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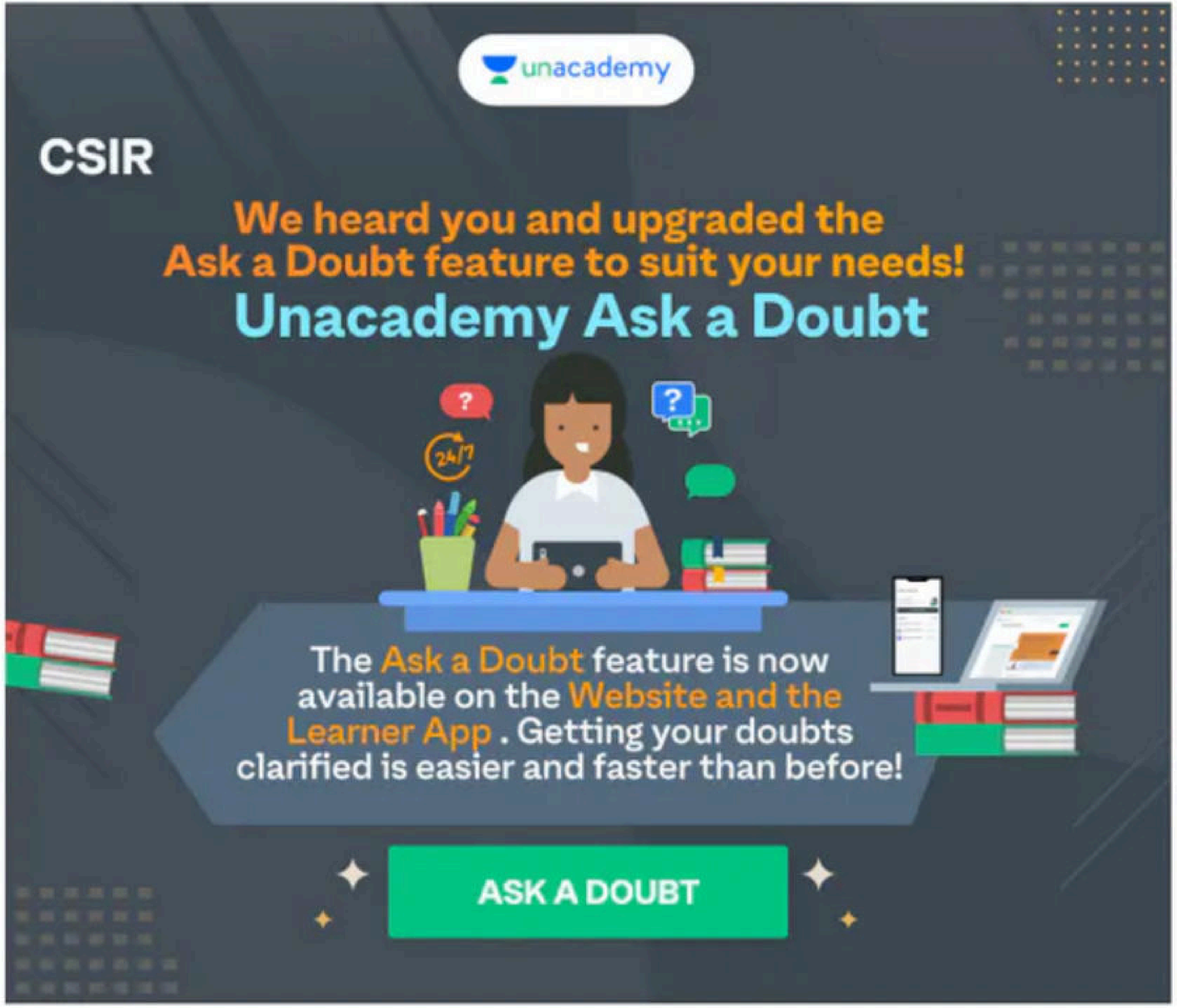
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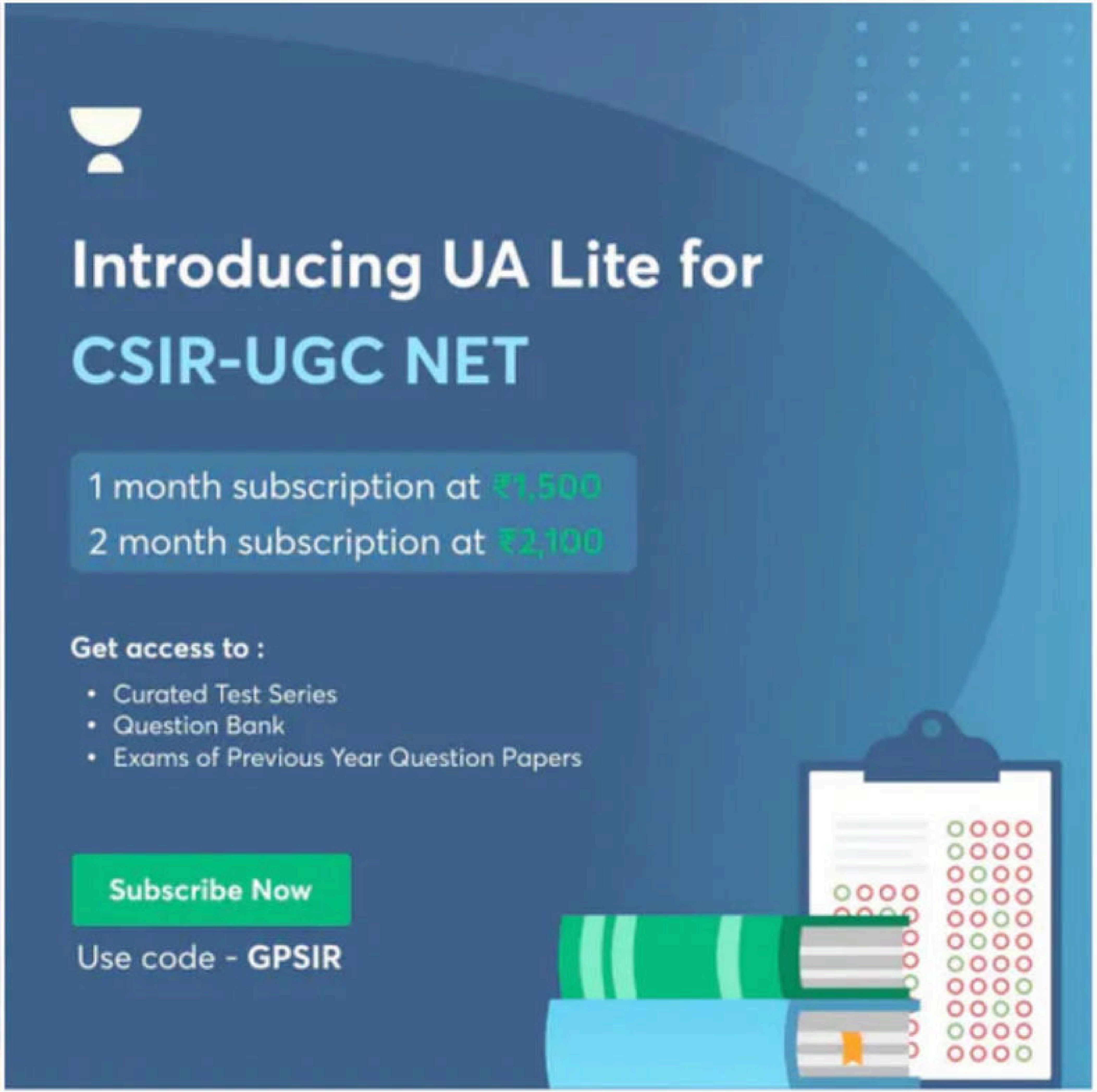
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Bernoulli's equation :

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 :

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

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

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

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.

$$\frac{dy}{dx} + P(x)y = Q(x)y^2$$

$$\frac{1}{y^2}\frac{dy}{dx} + \frac{P(x)}{y} = Q(x)$$

$$\text{Let } -\frac{1}{y} = t$$

$$-\left(-\frac{1}{y^2}\right)\frac{dy}{dx} = \frac{dt}{dx}$$

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

$$\frac{dx}{dy} + P(y)x = Q(y)x^4$$

$$\frac{1}{x^4}\frac{dx}{dy} + \frac{P(y)}{x^3} = Q(y)$$

$$\text{Let } \frac{1}{x^3} = t$$

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

$$\frac{dy}{dx} - \frac{\log x}{x} y^2 + \frac{y}{x} = 0$$

$$\frac{dy}{dx} + \frac{y}{x} = \frac{\log x}{x} y^2$$

$$\frac{1}{y^2}\frac{dy}{dx} + \frac{1}{xy} = \frac{\log x}{x}$$

let $\frac{1}{y} = t$

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

$$-\frac{dt}{dx} + \frac{t}{x} = \frac{\log x}{x}$$

$$\frac{dt}{dx} - \frac{t}{x} = -\frac{\log x}{x}$$

$$P = -\frac{1}{x}$$

$$Q = -\frac{\log x}{x}$$

$$IF = e^{\int -\frac{1}{x} dx} = e^{-\log x} = e^{\log \frac{1}{x}} = \frac{1}{x}$$

$$\log x = p \qquad \frac{1}{x}dx = dp$$

$$x = e^p$$

$$t \cdot IF = \int IF\, Q(x)\, dx + c$$

$$t\,\frac{1}{x} = \int \frac{1}{x}\cdot\left(-\frac{\log x}{x}\right) dx + c$$

$$\frac{1}{xy} = -\int \frac{\log x}{x}\,\frac{dx}{x} + c$$

$$\frac{1}{xy} = -\int \frac{p}{e^p}\, dp + c$$

$$\frac{1}{xy} = -\int e^{-p} p\, dp + c$$

$$\frac{1}{xy} = -\left(-pe^{-p} - e^{-p}\right) + c$$

$$\frac{1}{xy} = \frac{\log x}{x} + \frac{1}{x} + c$$

$$x\frac{dy}{dx} + y\log y = xye^{x}, \quad y(1)=1$$

$$\frac{dy}{dx} + \frac{y\log y}{x} = ye^{x}$$

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

$$P = \frac{1}{x}, \quad Q = e^{x}$$

$$\frac{dt}{dx} + \frac{t}{x} = e^{x}$$

$$I.F = e^{\int \frac{1}{x}dx} = e^{\log x} = x$$

$$t \cdot I.F = \int Q \cdot I.F\, dx + c$$

$$t \cdot x = \int e^{x} \cdot x\, dx + c$$

Let $\log y = t$

$$\frac{1}{y}\frac{dy}{dx} = \frac{dt}{dx}$$

$$\log y \cdot x = xe^{x} - e^{x} + c$$

Q.1. 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

$\sqrt{y} = p$

$\frac{1}{2\sqrt{y}}\frac{dy}{dt} = \frac{dp}{dt}$

$\frac{1}{\sqrt{y}}\frac{dy}{dt} = \frac{2dp}{dt}$

$t\frac{dy}{dt} - 3y = t^2y^{1/2}$

$\frac{dy}{dt} - \frac{3}{t}y = ty^{1/2}$

$\frac{1}{\sqrt{y}}\frac{dy}{dt} - \frac{3}{t}\sqrt{y} = t$

$2\frac{dp}{dt} - \frac{3p}{t} = t$

$\frac{dp}{dt} - \frac{3p}{2t} = \frac{t}{2}$

$P = \frac{-3}{2t}, \; Q = \frac{t}{2}$

$If = e^{-\int\frac{3}{2t}} = e^{-\frac{3}{2}\log t} = \frac{1}{t^{3/2}}$

$p.\,If = \int If \cdot Q\,dt + c$

$p.\frac{1}{t^{3/2}} = \int\frac{1}{t^{3/2}}\frac{t}{2}dt + c$

$\frac{y^{1/2}}{t^{3/2}} = \frac{1}{2}\int t^{-1/2}dt + c$

$\frac{y^{1/2}}{t^{3/2}} = \frac{1}{2}\frac{t^{1/2}}{1/2} + c$

$y^{1/2} = t^2 + ct^{3/2}$

$1 = 1 + c \Rightarrow c = 0$

$y^{1/2} = t^2$

$y = t^4$

$y = (2)^4$

$y = 16$

Dr.Gajendra Purohit (PhD,NET)
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Q.2. Solution of the differential equation

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

(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) $2\tan y = x^3 + 2c\,x^2$

$$x\frac{dy}{dx} + \sin 2y = x^3 \sin^2 y$$

$$\frac{dy}{dx} + \frac{2\sin y\cos y}{x} = x^2 \sin^2 y$$

$$\operatorname{cosec}^2 y\frac{dy}{dx} + \frac{2}{x}\cot y = x^2$$

$$\cot y = t$$

$$-\operatorname{cosec}^2 y\frac{dy}{dx} = \frac{dt}{dx}$$

$$-\frac{dt}{dx} + \frac{2t}{x} = x^2$$

$$\frac{dt}{dx} - \frac{2}{x}t = -x^2$$

$$P = -\frac{2}{x},\ Q = -x^2$$

$$IF = e^{-\int \frac{2}{x}dx} = e^{-2\log x} = \frac{1}{x^2}$$

$$t\,\frac{1}{x^2} = \int \frac{1}{x^2}(-x^2)\,dx + c$$

$$\frac{\cot y}{x^2} = -x + c$$

$$\cot y = -x^3 + cx^2$$

Q4. Consider the differential equation $\frac{dy}{dx} = ay - by^2$, where $a, b > 0$ and $y(0) = y_0$. As $x \to +\infty$ the solution $y(x)$ tends to

(a) 0 (b) a/b

(c) b/a (d) y_0

$\frac{dy}{dx} - ay = -by^2$

$\frac{1}{y^2}\frac{dy}{dx} - \frac{a}{y} = -b$

$-\frac{dt}{dx} - at = -b$

$\frac{dt}{dx} + at = b$

$\frac{1}{y} = t$

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

$P = a$, $Q = b$

$IF = e^{\int a\,dx} = e^{ax}$

$t \cdot IF = \int IF\, Q\,dx + C$

$t \cdot e^{ax} = \int e^{ax} b\,dx + C$

$t e^{ax} = \frac{e^{ax}}{a} b + C$

$\frac{1}{y} = b/a + Ce^{-ax}$

$\frac{1}{y_0} = b/a + C$

$C = \frac{1}{y_0} - b/a$

$\frac{1}{y} = \frac{b}{a} + \left(\frac{1}{y_0} - \frac{b}{a}\right)e^{-ax}$

$\frac{1}{y} = b/a$ $y = a/b$

EXACT DIFFERENTIAL EQUATION

Now consider the differential equation $Mdx + Ndy = 0$

An equation of the form $Mdx + Ndy = 0$ that is said to be exact

if $\dfrac{\partial M}{\partial y} = \dfrac{\partial N}{\partial x}$ holds.

$\int Mdx + \int Ndy = c$

N not containing x terms

Then solution of this differential equation

$$\int_{y=cons.} Mdx = \int_{neglect\ terms\ contain\ x.} Ndy$$

$$(ax+by+c)\,dx + (\cancel{bx}+ay+d)\,dy = 0$$

$$M = ax+by+c \qquad N = bx+ay+d$$

$$\frac{\partial M}{\partial y} = b = \frac{\partial N}{\partial x}$$

$$\int (ax+by+c)\,dx + \int (ay+d)\,dy = c$$

$$\frac{ax^2}{2} + bxy + cx + \frac{ay^2}{2} + dy = c$$

$(6xy - y^3)\,dx + (4y + \cancel{3x^2} - \cancel{6xy^2})\,dy = 0$

$y(1) = 1$ find $y(0)$

(a) ± 1 (b) $\pm \sqrt{2}$

(c) $\pm\sqrt{3}$ (d) $\pm\sqrt{5}$

$\frac{\partial M}{\partial y} = 6x - 3y^2$

$\frac{\partial N}{\partial x} = 6x - 3y^2$

$\int (6xy - y^3)\,dx + \int 4y\,dy = c$

$3x^2y - y^3x + 2y^2 = c$

$3 - 1 + 2 = c$

$c = 4$

$3x^2y - y^3x + 2y^2 = 4$

$0 - 0 + 2y^2 = 4$

$y = \pm\sqrt{2}$

If DE $(ax^2+bxy+y^2)dx + (2x^2+cxy+y^2)dy = 0$

is exact then $a+b+c = a+4+2 = \underline{a+6}$

(a) $a+2$ (b) $a+4$

~~(c) $a+6$~~ (d) $a+8$

$\frac{\partial M}{\partial y} = \underline{b}x + \underline{2}y$

$\frac{\partial N}{\partial x} = \underline{4}x + \underline{c}y$

$b=4, \; c=2$

Rules for finding IF

Rule – I :

If $\frac{1}{N}\left[\frac{\partial M}{\partial y}-\frac{\partial N}{\partial x}\right]$ is a function of x alone say f(x). Then $e^{\int f(x)dx}$ is an integrating factor of Mdx + Ndy = 0

Rule – II .

If $\frac{1}{M}\left(\frac{\partial N}{\partial x}-\frac{\partial M}{\partial y}\right)$ is a function of y, say f(y)

then $e^{\int f(y)dy}$ is an integrating factor of Mdx + Ndy = 0

Rule III :

If Mdx + Ndy = 0 is homogeneous and Mx + ny $\neq$ 0, then

$\dfrac{1}{Mx+Ny}$ is the integrating factor of $Mdx + Mdy = 0$

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Rule – IV :

If Mdx + Ndy = 0 is of the form,

$f_1(xy).ydx + f_2(xy).xdy = 0$ and then $\frac{1}{Mx - Ny}$ is the integrating factor.

Rule – V :

If the given differential equation Mdx + Ndy = 0 is of the form

$x^{\alpha} y^{\beta} (mydx + nxdy) + x^{\alpha`} y^{\beta`}(m`ydx + n`xdy) = 0$

Where α, β, m, n, $\alpha`$, $\beta`$, m` and n` are constants. Then the given equation has $x^h y^k$ as integrating factor.

Where h and k are obtained by the condition, so that given equation become exact $\left(\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}\right)$. Then by comparing both sides we get the values h and k

Q6. Let y(x) be the solution of the differential equation $(xy + y + e^{-x})dx + (x + e^{-x})dy = 0$ satisfying $y(0) = 1$. Then y(-1) is equal to **IIT JAM- 2017**

(a) $\frac{e}{e-1}$ (b) 0

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

Q7 . Let y(x) is a integrating factor of the differential equation

$$\left(y+\frac{1}{3}y^3+\frac{1}{2}x^2\right)dx+\frac{1}{4}(x+xy^2)dy=0$$

then y(x) is **IIT JAM -2018**

(a) Even function (b) Odd function

(c) Periodic function (d) Trignometric function

Q8. If $x^h y^k$ is an integrating factor of the differential equation $y(1+xy)dx + x(1-xy)dy = 0$, then the value of $h + k$ is

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(a) Divisible by 8

(b) Divisible by 2

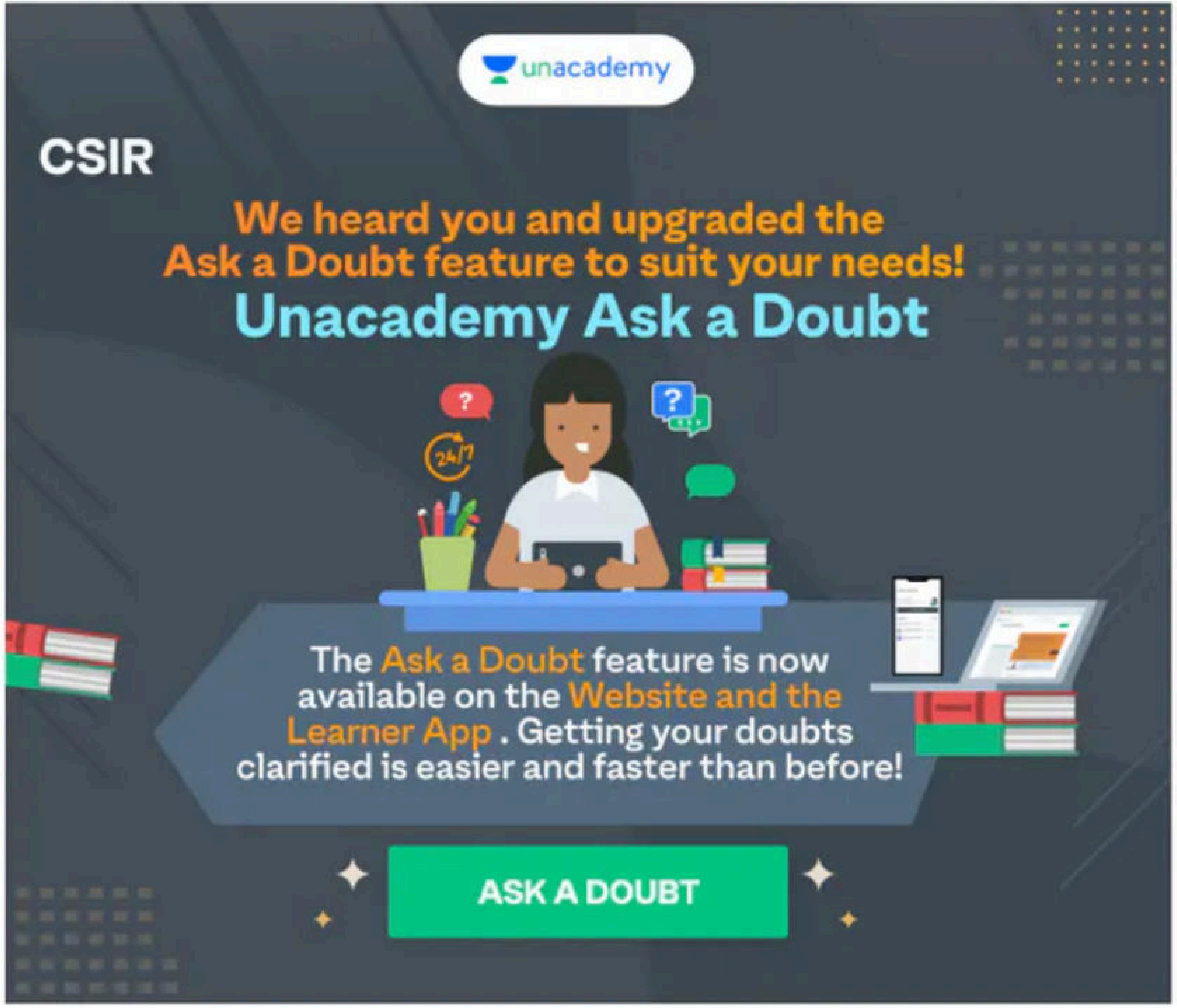
(c) Divisible by 5

(d) None of these

Q9. The non-zero value of n for which the differential equation $(3xy^2 + n^2x^2y)dx + (nx^3 + 3x^2y)dy = 0$, $x \neq 0$, becomes exact is **IIT JAM 2016**

(a) -3 (b) -2

(c) 2 (d) 3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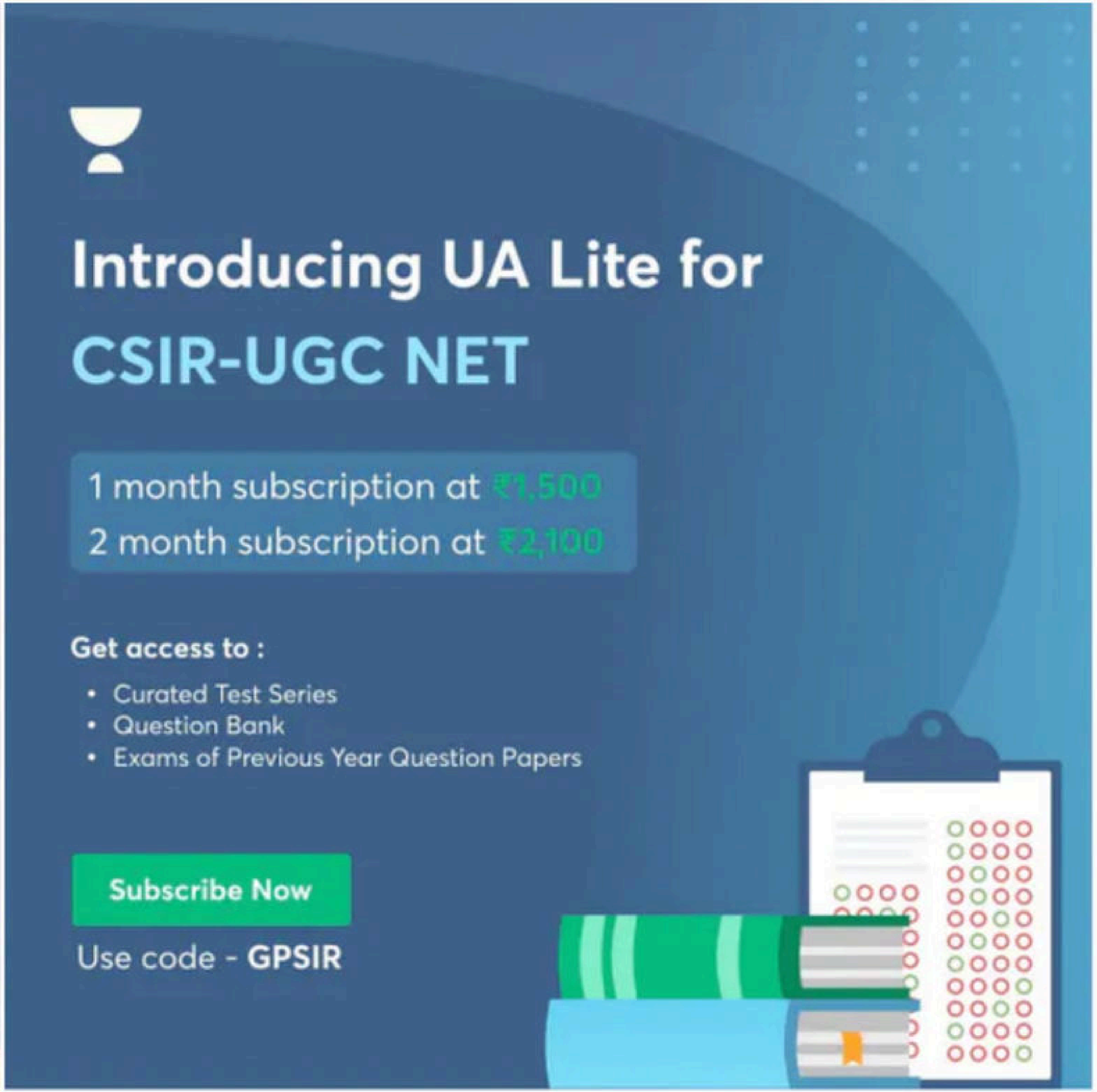
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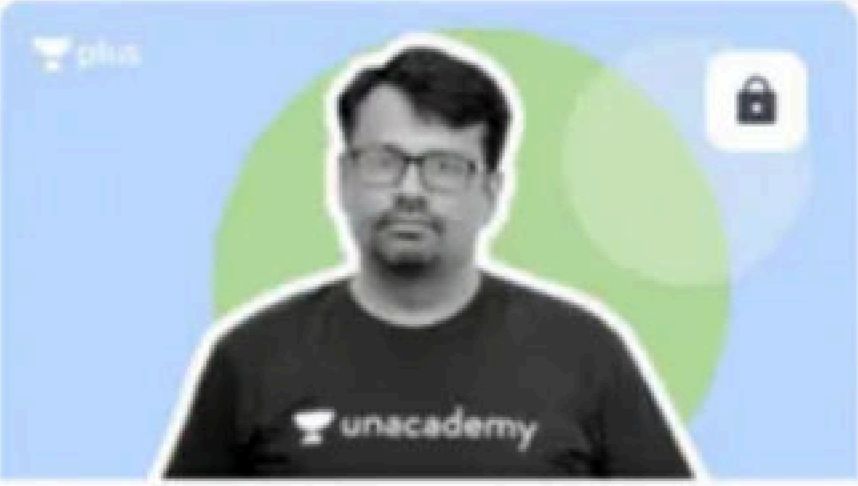

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- Works at **Pacific Science College**
- Studied at **M.Sc., NET, PhD(Algebra), MBA(Finance), BEd**
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