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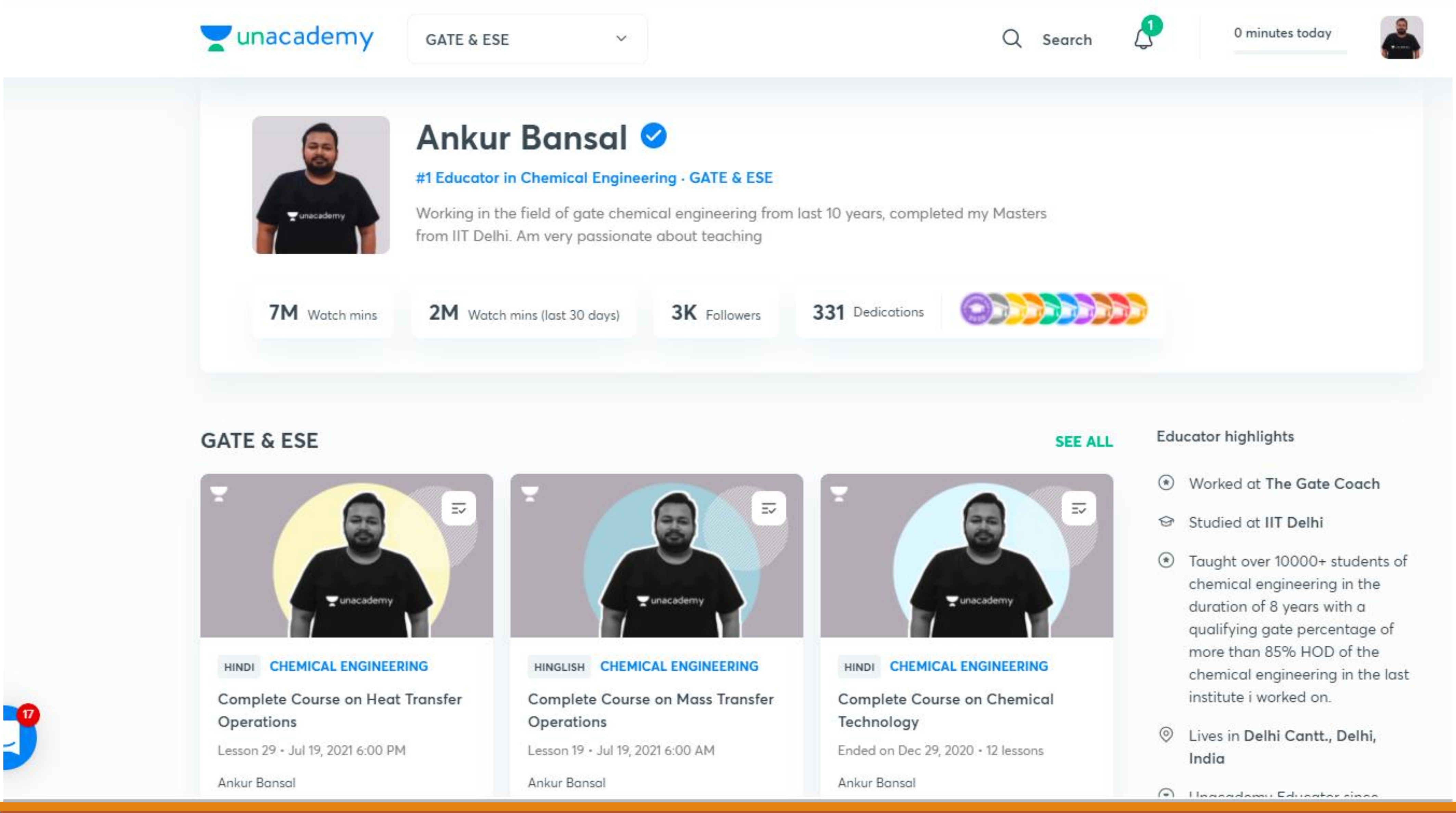

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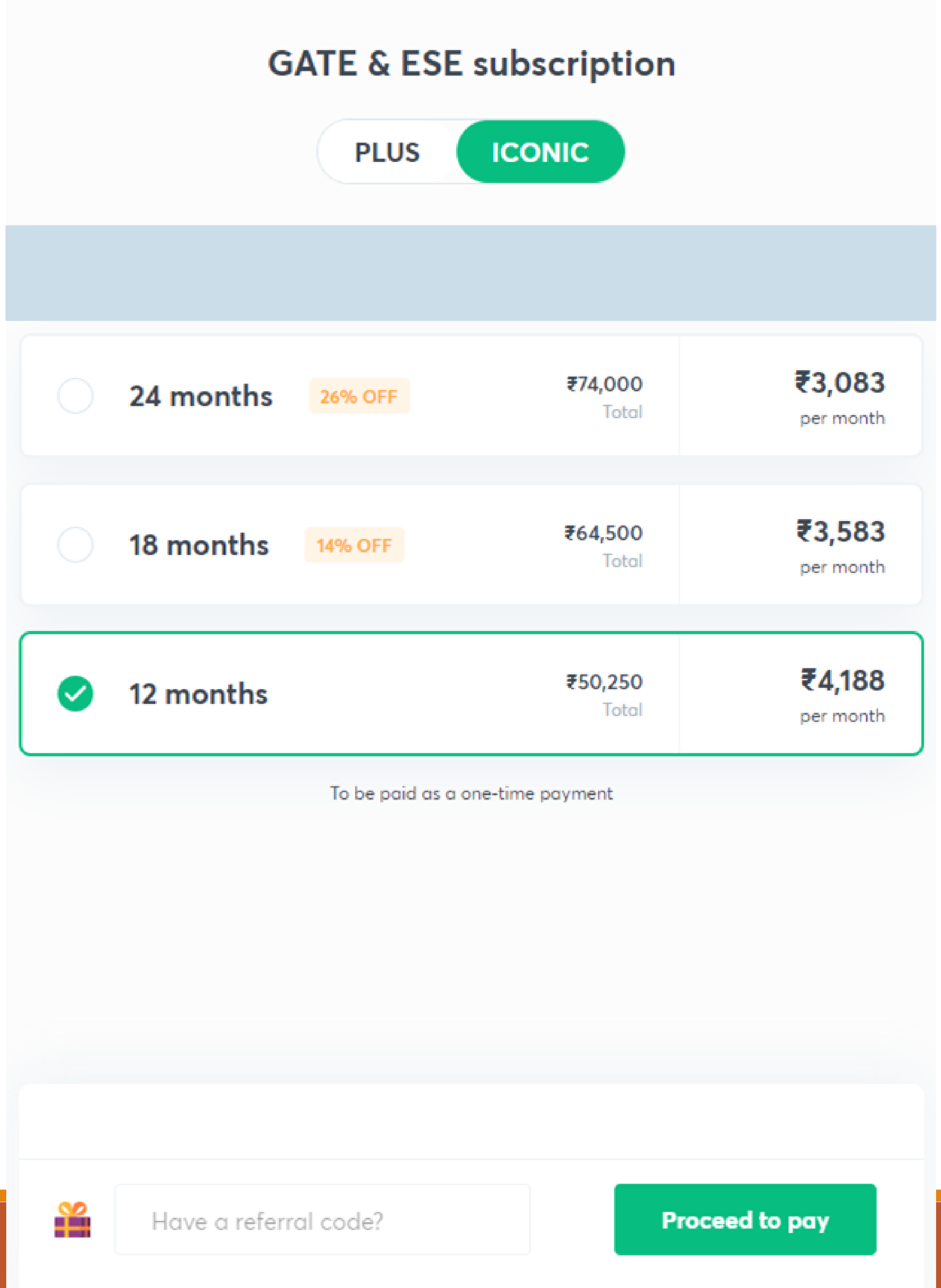
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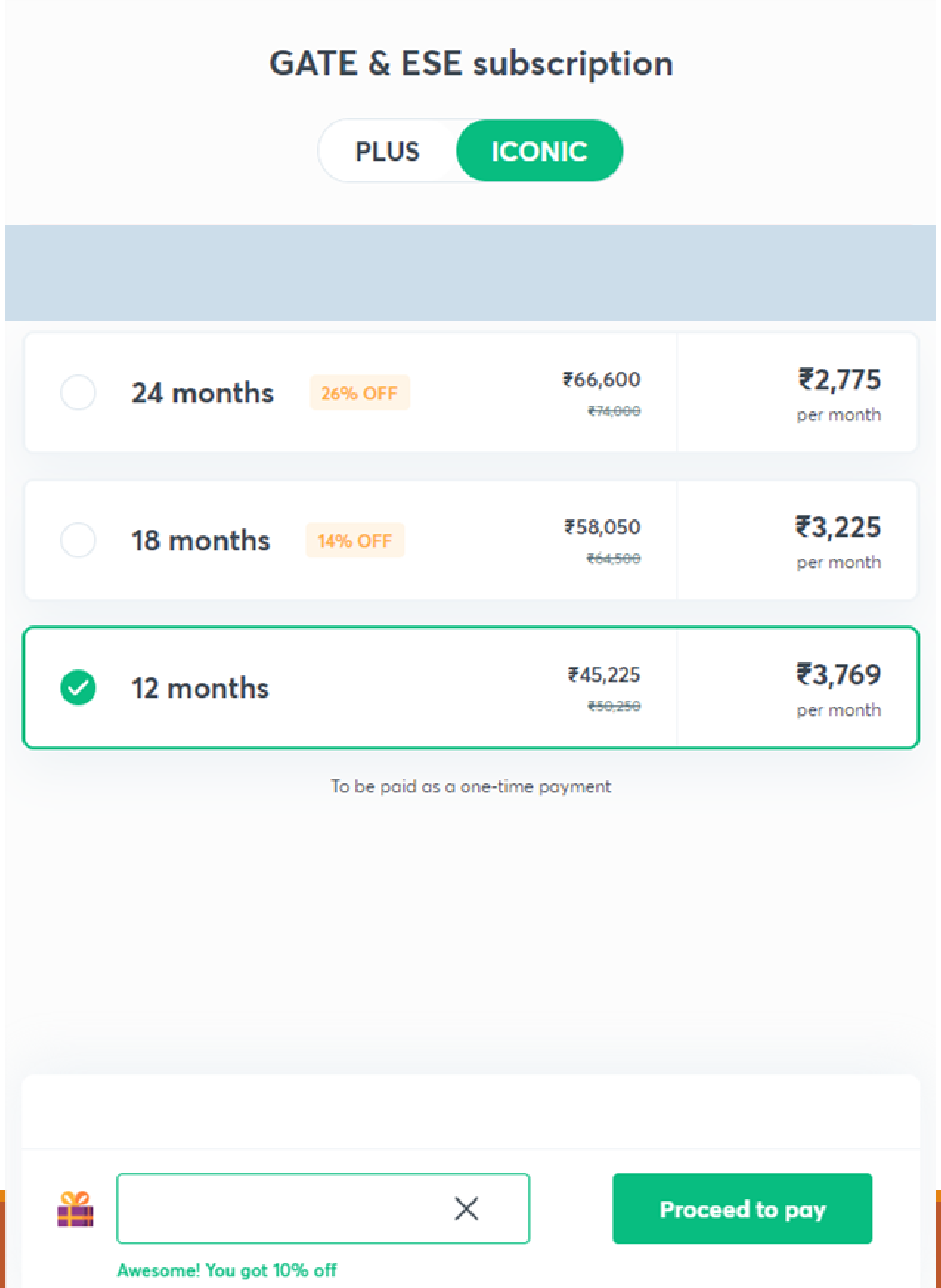
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HEAT TRANSFER

CONVECTION PYQ QUESTION

GATE 2001

1. Heat transfer by natural convection is enhanced in systems with

(a) High viscosity

(b) High coefficient of thermal expansion

(c) Low temperature gradients

(d) Low density change with temperature

Sol. B

For natural convection

$$Nu = f'\left(G_{r'} P_r\right)$$

$$\frac{hL}{k} = f\left[\frac{\rho^2 L^3 g \beta \Delta T}{\mu}, \frac{C_p \mu}{k}\right]$$

$$\therefore \ h \propto \beta$$

(thermal expansion coefficient)

2. The Sieder-Tate correlation for heat transfer in turbulent flow in a pipe gives $Nu \propto Re^{0.8}$, where Nu is the Nusselt number and Re is the Reynolds number for the flow. Assuming that this relation is valid, the heat transfer coefficient varies with pipe diameter (D) as

(a) $D^{-1.8}$ (b) $D^{-0.2}$

(c) $D^{0.5}$ (d) $D^{1.8}$

Sol. B

Sieder – Tate correlation for heat transfer

$$St = 0.023\, Re^{-0.2}\ Pr^{-\frac{2}{3}} \left(\frac{\mu_b}{\mu_w}\right)^{0.14}$$

$$\frac{Nu}{Re\,Pr} = 0.023\, Re^{-0.2}\ Pr^{-\frac{2}{3}}\ \frac{\mu_b}{\mu_w}^{0.14}$$

$$\therefore\ Nu = 0.023\, R_e^{0.8}\ Pr^{\frac{1}{3}}\ \frac{\mu_b}{\mu_w}^{0.14}$$

$$Nu \propto Re^{0.8}$$

$$\frac{h\,D}{k} \propto \left(\frac{\rho VD}{\mu}\right)^{0.8}$$

$$\therefore\ h \propto D^{-0.2}$$

3. In forced convection, the Nusselt number Nu is a function of

(A) Re and Pr

(B) Re and Gr

(C) Pr and Gr

(D) Re and Sc

A is the correct answer

GATE 2005

1. Consider the flow of a gas with density 1 kg/m^3, viscosity 1.5×10^{-5} kg/(ms), specific heat C_p = 846 (J/kg K) and thermal conductivity k = 0.01665 W/(mK), in a pipe of diameter D = 0.01 m and length L = 1 m, and assume the viscosity does not change with temperature. The Nusselt number for a pipe with (L/D) ratio greater than 10 and Reynolds number greater than 20000 is given by $Nu = 0.026\ Re^{0.8}\ Pr^{1/3}$ While the Nusselt number for a laminar flow for Reynolds number less than 2100 and (Re Pr D/L) < 10 is $Nu = 1.86\ [Re\ Pr\ (D/L)]^{1/3}$. If the gas flows through the pipe with an average velocity of 0.1 m/s, the heat transfer coefficient is

(A) 0.68 $W/(m^2\ K)$

(B) 1.14 $W/(m^2\ K)$

(C) 2.47 $W/(m^2\ K)$

(D) 24.7 $W/(m^2\ K)$

Ans(C)

$$Re = \frac{\rho\ uD}{\mu} = \frac{1\times 0.1\times 0.01}{1.5\times 10^{-5}} = 66.67$$

$$\text{Prandtl Number, } Pr = \frac{C_{P.}\mu}{K} = \frac{846\times 1.5\times 10^{-5}}{0.01665} = 0.76$$

$$\frac{D}{L} = \frac{0.01}{1} = 0.01$$

Since Re < 2100 and Pr<10,so by given equation

$$Nu = 1.86[RePr(D/L)]^{1/3}$$

$$\frac{hD}{K} = 1.86[66.67\times 00.76\times 0.01/3]$$

$$\Rightarrow \quad \frac{h\times 0.01}{0.01665} = 1.86[0.506692]^{1/3}$$

$$\Rightarrow \quad h = 2.47 W/m^2k$$

GATE 2006

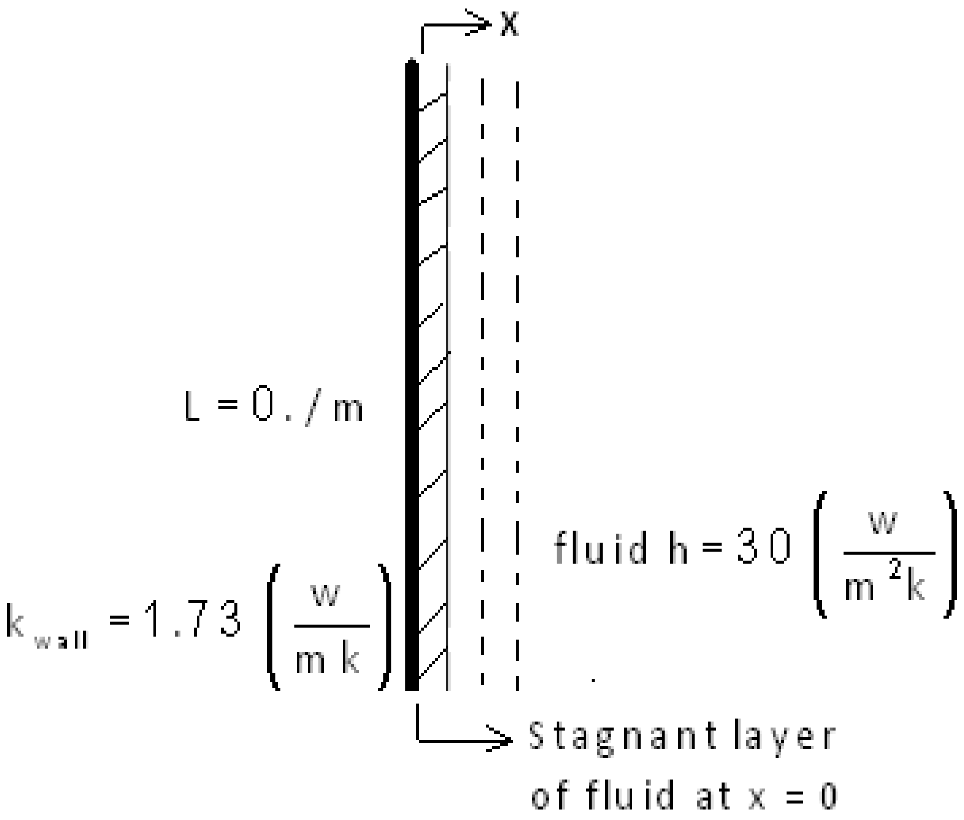
1. One dimensional steady state heat transfer occurs from, a flat vertical wall of length 0.1 m into the adjacent fluid. The heat flux into this fluid is 21 W/m^2. The wall thermal conductivity is 1.73 W/(mK). If the heat transfer coefficient is 30 $W/(m^2K)$ and the Nusselt number based on the wall length is 20, then the magnitude of the temperature gradient at the wall on the fluid side (in K/m) is

(A) 0.7 (B) 12.14

(C) 120 (D) 140

Sol. (D)

We know that



$$q = 21\left(\frac{w}{m^2}\right)$$

$$h = 30\left(\frac{w}{mk}\right)$$

$$Nu = \frac{hL}{k_{fluid}} \Rightarrow k_{fluid} = \frac{hL}{Nu} = 0.15$$

$$k_{fluid} = 0.15\frac{W}{mK}$$

Now flux of heat transfer through stagnant layer

[at x = 0] = flux of heat convected by fluid

$$k_{fluid}\left(\frac{\partial T}{\partial x}\right)_{x=0} = h\left[T_w - T_\infty\right]$$

$$\frac{Q}{A} = q = k_{fluid}\left(\frac{\partial T}{\partial x}\right)_{x=0} = h\left[T_w - T_\infty\right]$$

$$\left(\frac{\partial T}{\partial x}\right)_{x=0} = \frac{q}{k_{fuid}} = 140\left(\frac{K}{m}\right)$$

GATE 2008

1. Hot liquid is flowing at a velocity of 2 m/s through a metallic pipe having an inner diameter of 3.5 cm and length 20 m. The temperature at the inlet of the pipe is 90°C. Following data is given for liquid at 90°C.

Density = 950 kg/m^3 ;

Specific heat = 4.23 kJ/(kg °C)

Viscosity = 2.55×10^{-4} kg/(m.s);

Thermal conductivity = 0.685 W/(m °C)

The heat transfer coefficient in ($kW/m^2\,^oC$) inside the tube is

(A) 222.22 (B) 111.11

(C) 22.22 (D) 11.11

(D)

$$Re = \frac{\rho VD}{\mu} = 260784 \text{ which is} > 2100$$

From turbulent condition,

$$Nu = 0.023(Re)^{0.8}(Pr)^{0.3} \quad \text{(Because the fluid is getting cooled)}$$

$$\Rightarrow \frac{h_i 1}{k} = 0.023\left(\frac{\rho VD}{\mu}\right)^{0.8}\left(\frac{C\rho\mu}{k}\right)^{0.3}$$

$$\Rightarrow h_i = \frac{0.023\times k}{1}\left(\frac{\rho VD}{\mu}\right)^{0.8}\left(\frac{C\rho.\mu}{k}\right)^{0.3}$$

$$= 11.11$$

GATE 2010

1. The ratio Nusselt number to Biot number is

(a) Conductive resistance of fluid/conductive resistance of solid

(b) Conductive resistance of fluid/convective resistance of fluid

(c) Conductive resistance od solid/conductive resistance of fluid

(d) Unity

(A) is correct answer

GATE 2012

1. If the Nusselt number (Nu) for heat transfer in a pipe varies with Reynolds number (Re) as $Nu \propto Re^{0.8}$ then for constant average velocity in the pipe, the heat transfer coefficient varies with the pipe diameter D as

(A) $D^{-1.8}$ (B) $D^{-0.2}$

(C) $D^{0.2}$ (D) $D^{1.8}$

(B)

we have

$$\frac{hD}{k}\alpha\left(\frac{uD\rho}{\mu}\right)^{0.8}$$

$$h\,\alpha\,D^{-0.2}$$

GATE 2013

1. Calculate the heat required (in kJ, up to 1 digit after the decimal point) to raise the temperature of 1 mole of a solid material from 100°C to 1000°C. The specific heat (C_p) of the material (in J/mol-K) is expressed as $C_p = 20 + 0.005\ T$, where T is in K. Assume no phase change.________

Ans. 21.703

We know that

$$\partial Q = C_p dt = (20 + 0.005T)dT$$

$$_1Q_2 = \int_{T_1}^{T_2} (20 + 0.005T)dT$$

$$= 20(T_2 - T_1) + \frac{0.005}{2}(T_2^2 - T_1^2)$$

$$= (T_2 - T_1)\left[20 + \frac{0.005}{2}(T_2 + T_1)\right]$$

$$= (1273 - 373)\left[20 + \frac{0.005}{2}(1273 + 373)\right]$$

$$= 21703.5\,J$$

$$= 21.7\,kJ$$

GATE 2014

1. The bottom face of a horizontal slab of thickness 6 mm is maintained at 300 ^oC. The top face is exposed to a flowing gas at 30 ^oC. The thermal conductivity of the slab is 1.5 W m^{-1} K^{-1} and the convective heat transfer coefficient is 30 W m^{-2} K^{-1}. At steady state, the temperature (in ^oC) of the top face is _____

Sol. 271. 07

We have

At steady state

Heat flux due to conduction = heat flux due to convection

$$\Rightarrow -k\frac{(573-T_s)}{6\times10^{-3}} = h(T_s-303)$$

$$\Rightarrow 1.5(573-T_s) = 6\times10^{-3}\times(T_s-303)$$

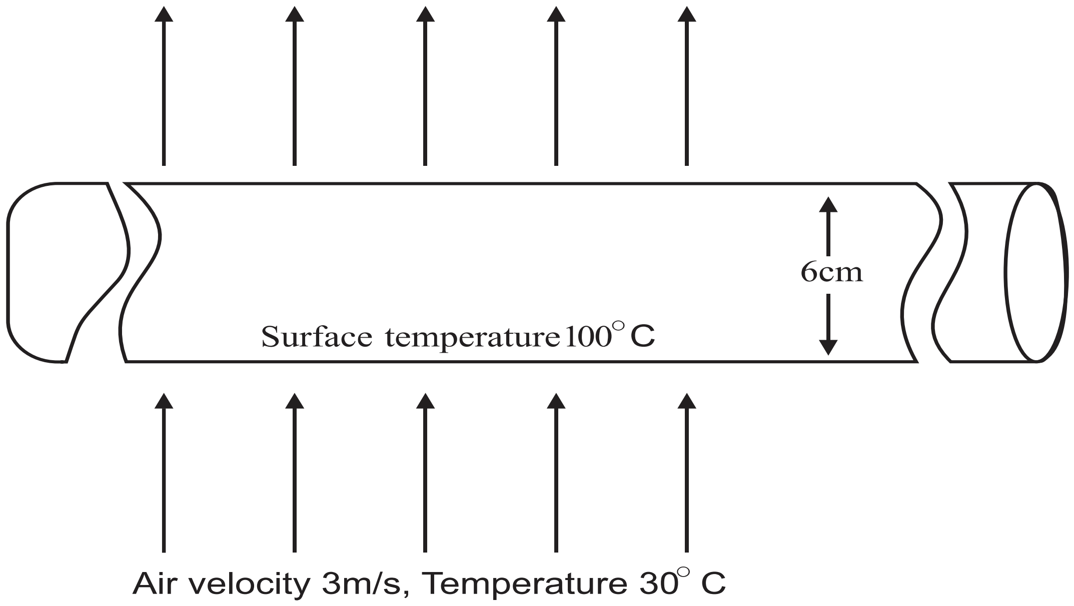
$$859.5-1.5T_s = 0.18T_s-54.54$$

$$T_s = 544.07\text{ K} = 271.07^0\text{C}$$

GATE 2015

1. Air is flowing at a velocity of 3m/s perpendicular to a long pipe as shown in the figure below. The outer diameter of the pipe is d = 6 cm and temperature at the outside surface of the pipe is maintained at 100 °C. The temperature of the air far from the tube is 30 °C. Data for kinematic viscosity, $\vartheta = 18 \times 10^{-6} \frac{m^2}{s}$. Thermal conductivity, $k = 0.3 \frac{W}{mK}$ Using the Nusselt number cor-relation: Nu $= \frac{hD}{k} = 0.024 \times Re^{0.8}$. The rate of heat loss per unit

Length (W / m) from the pipe to air (up to one decimal place) is ____



Answer : 250.9

$$Re = \frac{\rho VD}{\mu} = 10,000$$

$$Nu = 0.024 \times Re^{0.8} = 38.037$$

$$Nu = \frac{hD}{k}, \text{Calculating h comes out to be}, h = 19.019 \frac{W}{m^2K}$$

$$\text{Rate of heat loss} = h\,(\pi DL)\,(T_s - T_\infty)$$

$$\text{Rate of heat loss per unit length} = h\,(\pi D)\,(T_s - T_\infty) = 250.9$$

GATE 2016

93. Match the dimensionless numbers in Group-1 with the ratios in Group-2.

Group-1	Group-2
P. Biot number	I buoyancy force / viscous force
Q. Schmidt number	II. Internal thermal resistance of a solid / boundary layer thermal resistance
R. Grashof number	III. Momentum diffusivity / mass diffusivity

(A) P-II, Q-I, R-III

(B) P-I, Q-III, R-II

(C) P-III, Q-I, R-II

(D) P-II, Q-III, R-I

Ans. D is the correct answer.

GATE 2017

99. A fluid flows over a heated horizontal plate maintained at temperature T_w. The bulk temperature of the fluid is T_∞. The temperature profile in

The thermal boundary layer is given by

$$T = T_w + \left(T_w - T_\infty\right)\left[\frac{1}{2}\left(\frac{y}{\delta_t}\right)^3 - \frac{3}{2}\left(\frac{y}{\delta_t}\right)\right]' \; 0 \le y \le \delta_t$$

Here, y is the vertical distance from the

plate, δ is the thickness of thermal boundary layer and k is the thermal conductivity of the fluid. The local heat transfer coefficient is given by

(A) $\frac{k}{2\delta_t}$

(B) $\frac{k}{\delta_t}$

(C) $\frac{3k}{2\delta_t}$

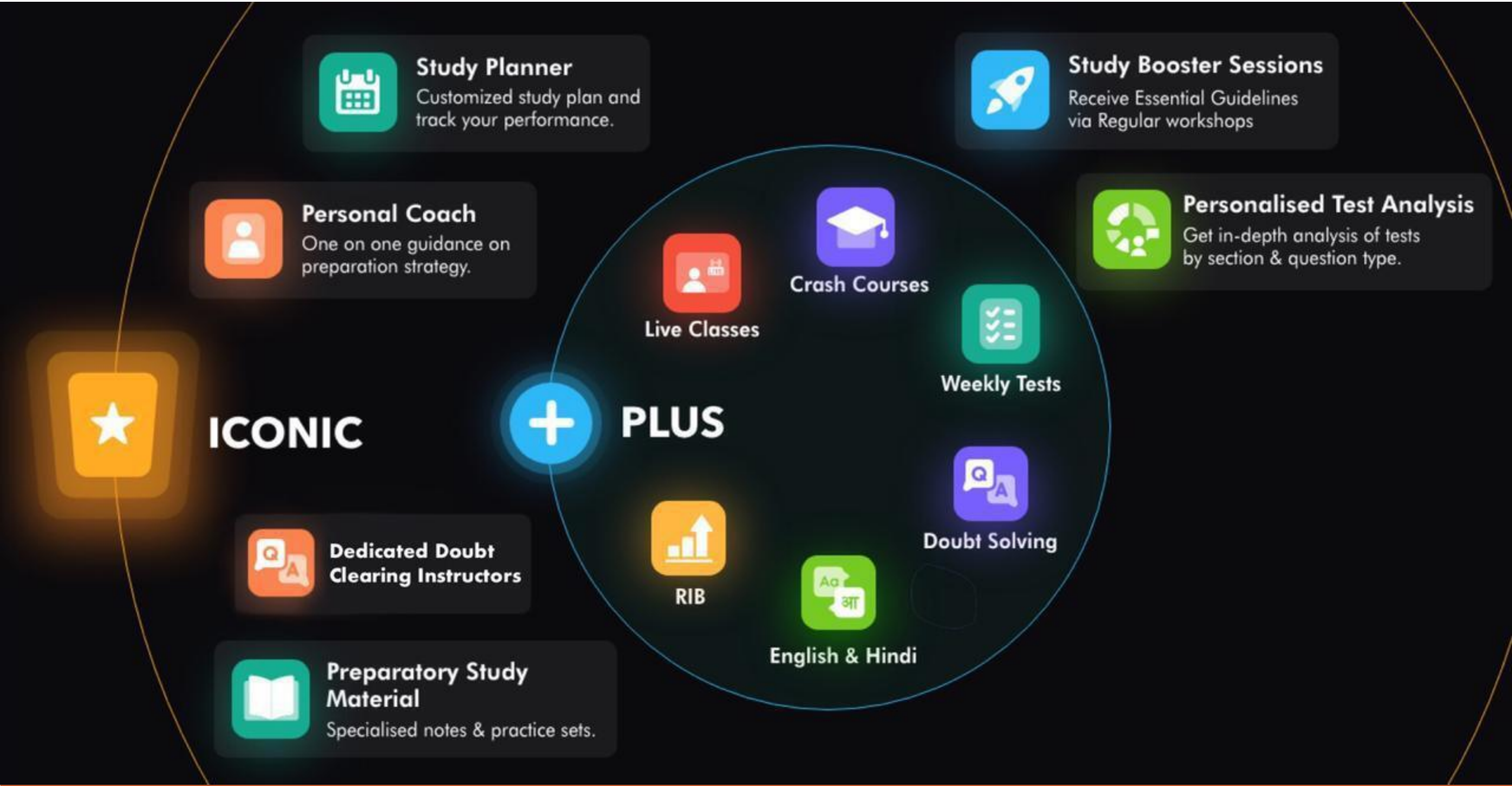
(D) $\frac{2k}{\delta_t}$

Ans. (C)

$$-kA\left.\frac{\partial T}{\partial y}\right|_{y=0} = hA\left(T_w - T_\infty\right)$$

$$h = \frac{-k\left[\left(T_w - T_\infty\right)\left(\frac{1}{2}\cdot\frac{1}{\delta_t^3}.3y^2 - \frac{3}{2}\cdot\frac{1}{\delta_t}\right)\right]_{y=0}}{\left(T_w - T_\infty\right)}$$

$$= \frac{3k}{2\delta_t}$$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