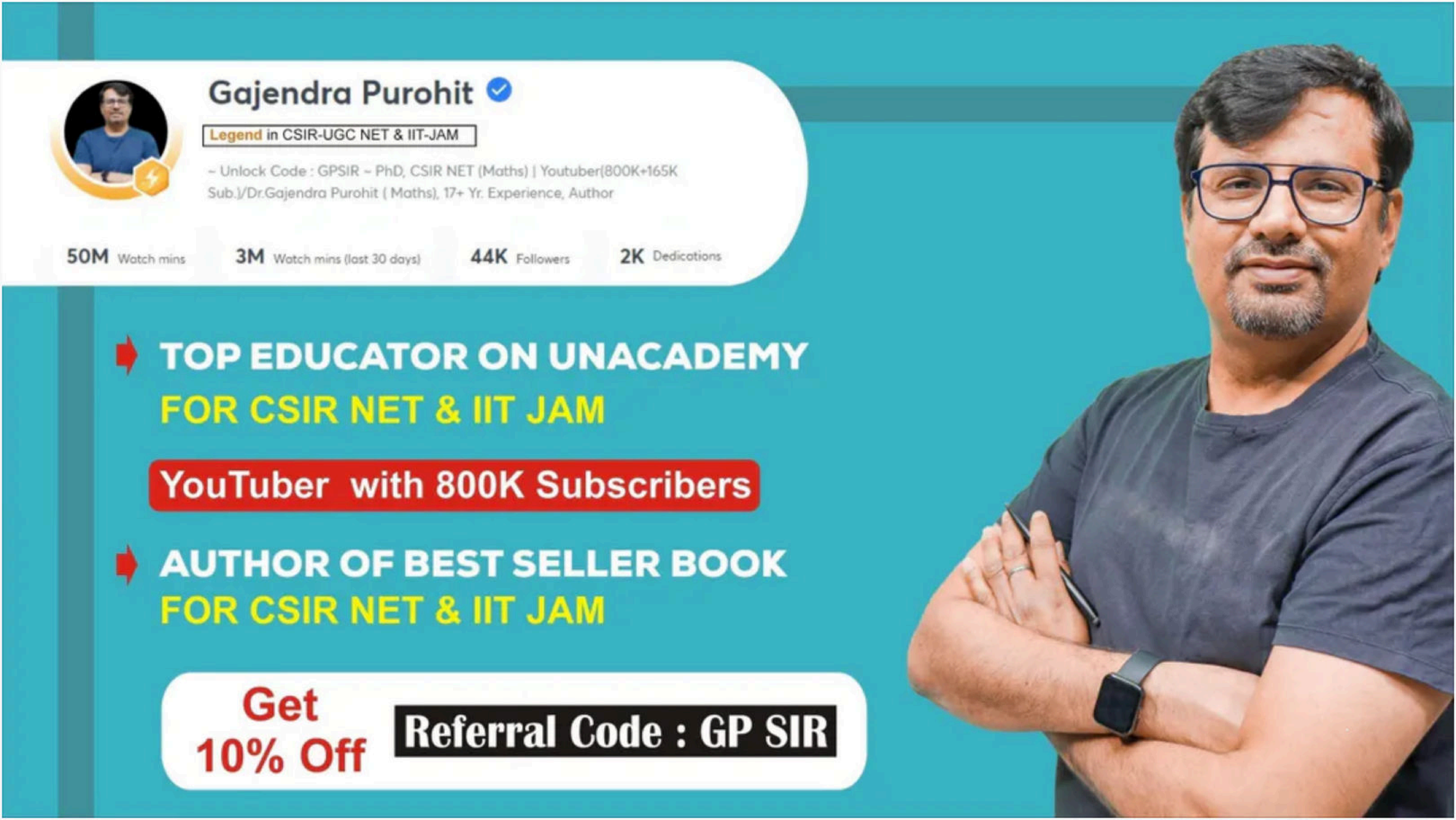

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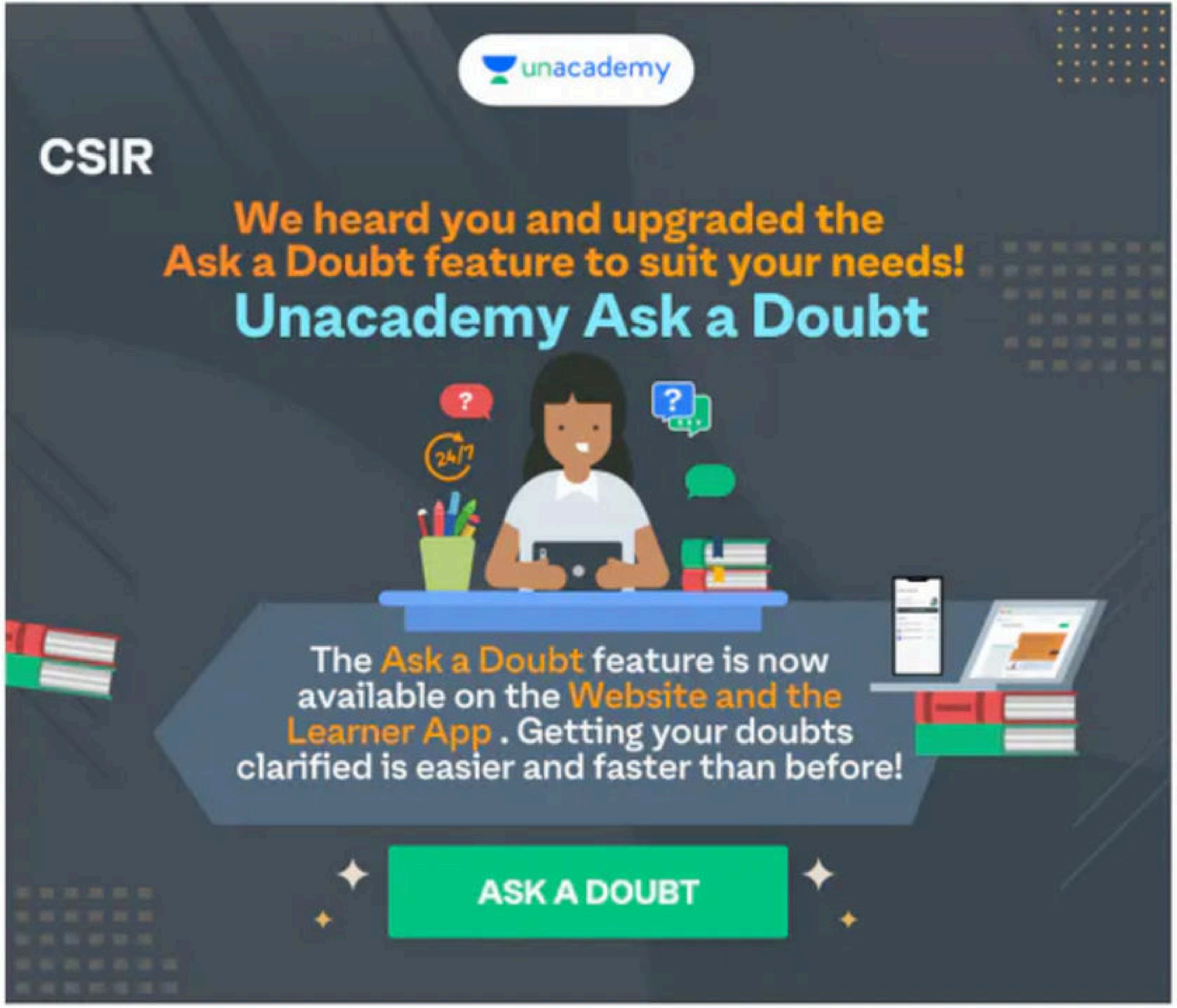
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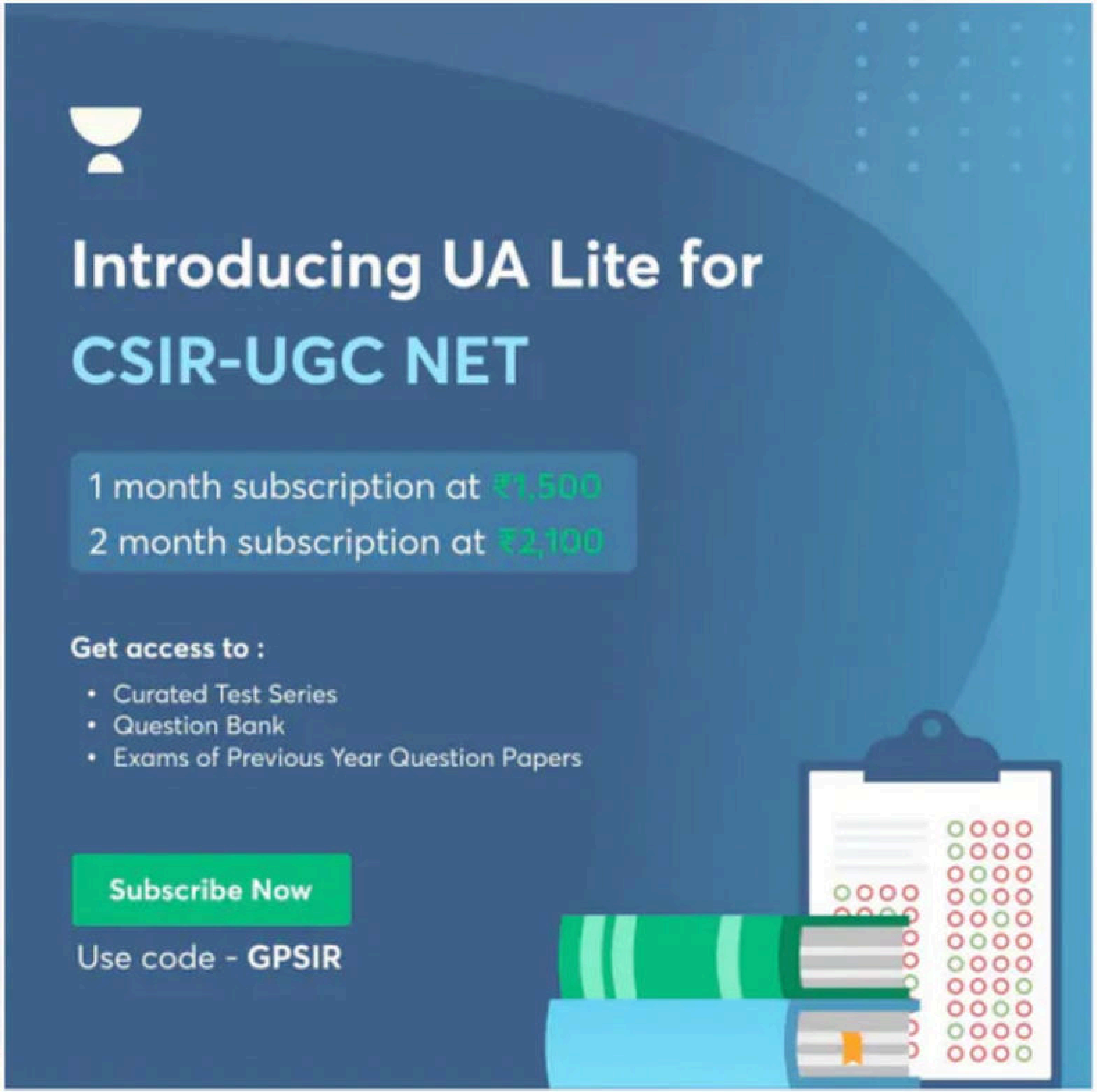
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LINEAR DIFFERENTIAL EQUATION

A first order differential equation is called linear if it can be written in the form $\left(\frac{dy}{dx}\right)+py=Q$,

Where p & Q are constant or function of x alone.

Working rule for solution of LDE

(1) I.F. (Integrating factor)

$$IF=e^{\int Pdx}$$

(2) $IF.y=\int IF.Qdx+C$

Solve this and get required solution.

$$\frac{dy}{dx} + P(x)\,y = Q(x)$$

$$I.F = e^{\int P(x)\,dx}$$

$$y \cdot I.F = \int I.F \, Q \, dx + C$$

$$\frac{dx}{dy} + P(y)\,x = Q(y)$$

$$I.F = e^{\int P(y)\,dy}$$

$$x \cdot I.F = \int I.F \, Q \, dy + C$$

$$x\cos x \frac{dy}{dx} + y(x\sin x + \cos x) = 1$$

$$\frac{dy}{dx} + y\left(\frac{x\sin x + \cos x}{x\cos x}\right) = \frac{1}{x\cos x}$$

$$\frac{dy}{dx} + \left(\tan x + \frac{1}{x}\right)y = \frac{1}{x\cos x}$$

$$IF = e^{\int (\tan x + 1/x)dx}$$

$$= e^{\log\sec x + \log x}$$

$$= e^{\log x\sec x}$$

$$= x\sec x$$

$$y \cdot IF = \int \cancel{r}f\,dx + c$$

$$yx\sec x = \int x\sec x \frac{1}{\cancel{x}\cos x}dx + c$$

$$yx\sec x = \int \sec^2 x\,dx + c$$

$$yx\sec x = \tan x + c$$

$$(1+y^2) + (x - e^{\tan^{-1}y})\frac{dy}{dx} = 0$$

$$(1+y^2)\frac{dx}{dy} + x - e^{\tan^{-1}y} = 0$$

$$(1+y^2)\frac{dx}{dy} + x = e^{\tan^{-1}y}$$

$$\frac{dx}{dy} + \frac{1}{1+y^2}x = \frac{e^{\tan^{-1}y}}{1+y^2}$$

$$x \cdot If = \int If\,Q\,dy + C$$

$$x e^{\tan^{-1}y} = \int e^{\tan^{-1}y}\frac{e^{\tan^{-1}y}}{1+y^2}dy + C$$

$$x e^{\tan^{-1}y} = \int e^{t} \cdot e^{t}\,dt + C$$

$$x e^{\tan^{-1}y} = \frac{e^{2t}}{2} + C$$

$$\frac{dx}{dy} + P(y)x = Q(y)$$

$$If = e^{\int \frac{1}{1+y^2}dy}$$

$$= e^{\tan^{-1}y}$$

$$\tan^{-1}y = t$$

$$\frac{1}{1+y^2}dy = dt$$

$$x e^{\tan^{-1}y} = \frac{e^{2\tan^{-1}y}}{2} + C$$

Note : Consider the first order and first degree linear differential equation $\frac{dy}{dx}+P(x)y=Q(x)$

(1) If P(x) & Q(x) are continuous and bounded for all $\alpha, \beta \in R$ then $\exists$ unique solution such that $u(\alpha)=\beta$.

$$(x^2 - x)\frac{dy}{dx} = (2x-1)y \qquad y(x_0) = y_0$$

$$\frac{dy}{dx} - \frac{2x-1}{x^2-x}\, y = 0$$

~~(a) (2,1)~~

(b) (1,1)

(c) (0,1)

(d) (1,2)

$$P = -\left(\frac{2x-1}{x^2-x}\right)$$

$x=0,\ x=1$

Q.1. Let $\frac{dy}{dx}+\left(\frac{2x+1}{x}\right)y=e^{-2x}$; x > 0, then the solution y(x) of DE is

(a) $y(x) \to 0$ as $x \to \infty$ (b) $y(x) \to \infty$ as $x \to \infty$

(c) $y(x) \to -\infty$ as $x \to \infty$ (d) None of these

$e^{-\infty}=0$

$IF = e^{\int\left(\frac{2x+1}{x}\right)dx}$

$= e^{2x+\log x}$

$= xe^{2x}$

$y.IF = \int IF\, Q\, dx + c$

$yxe^{2x} = \int xe^{2x} \cdot e^{-2x} dx + c$

$yxe^{2x} = x^2/2 + c$

$y = e^{-2x}\left(\frac{x}{2}+\frac{c}{x}\right)$

Q.2. $\frac{dy}{dx}+2xy=e^{-x^2}$, then the general solution of the DE is

(a) y(x) is bounded on R

(b) y(x) is bounded on R^+

(c) $y(x) \to 0$ as $x \to \infty$

(d) $y(x) \to \infty$ as $x \to \infty$

$IF = e^{\int 2x\,dx}$

$= e^{x^2}$

$(-\infty, \infty)$

$y \cdot e^{x^2} = \int e^{x^2} \cdot e^{-x^2} dx + c$

$(0, \infty)$

$y e^{x^2} = x + c$

$y = e^{-x^2}(x+c)$

$e^{-\infty}$

$\lim_{x \to \infty} \frac{x+c}{e^{x^2}} = \lim_{x \to \infty} \frac{1}{e^{x^2} 2x} = 0$

$$\lim_{x \to \infty} \frac{e^{x}+1}{e^{x}+2}$$

$$\lim_{x \to \infty} \frac{\cancel{e^{x}}\left(1+e^{-x}\right)}{\cancel{e^{x}}\left(1+2e^{-x}\right)} = 1$$

Q.3. Solve $\dfrac{dy}{dx}+y=f(x)$ where $f(x)=\begin{cases}1 & 0\le x\le 1\\ 0 & x>1\end{cases}$ s.t. $y(0)=0$.

$y(1)=?$

$0\le x\le 1$

$\dfrac{dy}{dx}+y=1$

$y=c_1e^{-x}+1$

$0=c_1+1$

$c_1=-1$

$\boxed{y=-e^{-x}+1}$

$x>1$

$\dfrac{dy}{dx}+y=0$

$\boxed{y=c_2e^{-x}}$

$-e^{-1}+1=c_2e^{-1}$

$\boxed{c_2=-1+e}$

$y=(e-1)e^{-x}$

$y(1)=(e-1)e^{-1}$

$=\dfrac{e-1}{e}$

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Q.4. $\frac{dy}{dx} - ay = e^{ax}$; y(0) = 0; a ∈ R then

(a) If $a > 0$, $y(x) \to \infty$ as $x \to \infty$

(b) If $a < 0$; y(x) is bounded on R^+.

(c) If $a < 0$; $y(x) \to -\infty$ as $x \to -\infty$.

(d) None of these

$I.F = e^{\int -a\,dx} = e^{-ax}$

$y e^{-ax} = \int e^{-ax} e^{ax} dx + c$

$y e^{-ax} = x + c$

$y = (x + c) e^{+ax}$

$0 = (0 + c) = 0$

$\boxed{y = e^{+ax} x}$

$(0, \infty)$

$a = 2$

$a = -2$

$y = x e^{2x}$

$y = x e^{-2x}$

$= -\infty e^{+2\infty}$

e^{∞}

$e^{-\infty} = 0$

Q $\frac{dy}{dx} + 2y = 2 + e^{-x^2}$, $y(0) = 0$ $\quad IF = e^{2x}$

then $\lim_{x \to \infty} y(x)$

$$y \cdot e^{2x} = \int e^{2x} (2 + e^{-x^2}) \, dx + c$$

$$y e^{2x} = 2 \int e^{2x} \, dx + \int e^{2x - x^2} \, dx + c$$

$$y e^{2x} = \cancel{2} \frac{e^{2x}}{\cancel{2}} + \int e^{2x - x^2} \, dx + c$$

$$y = 1 + e^{-2x} \left[\int e^{2x - x^2} \, dx + c \right]$$

$$(xy + y + e^{-x})\,dx + (x + e^{-x})\,dy = 0, \quad y(0) = 1$$

Then $y(-1) = ?$

(a) $\frac{e}{e-1}$

(b) ~~$\frac{2e}{e-1}$~~

(c) $\frac{e}{1-e}$

(d) 0

$$(x + e^{-x})\frac{dy}{dx} + (x+1)y = -e^{-x}$$

$$\frac{dy}{dx} + \frac{x+1}{x + e^{-x}}\,y = -\frac{e^{-x}}{x + e^{-x}}$$

$$\frac{dy}{dx} + \frac{(x+1)e^{x}}{xe^{x}+1}\,y = \frac{-1}{xe^{x}+1}$$

$$IF = e^{\int \frac{(x+1)e^{x}}{xe^{x}+1}dx}$$

$$e^{\ln(xe^{x}+1)}$$

$$= xe^{x}+1$$

$$y(xe^{x}+1) = -\int \frac{1}{\cancel{xe^{x}+1}}\,\cancel{(xe^{x}+1)}\,dx + C$$

$$y(xe^{x}+1) = -x + C$$

$$1(0+1) = C$$

$$y(xe^{x}+1) = 1 - x$$

$$y(-e^{-1}+1) = 2$$

$$y = \frac{2}{1-e^{-1}} = \frac{2e}{e-1}$$

Q.5 The equation of the curve passing through the point $\left(\frac{\pi}{2},1\right)$ and having slope $\frac{\sin(x)}{x^2}-\frac{2y}{x}$ at each point (x, y) with $x \neq 0$ is

(a) $-x^2y+\cos(x)=\frac{-\pi^2}{4}$

(b) $x^2y+\cos(x)=\frac{\pi^2}{4}$

(c) $x^2y-\sin(x)-\frac{\pi^2}{4}-1$

(d) $x^2y+\sin(x)=\frac{\pi^2}{4}+1$

Bernoulli's equation :

An equation of the form $\frac{dy}{dx}+Py=Qy^n$, where P and Q are constant or function of x alone and n is constant except 0 and 1 is called Bernoulli's equation.

Working rule :

$$\frac{1}{y^n}\frac{dy}{dx}+Py^{1-n}=Q \qquad ....(1)$$

Suppose $y^{1-n}=t$

$$(1-n)y^{-n}\frac{dy}{dx}=\frac{dt}{dx}$$

Put in (1)

$$\frac{1}{(1-n)}\frac{dt}{dx}+P(x)t=Q(x)$$

$$\frac{dt}{dx}+(1-n)P.t=(1-n)Q$$

Which is FOFD linear DE.

Q.6. Consider the ODE $ty' - 3y = t^2y^{1/2}$, $y(1) = 1$. Find the value of $y(2)$

(a) 14 (b) 16

(c) 0 (d) 8

Q.7. Solution of the differential equation

$xy' + \sin 2y = x^3 \sin^2 y$ is

(a) $\cot y = -x^3 + c x^2$ (b) $2\cot y = x^3 + 2c x^2$

(b) $\tan y = -x^3 + c x^2$ (d) $2\tan y = x^3 + 2c x^2$

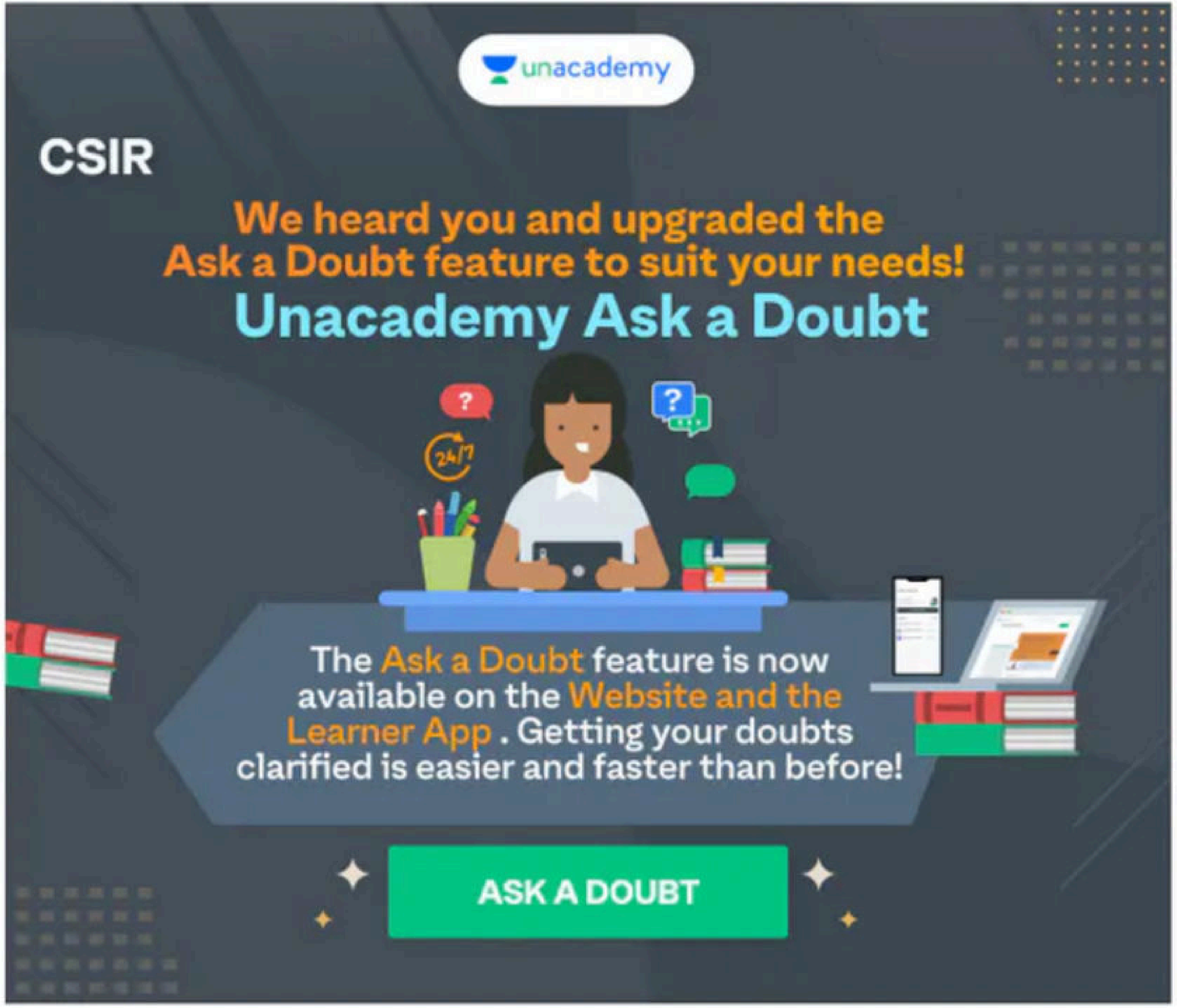
Q.8. The general solution of differential equation $\frac{dy}{dx}=\left(1+y^2\right)\left(e^{-x^2}-2x\tan^{-1}y\right)$ is

(a) $e^{x^2}\tan^{-1}y=x+c$

(b) $e^{-x^2}\tan y=x+c$

(c) $e^{x}\tan y=x^2+c$

(d) $e^{-x}\tan^{-1}y=x^3+c$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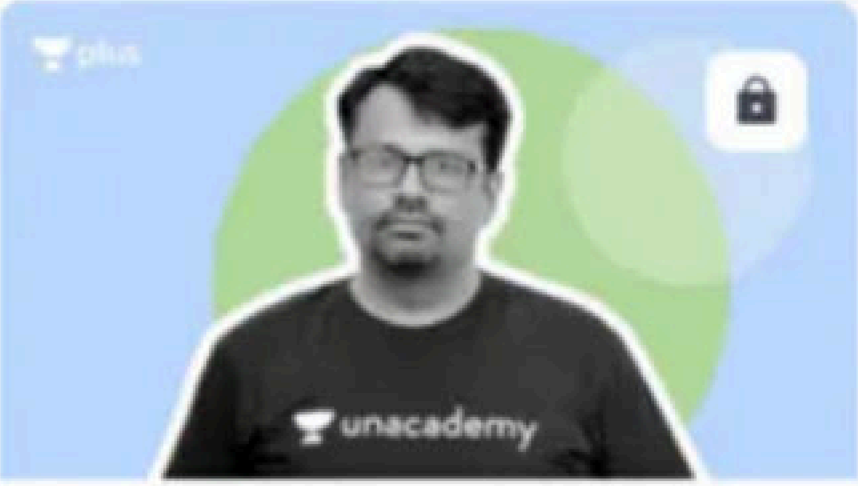

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