since temperature difference with surrounding is small.

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

$$\Rightarrow \quad \frac{R_1}{R_2} = \frac{60-50}{55-50} = \frac{10}{5} = 2$$

Ans (2)

Q) A hot body placed in air is cooled according to Newton's law of cooling, the rate of decrease of temperature being K times the temperature difference from the surroundings. Starting from t = 0, the time in which the body loses half the maximum heat is given by $\frac{lnx}{K}$, where x is equal to

Ans. 2

Body looses half the maximum heat $\Rightarrow$ temperature falls to half of max fall.

$$-\frac{dT}{dt} = bA(T-T_0)$$

$$\Rightarrow \int_{T_i}^{T} \frac{dT}{T-T_0} = -bA\int_0^t dt \Rightarrow \ln\left(\frac{T-T_0}{T_i-T_0}\right) = -bAt$$

At half of maximum fall of temperature

$$T-T_0 = \frac{T_i-T_0}{2}$$

$$\Rightarrow \quad t = \frac{\ln 2}{bA}$$

Ans (2)

For Video Solution of this DPP, Click on below link

Video Solution on Website:-

https://physicsaholics.com/home/courseDetails/68

Video Solution on YouTube:-

https://youtu.be/EirLXuNXWbk

Chalo Niklo