# First Order & First Degree ODE - V

Detailed Course on Differential Equation for IIT JAM' 23 - II

Gajendra Purohit • Lesson 4 • Aug 10, 2022

## Gajendra Purohit

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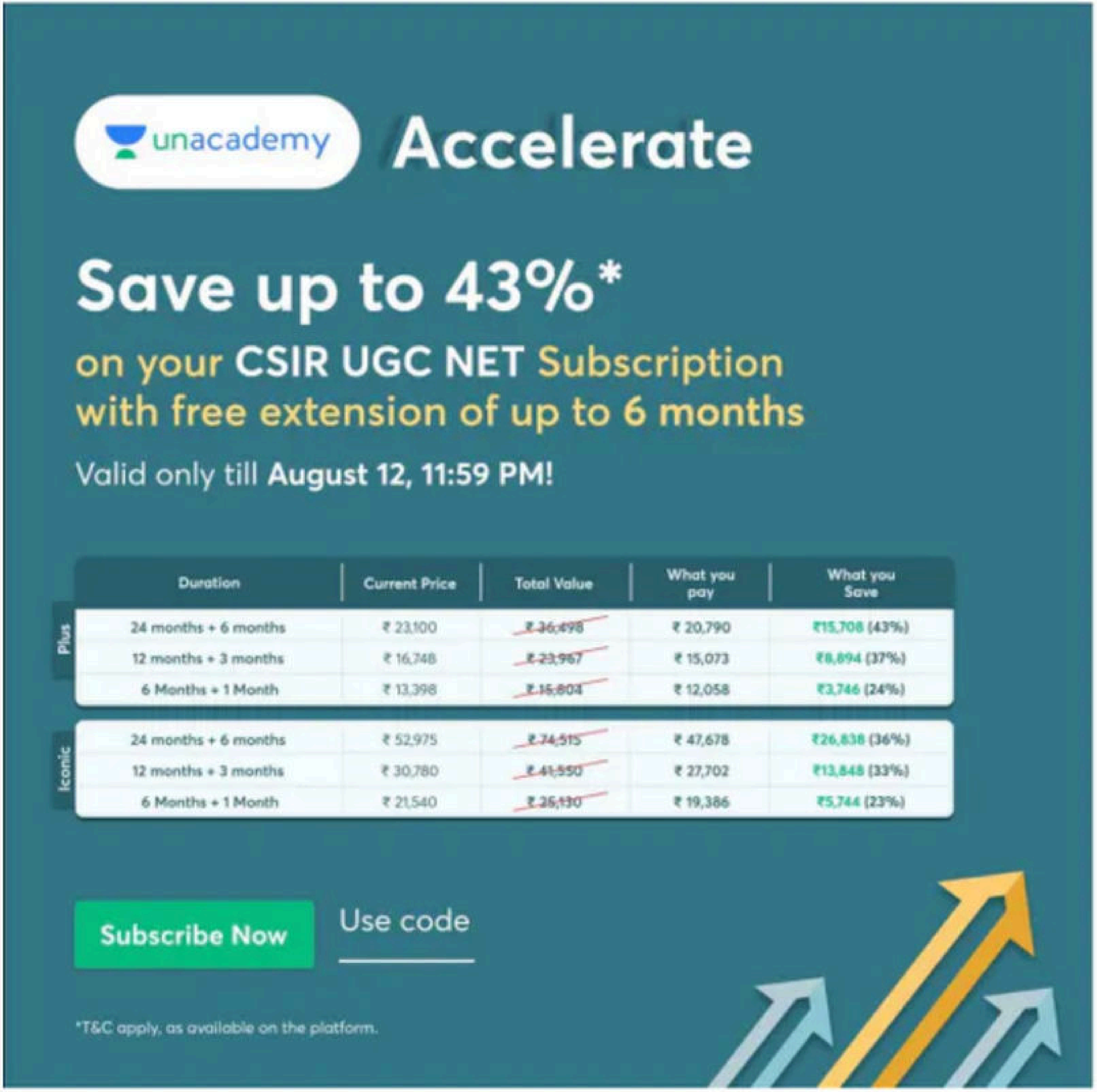
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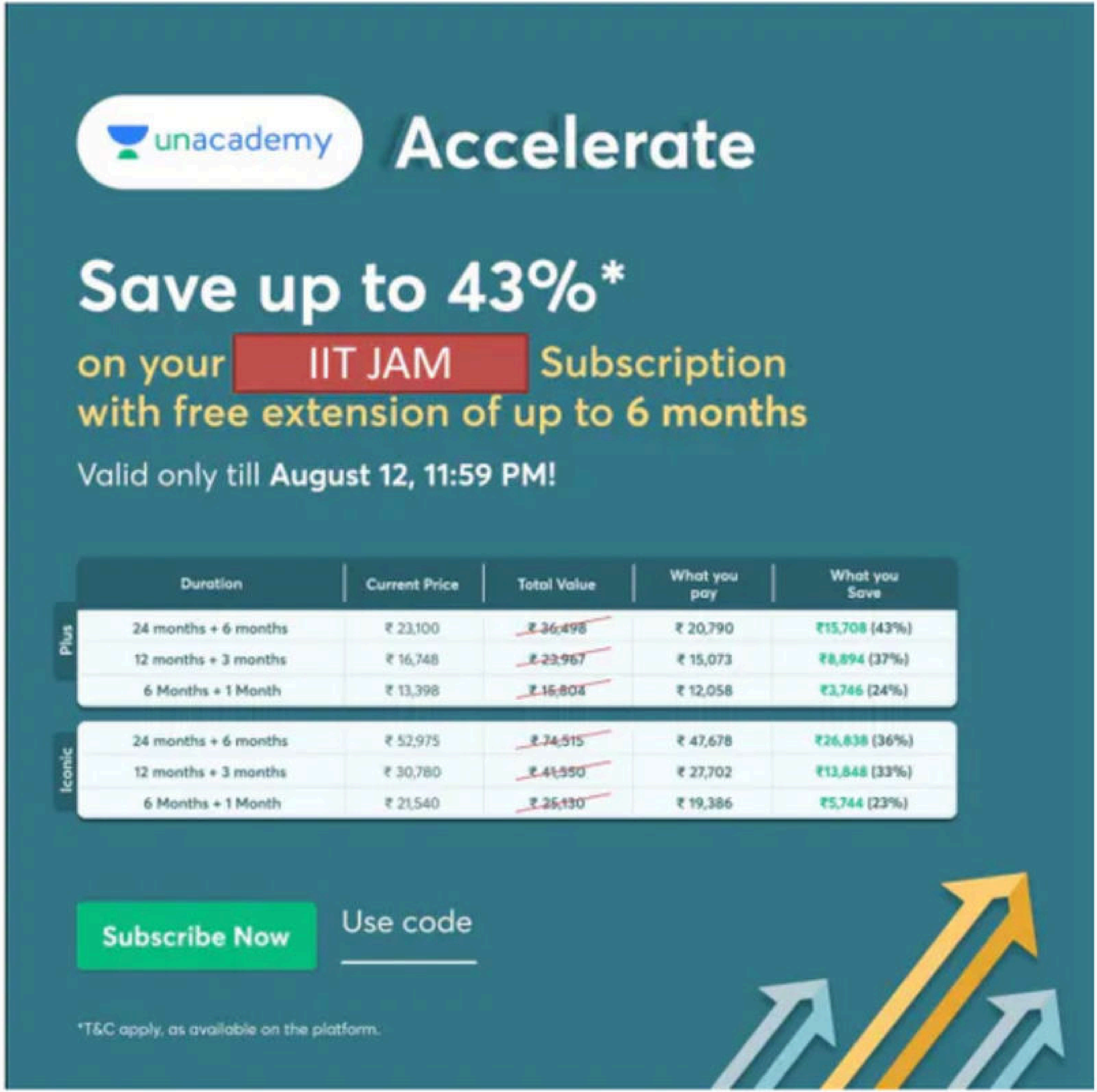
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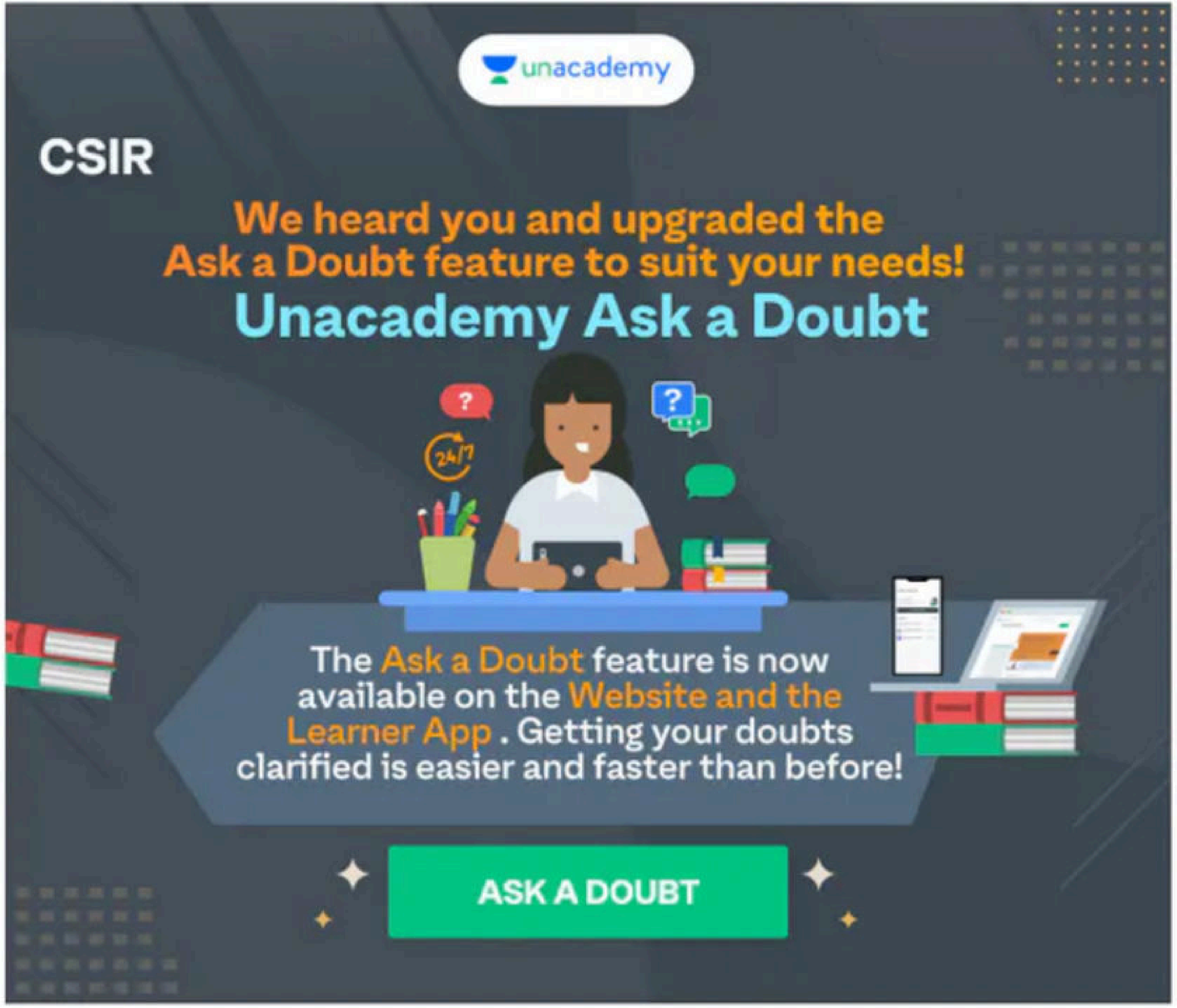
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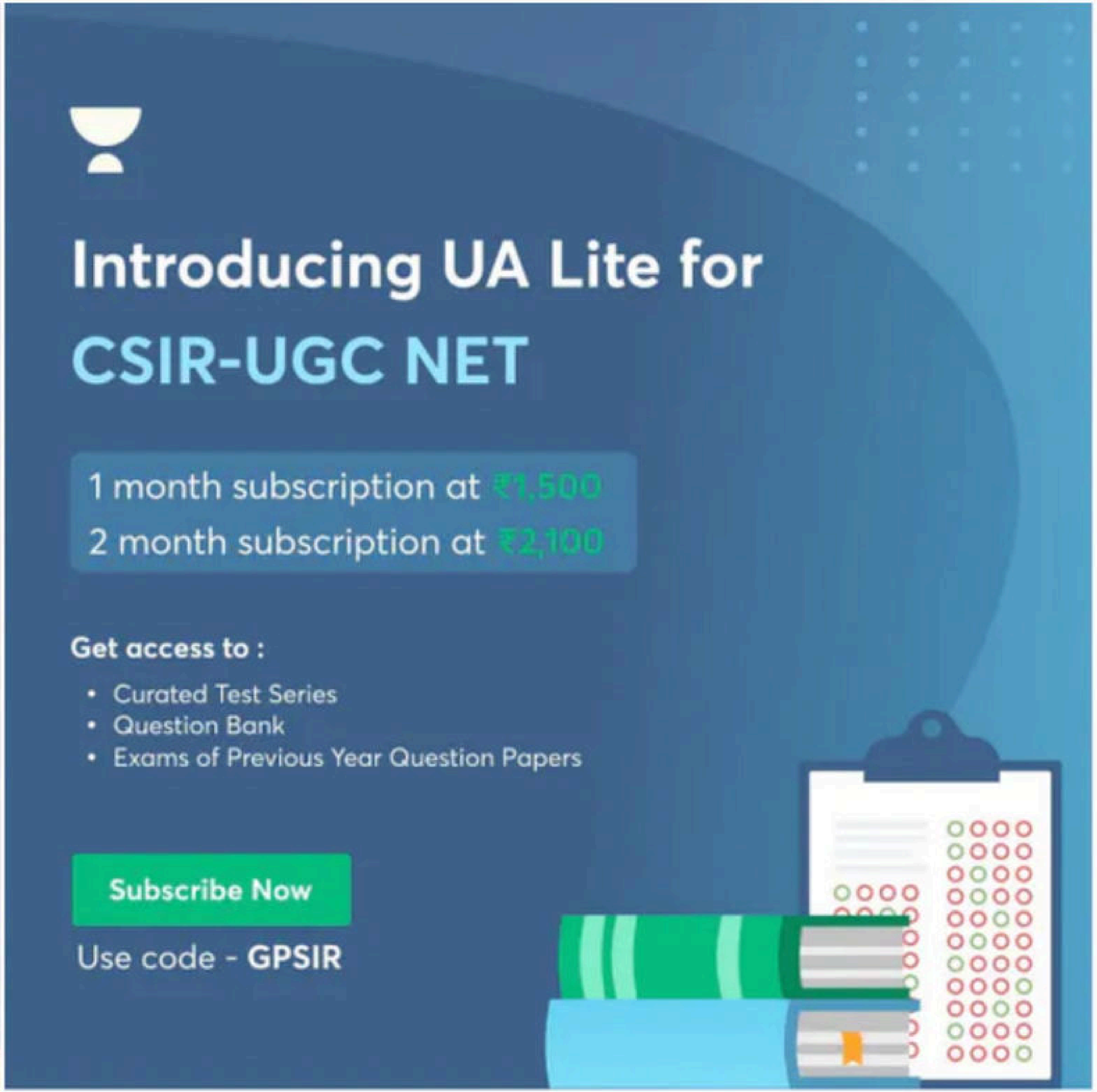
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## HOMOGENEOUS DIFFERENTIAL EQUATION

**Homogeneous Function :** A function f(x, y) is called homogeneous function of degree 'n' if $f(\lambda x, \lambda y) = \lambda^n f(x, y)$; for all x, y; $\lambda \geq 0$

**Example :** $f(x, y) = 2x^3 - 3xy^2 + 4y^3$

**Solution :** $f(\lambda x + \lambda y) = 2\lambda^3x^3 - 3\lambda^3xy^2 + 4\lambda^3y^3$

$$= \lambda^3 f(x, y)$$

This function is homogeneous of degree 3.

**Note :** A differential equation of first order and first degree is said to be homogeneous if it can be put in the form $\frac{dy}{dx} = \phi\left(\frac{y}{x}\right) = \phi\left(\frac{x}{y}\right)$.

$$f(x,y) = \frac{x^2+y^2}{xy+x^2}$$

$$f(x,y) = \frac{x^2\left(1+\left(\frac{y}{x}\right)^2\right)}{x^2\left(\left(\frac{y}{x}\right)+1\right)}$$

$$= x^0 f\left(\frac{y}{x}\right)$$

$$f(x,y) = \frac{x^3 + y^3}{x^2 + y^2}$$

$$f(x,y) = \frac{x^3\left(1 + \left(\frac{y}{x}\right)^3\right)}{x^2\left(1 + \left(\frac{y}{x}\right)^2\right)} = x^1 f\left(\frac{y}{x}\right)$$

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$$f(x,y) = e^{\frac{2x+y}{3x-y}} = e^{\frac{2 + y/x}{3 - y/x}} = e^{f\left(\frac{y}{x}\right)}$$

**Note :**

1. Every homogeneous first order DE is reducible into seperable variable.

2. A function f(x, y) is homogeneous of degree n then $x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} = nf$.

$f = \frac{x^3 + 3xy^2}{y^3 + 3x^2y}$

$x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} = 0f = 0$

$$f = \frac{x^2+y^2}{x+y}$$

$$x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} = 1 \cdot f$$

$$(x^3+3xy^2)\,dx + (y^3+3x^2y)\,dy = 0$$

$$\frac{dy}{dx} = -\frac{(x^3+3xy^2)}{(y^3+3x^2y)}$$

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

**Working Rule for solving homogeneous equation :**

Let $\frac{dy}{dx} = f\left(\frac{y}{x}\right)$ is a homogeneous equation, then

Step – 1 : Put y/x = v ⇒ y = vx

Step – 2 : $\frac{dy}{dx} = v + x\frac{dv}{dx}$

Step – 3 : Put both value in DE

Step – 4 : Using separation of variable we get required solution.

$$(x^3+3xy^2)dx+(y^3+3x^2y)dy=0$$

Let $y=vx$

$$\frac{dy}{dx}=v+x\frac{dv}{dx}$$

$$\frac{dy}{dx}=\frac{-(x^3+3xy^2)}{y^3+3x^2y}$$

$$x\frac{dv}{dx}=\frac{-(x^3+3x^3v^2)}{v^3x^3+3x^3v}-v$$

$$x\frac{dv}{dx}=-\left[\frac{(1+3v^2)}{v^3+3v}+v\right]$$

$$x\frac{dv}{dx}=-\left(\frac{1+3v^2+v^4+3v^2}{v^3+3v}\right)$$

$$x\frac{dv}{dx}=-\frac{(1+6v^2+v^4)}{v^3+3v}$$

$$\int\frac{v^3+3v}{1+6v^2+v^4}\,dv=-\int\frac{dx}{x}$$

$$1+6v^2+v^4=t$$

$$(12v+4v^3)dv=dt$$

$$(3v+v^3)dv=\frac{dt}{4}$$

$$\frac{1}{4}\int\frac{dt}{t}=-\int\frac{dx}{x}$$

$$\log t=-4\log x+\log c$$

$$\log t=\log\frac{c}{x^4}$$

$$t=\frac{c}{x^4}$$

$$x^4(1+6v^2+v^4)=c$$

**Q.1.** The differential equation $(x^2+y^2)\frac{dy}{dx}=xy$ s.t. $y(0)=1$ has

$1 = c$

(a) Unique solution (b) Infinite solution

(c) Two solution (d) None of these

Let $y = vx$

$$\frac{dy}{dx} = v + x\frac{dv}{dx}$$

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

$$v + x\frac{dv}{dx} = \frac{vx^2}{x^2+v^2x^2}$$

$$v + x\frac{dv}{dx} = \frac{v}{1+v^2}$$

$$x\frac{dv}{dx} = \frac{v}{1+v^2} - v$$

$$x\frac{dv}{dx} = \frac{\cancel{v} - \cancel{v} - v^3}{1+v^2}$$

$$\int \frac{1+v^2}{v^3} = -\int \frac{dx}{x} + \lg c$$

$$\int \frac{1}{v^3}\,dv + \int \frac{1}{v}\,dv = -\lg x + \lg c$$

$$-\frac{1}{2v^2} + \lg v = \lg \frac{c}{x}$$

$$\lg v - \lg \frac{c}{x} = \frac{1}{2v^2}$$

$$\lg \frac{vx}{c} = \frac{1}{2v^2}$$

$$\frac{vx}{c} = e^{\frac{1}{2v^2}}$$

$$\frac{y}{\cancel{x}}\cancel{x} = c\, e^{\frac{x^2}{2y^2}}$$

$$y = c\, e^{x^2/2y^2}$$

**Q.2.** The general solution of the differential equation $(x^2 - y^2)dx + 2xydy = 0$ is

(a) $x^2 + y^2 = c$

(b) $x^2 - y^2 = c$

(c) $x^2 + y^2 = cx$

(d) None

$y = vx$

$\frac{dy}{dx} = v + x\frac{dv}{dx}$

$\frac{dy}{dx} = \frac{y^2 - x^2}{2xy}$

$v + x\frac{dv}{dx} = \frac{v^2x^2 - x^2}{2x^2v}$

$x\frac{dv}{dx} = \frac{v^2 - 1}{2v} - v$

$x\frac{dv}{dx} = \frac{v^2 - 1 - 2v^2}{2v}$

$\int \frac{2v}{1+v^2}dv = -\int \frac{dx}{x} + \log c$

$\log(1+v^2) = -\log x + \log c$

$\log(1+v^2) = \log \frac{c}{x}$

$(1+v^2)x = c$

$\left(1 + \frac{y^2}{x^2}\right)x = c$

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

$x^2 + y^2 = cx$

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**Q.3.** Consider the following difference equation

$$x(ydx + xdy)\cos\frac{y}{x} = y(xdy - ydx)\sin\frac{y}{x}$$

Which of the following is solution of the above equation?

$xy\cos\frac{y}{x} = c$

(a) $\frac{x}{y}\cos\frac{y}{x} = c$ (b) $\frac{x}{y}\sin\frac{y}{x} = c$

(c) $xy\cos\frac{y}{x} = c$ (d) $xy\sin\frac{y}{x} = c$

$\frac{(ydx + xdy)}{xdy - ydx} = \frac{y}{x}\tan\frac{y}{x}$

$\frac{\left(y + x\frac{dy}{dx}\right)}{\left(x\frac{dy}{dx} - y\right)} =$

$y = vx$

$\frac{dy}{dx} = v + x\frac{dv}{dx}$

$dy = v\,dx + x\,dv$

$\frac{vx\,dx + xv\,dx + x^2 dv}{\cancel{xv\,dx} + x^2 dv - \cancel{vx\,dx}} = v\tan v$

$\frac{2vx\,dx + x^2 dv}{x^2 dv} = v\tan v$

$2\frac{v}{x}\frac{dx}{dv} + 1 = v\tan v$

$2\frac{v}{x}\frac{dx}{dv} = v\tan v - 1$

$\int 2\frac{dx}{x} = \int\left(\frac{v\tan v - 1}{v}\right)dv + \log c$

$2\log x = -\log\cos v - \log v + \log c$

$\log x^2 + \log\cos v + \log v = \log c$

$x^2 v\cos v = c$

$x^2 \frac{y}{x}\cos\frac{y}{x} = c$

$$\left(x\sin\frac{y}{x} - y\cos\frac{y}{x}\right)dx + x\cos\frac{y}{x}\,dy = 0, \quad y(0)=0$$

(a) $x\sin\frac{y}{x} = 1$

~~(b) $y = \pm n\pi x$~~

(c) $y = x\sin\frac{y}{x}$

(d) $x = y$

$x\sin\frac{y}{x} = c$ $\quad c=0$

$x\sin\frac{y}{x} = 0$

$\sin\frac{y}{x} = 0 = \sin n\pi$

$y = \pm n\pi x$

let $y = vx$

$\frac{dy}{dx} = v + x\frac{dv}{dx}$

$dy = v\,dx + x\,dv$

$(x\sin v - vx\cos v)dx$

$+ x\cos v\,[v\,dx + x\,dv] = 0$

$\sin v - v\cos v = -\cos v\,\frac{(v\,dx + x\,dv)}{dx}$

$\tan v - \cancel{v} = -\cancel{v} - x\frac{dv}{dx}$

$\int \tan v\,dv = -\int\frac{dx}{x} + \ln c$

$\log\sin v = \ln\frac{c}{x}$

$x\sin v = c$

dn $\frac{y}{x}$

## Equation reducible to homogeneous form

Equation of the form $\frac{dy}{dx} = \frac{ax+by+c}{a`x+b`y+c`}$, where $\frac{a}{a`} \neq \frac{b}{b`}$ can be reduced to homogeneous form.

$\frac{a}{a_1} \neq \frac{b}{b_1}$

$\frac{dy}{dx} = \frac{x+y+5}{2x+2y+2}$

**Working rule :**

(1) Take x = X + h & y = Y + k, then $\frac{dy}{dx} = \frac{dY}{dX}$.

(2) Put all values in above DE

$$\frac{dY}{dX} = \frac{aX+bY+ah+bk+c}{a`x+b`y+a`h+b`k+c`}$$

h, k -

(3) Find value of h & k for which ah + bk + c = 0 & a`h + b`k + c` = 0.

Then $\frac{dY}{dX} = \frac{aX+bY}{a`X+b`Y}$ which homogeneous.

(4) Solve this DE and put X = x – h & Y = y – k

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

$x = X + h$

$y = Y + k$

$h + 2k - 3 = 0$

$2h + k - 3 = 0$

$h = k = 1$

$$\frac{dY}{dX} = \frac{(X+h)+2(Y+k)-3}{2(X+h)+(Y+k)-3}$$

$X = x-1$

$Y = y-1$

$$\frac{dY}{dX} = \frac{X+2Y+h+2k-3}{2X+Y+2h+k-3}$$

$$\frac{dY}{dX} = \frac{X+2Y}{2X+Y}$$

Let $Y = vX$, $\frac{dY}{dX} = v + X\frac{dv}{dX}$

$$v + X\frac{dv}{dX} = \frac{X+2vX}{2X+vX}$$

$$v + X\frac{dv}{dX} = \frac{1+2v}{2+v}$$

$$X\frac{dv}{dX} = \frac{1+2v}{2+v} - v$$

$$X\frac{dv}{dX} = \frac{1+2\cancel{v}-\cancel{2v}-v^2}{2+v}$$

$$\int \frac{2+v}{1-v^2}\,dv = \int \frac{dX}{X} + \log c$$

$$2\int \frac{1}{1-v^2}\,dv + \int \frac{v}{1-v^2}\,dv = \log X c$$

$$2\log\frac{1+v}{1-v} - \frac{1}{2}\log(1-v^2) = \log X c$$

$$\log \frac{(1+v)^2}{(1-v)^2}\sqrt{(1-v^2)} = Xc$$

**Q.6.** Solution of $\frac{dy}{dx} = \frac{(xy^2 - x^2y)}{x^3}$ s.t. $y(1) = 2$

(a) Unique solution

(b) No solution

(c) Infinite solution

(d) None of these

$v + x\frac{dv}{dx} = \frac{v^2 - v}{?}$

$x\frac{dv}{dx} = v^2 - 2v$

$\int \frac{dv}{v(v-2)} = \int \frac{dx}{x} + c$

$\frac{1}{v(v-2)} = \frac{A}{v} + \frac{B}{v-2}$

$= -\frac{1}{2v} + \frac{1}{2(v-2)}$

$-\int \frac{1}{v}dv + \int \frac{1}{v-2}dv = 2\log x c$

$-\log v + \log(v-2) = \log x^2 c^2$

$\frac{v-2}{v} = x^2 c$

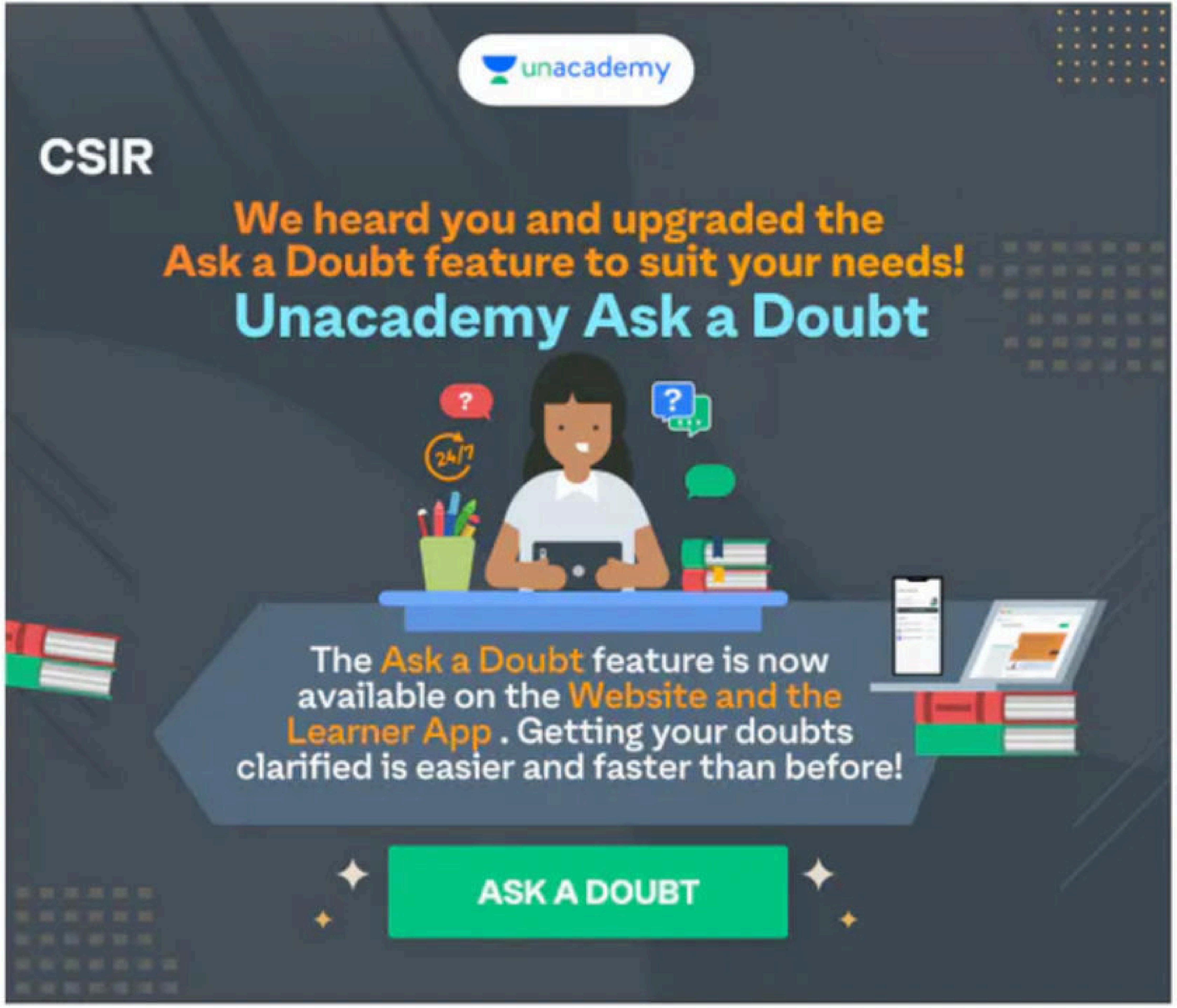
$\frac{y/x - 2}{y/x} = x^2 c$

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

$2 - 2 = 2\cdot 1 \cdot c$

$c = 0$

$y - 2x = 0$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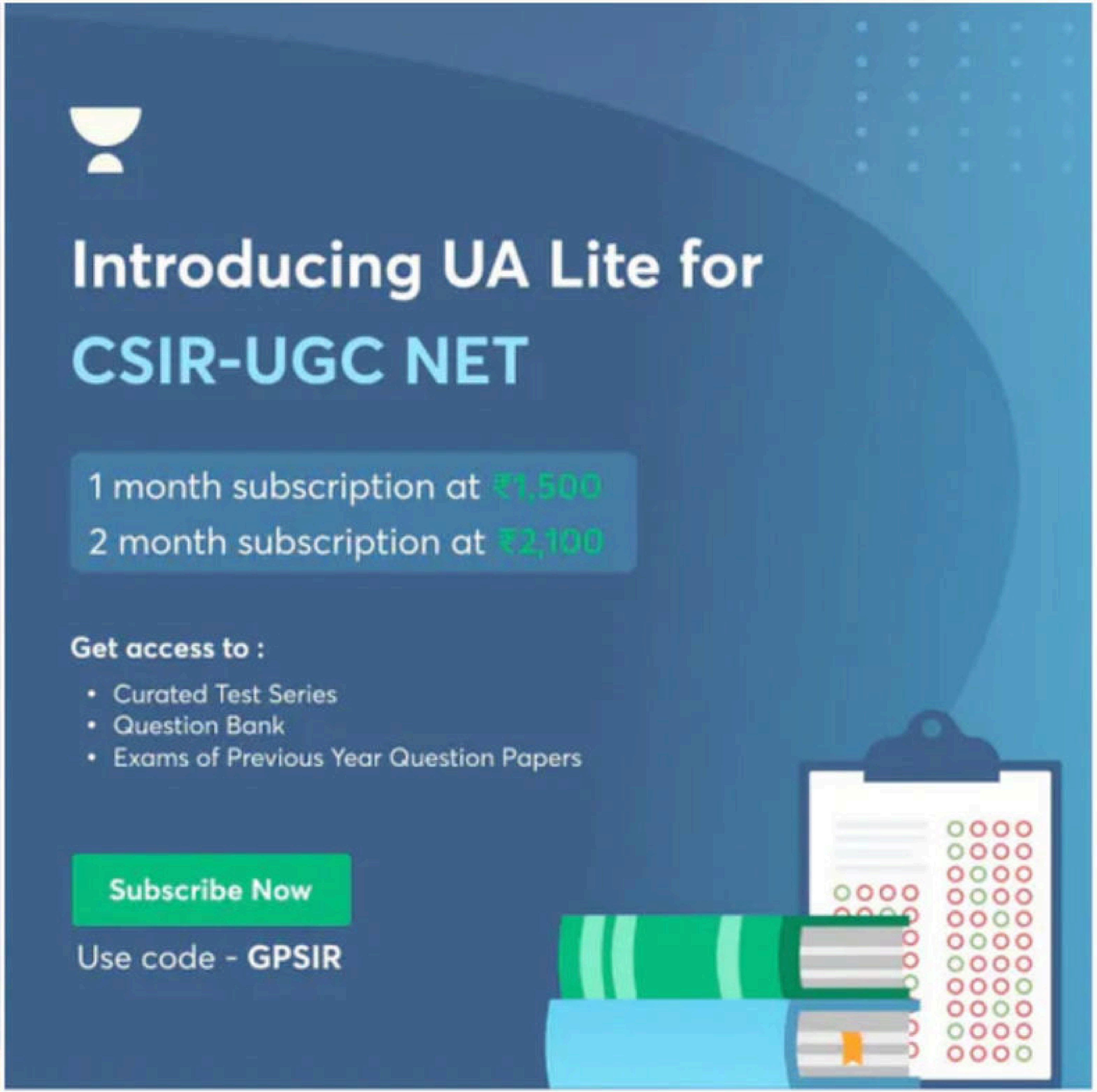
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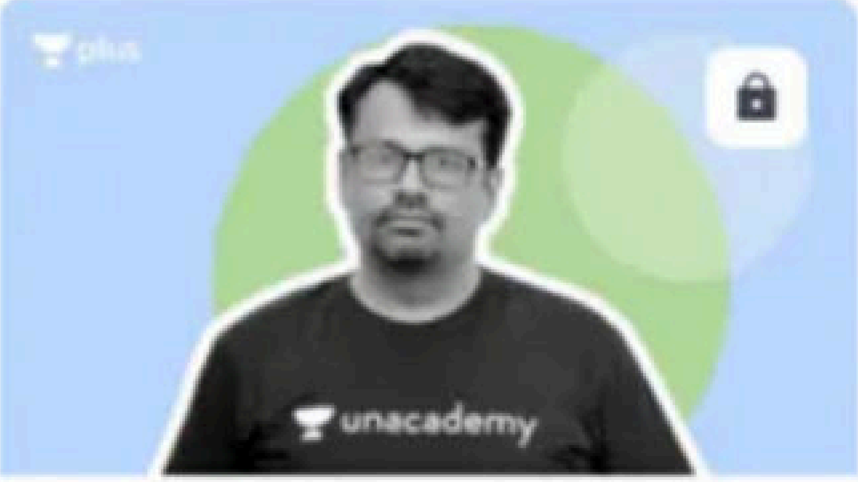


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| 12 months | Save 54% | ₹ 1,248 / mo | Total ₹ 14,974 |
| 9 months | Save 45% | ₹ 1,497 / mo | Total ₹ 13,475 |
| 6 months | Save 25% | ₹ 2,042 / mo | Total ₹ 12,252 |
| 3 months | Save 17% | ₹ 2,269 / mo | Total ₹ 6,807 |
| 1 month | | ₹ 2,723 / mo | Total ₹ 2,723 |

24 months and 12 months: You get 6 months extra for free — Offer expires 15 Jun 2022

To be paid as a one-time payment

Have a referral code?

Proceed to pay

## Get 10% Off

## After Using My Referral Code

**GPSIR**

Awesome! You get 10% off

No cost EMI available on 6 months & above subscription plans

| | | | |
|---|---|---|---|
| 24 months | Save 67% | ₹ 817 / mo | ~~₹ 21,700~~ ₹ 19,602 |
| 12 months | Save 54% | ₹ 1,123 / mo | ~~₹ 14,974~~ ₹ 13,477 |
| 9 months | Save 45% | ₹ 1,348 / mo | ~~₹ 13,475~~ ₹ 12,128 |
| 6 months | Save 25% | ₹ 1,838 / mo | ~~₹ 12,252~~ ₹ 11,027 |
| 3 months | Save 17% | ₹ 2,042 / mo | ~~₹ 6,807~~ ₹ 6,126 |

24 months and 12 months: You get 6 months extra for free — Offer expires 15 Jun 2022

Proceed to pay