Physicsaholics

DPP – 4 (Heat Transfer)

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Passage (Q.1 to Q.4)

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 1. 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

Q 2. 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) $\frac{40}{3}W$

Q 3. 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

Q 4. 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

Q 5. 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

Q 6. A planet having surface temperature T has solar constant S. An angle θ is subtended by the sun at planet then
(a) S ∝ T^2
(b) S ∝ T

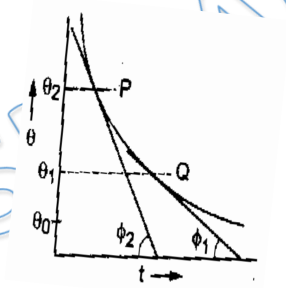
(c) S ∝ θ^0
(d) S ∝ θ^2

Q 7. 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

Q 8. 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

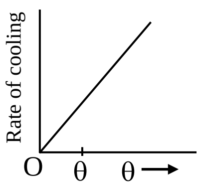
Q 9. A planet is at an average distance d from the sun, and its average surface temperature is T. Assume that the planet receives energy only from the sun, and loses energy only through radiation from its surface. Neglect atmospheric effects. If $T \propto d^{-n}$, the value of n is
(a) 2 (b) 1
(c) 1/2 (d) 1/4

Q 10. 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.

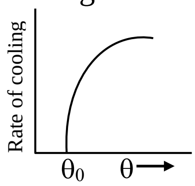


(a) $\frac{\tan\varphi_2}{\tan\varphi_1} = \frac{\theta_1-\theta_0}{\theta_2-\theta_0}$ (b) $\frac{\tan\varphi_2}{\tan\varphi_1} = \frac{\theta_2-\theta_0}{\theta_1-\theta_0}$
(c) $\frac{\tan\varphi_1}{\tan\varphi_2} = \frac{\theta_1}{\theta_2}$ (d) $\frac{\tan\varphi_1}{\tan\varphi_2} = \frac{\theta_2}{\theta_1}$

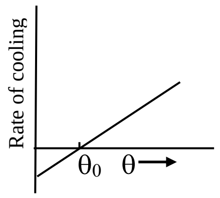
Q 11. If the temperature of a body (θ) is slightly more than the temperature of the surrounding (θ_0), then the rate of cooling is correctly represented by –

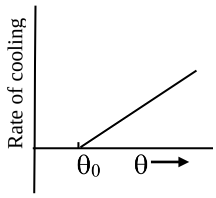


(A)



(B)

(C) 

(d) 

Q 12. 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.

Q 13. 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 $\frac{\ln x}{K}$, where x is equal to

Q 14. 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) $Q_A=Q_B=Q_C$

Q 15. 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

Q 16. 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 × 10^{-3} mK , Then

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

Q 17. 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

Q 18. Two bodies A and B have thermal emissivity's 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

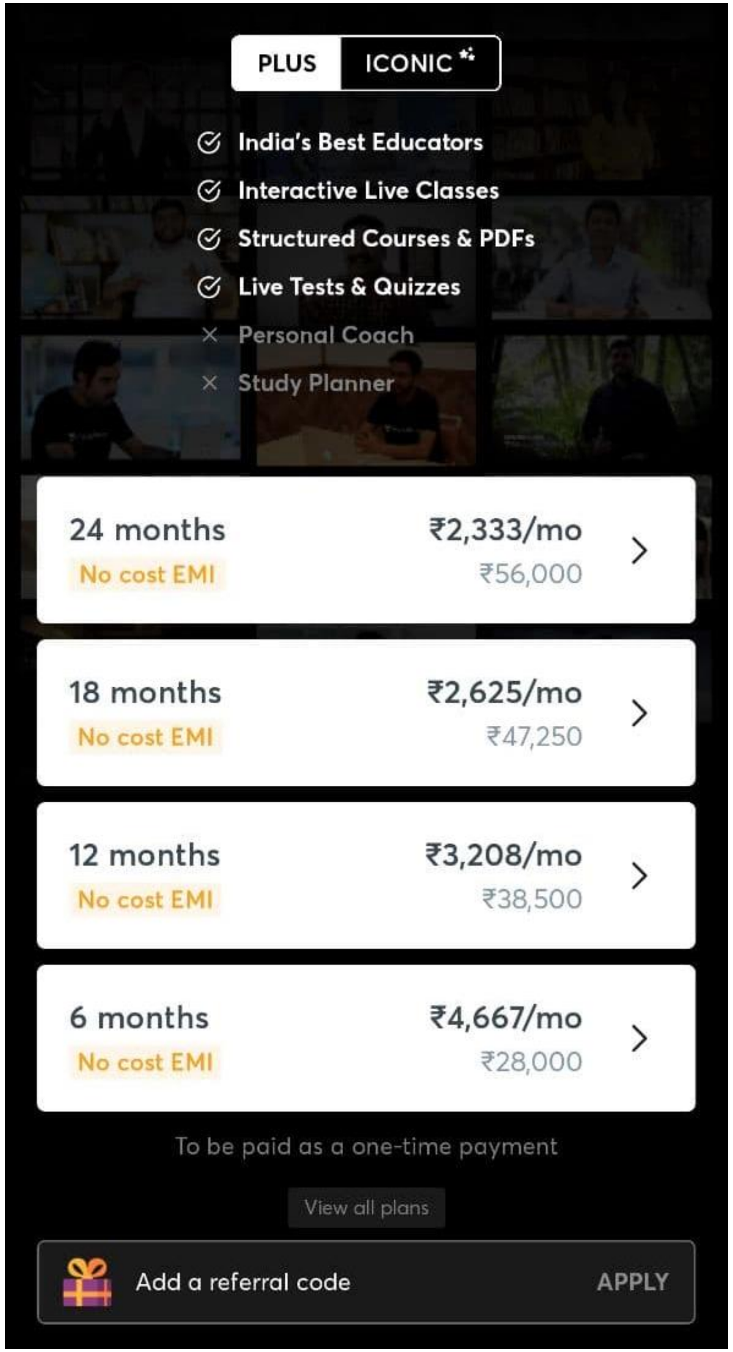
(b) λ_B = 1.5μm

(c) the temperature of B is 11604 K

(d) the temperature of B is 2901 K

Answer Key

Q.1 c	Q.2 b	Q.3 d	Q.4 a	Q.5 c
Q.6 d	Q.7 d	Q.8 c	Q.9 c	Q.10 b
Q.11 d	Q.12 2	Q.13 2	Q.14 b	Q.15 a, c
Q.16 a, b	Q.17 A(r), B(p), C(q), D(p)	Q.18 a, b		



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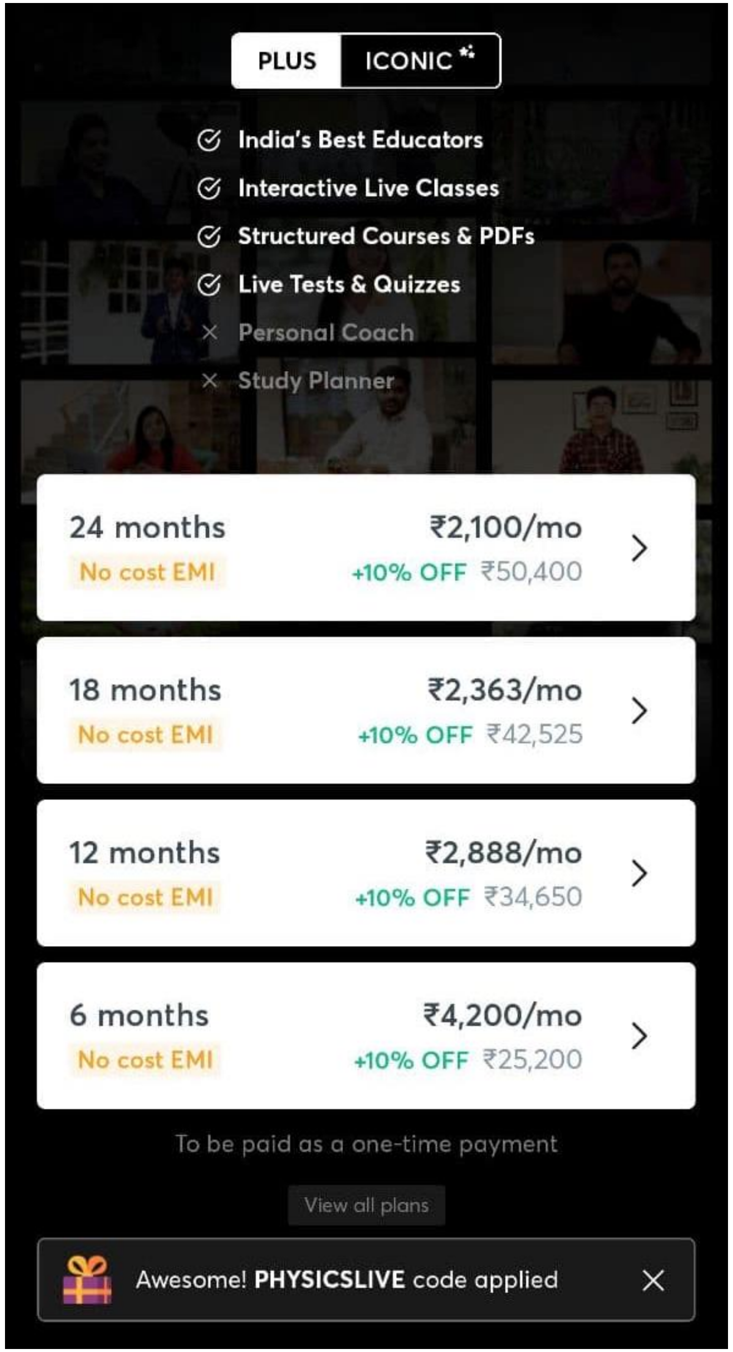

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Written Solution

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

By Physicsaholics Team

Solution.1

At $T = 50^\circ C$

$$\frac{dT}{dt} = 0 \Rightarrow \frac{d\theta}{dt} = 0$$

Power loss to surrounding = Power gain by heater

= 20W

Ans(c)

Solution.2

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

$$\frac{\text{Rate of heat loss at } 30^\circ}{\text{,, ,, ,, ,, ,, } 50^\circ} = \frac{30-20}{50-20} = \frac{10}{30}$$

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

Ans (b)

Solution.3

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)

Solution.4

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)

Solution.5

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

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

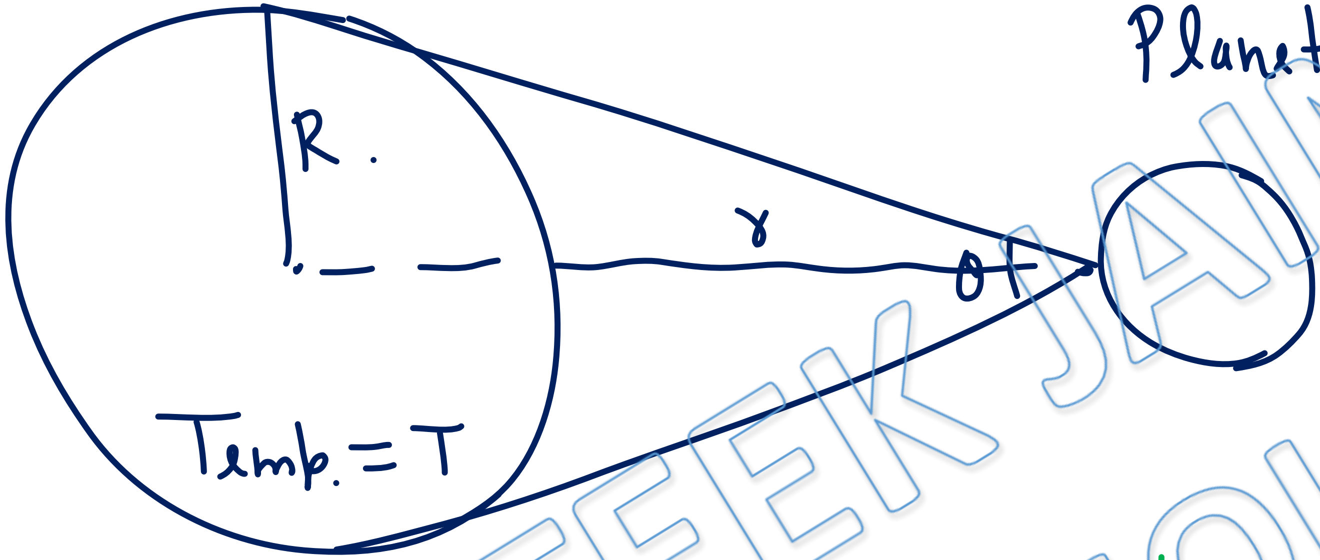
$$\Rightarrow \frac{55-45}{\Delta t} = CA\left(\frac{55+45}{2} - 30\right)$$

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

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

Ans(c)

Solution.6



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)

Solution.7

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

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

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

for A → $\rho s = 2\times 3 = 6$

for B → $\rho s = 3\times 6 = 18$

for C → $\rho s = 5\times 2 = 10$

for D → $\rho s = 1\times 4 = 4$

Ans.d

Solution.8

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

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

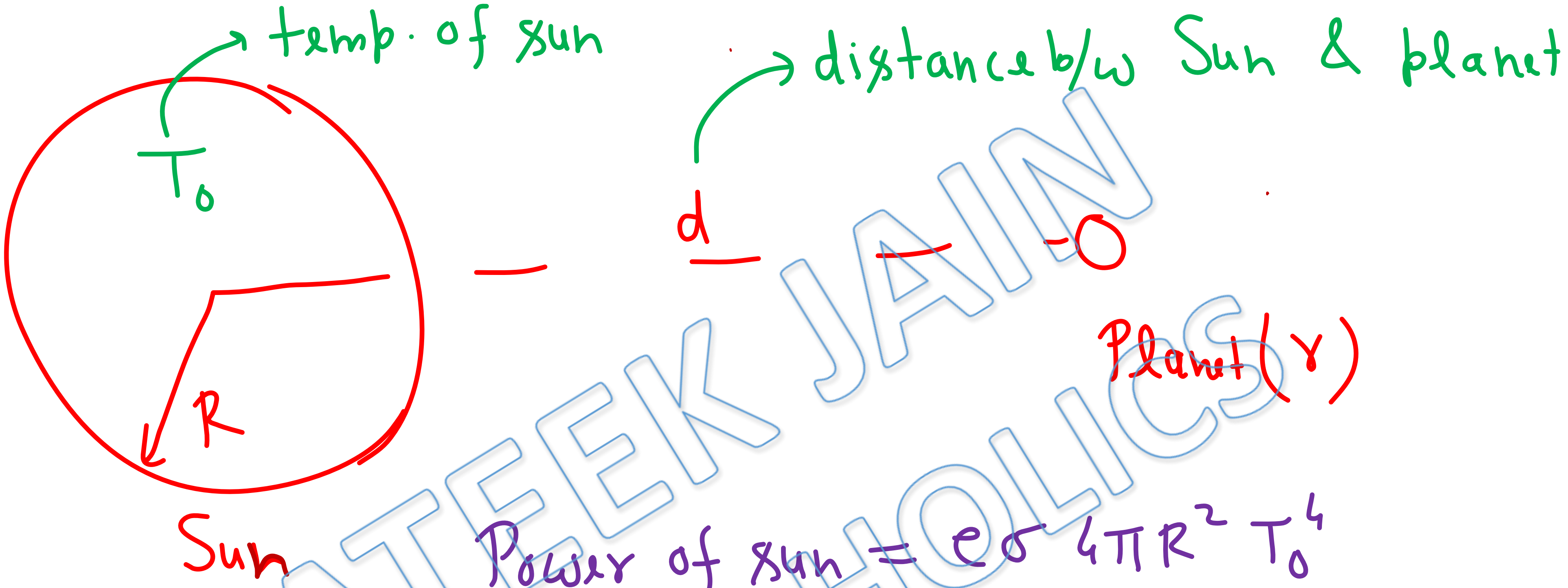
$$\Rightarrow \quad \frac{40-30}{\Delta t} = CA\left(\frac{40+30}{2} - 20\right)$$

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

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

Ans(c)

Solution.9



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)

Solution.10

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

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

ϕ → angle of tangent with -ve t axis.

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

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

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

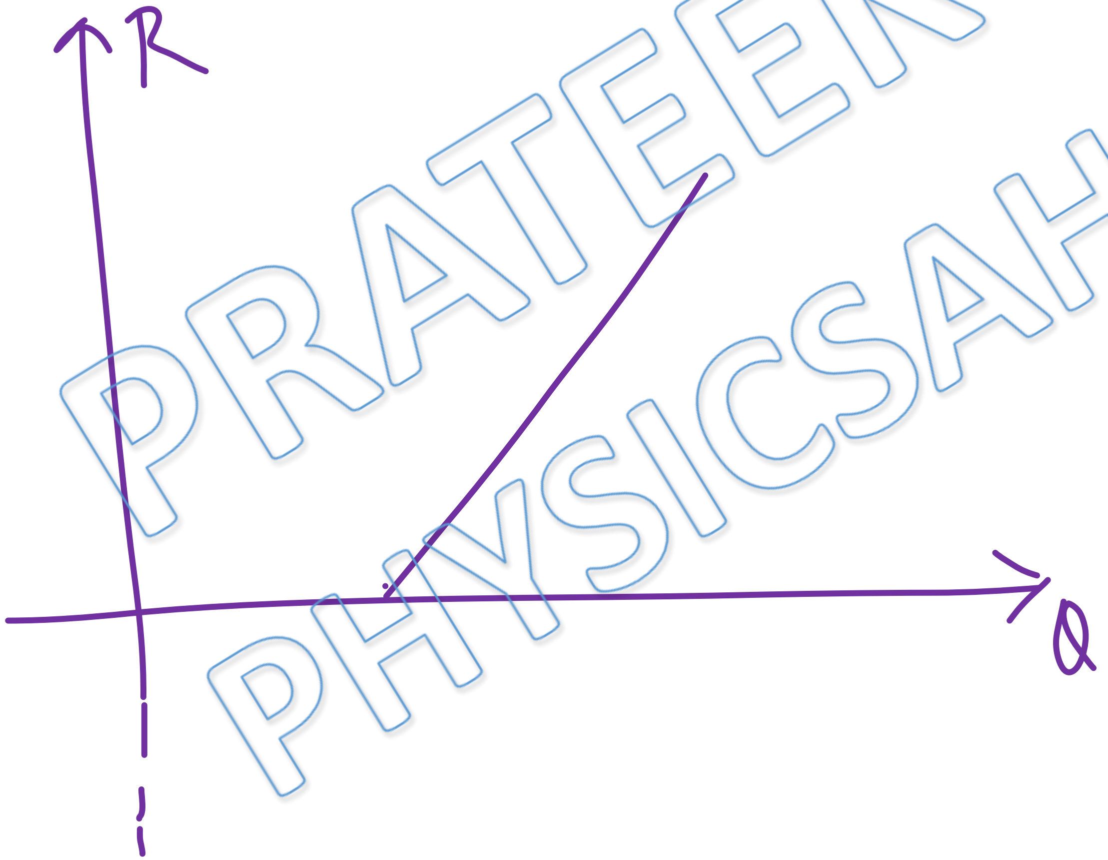
$$\Rightarrow \frac{\tan\phi_1}{\tan\phi_2} = \frac{\theta_1-\theta_0}{\theta_2-\theta_0}$$

Ans.b

Solution.11

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

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



Ans(d)

Solution.12

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)

Body looses half the maximum heat ⇒ temperature falls to half of max fall.

Solution.13

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

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

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)

Solution.14

$\lambda \rightarrow$ wavelength corresponding to maximum 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 $\rightarrow \frac{r^2}{\lambda^4} = \frac{36}{625 \times 10^8} = \frac{4}{69 \times 10^8}$

$\Rightarrow Q_B > Q_C > Q_A$

Ans(b)

Solution.15

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)

Solution.16

$$\lambda_m T = b$$

$$\Rightarrow \lambda_m = \frac{2.88 \times 10^{-3}}{2880} = 10^{-6}\,m = 10000\,A^0$$

$\Rightarrow$ U_2 is greater than U_1 & U_3

Ans (a, b)

Solution.17

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)

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

Solution.18

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

$$(e\sigma AT^4)_A = (e\sigma AT^4)_B$$

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)

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Chalo Niklo