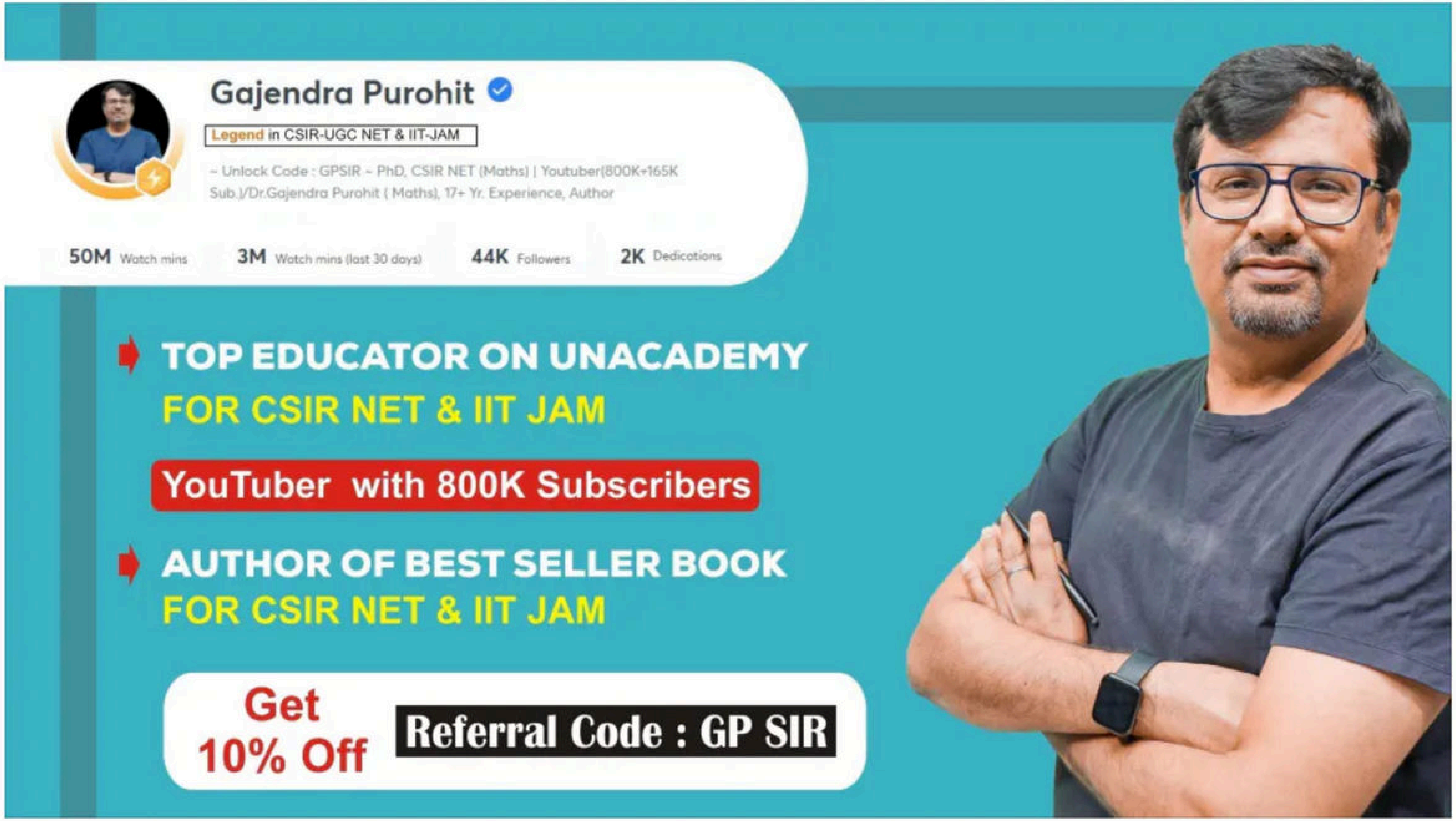
Integral Calculus - Part XII

Detailed Course on Integral Calculus - IIT JAM' 23

Gajendra Purohit • Lesson 15 • July 27, 2022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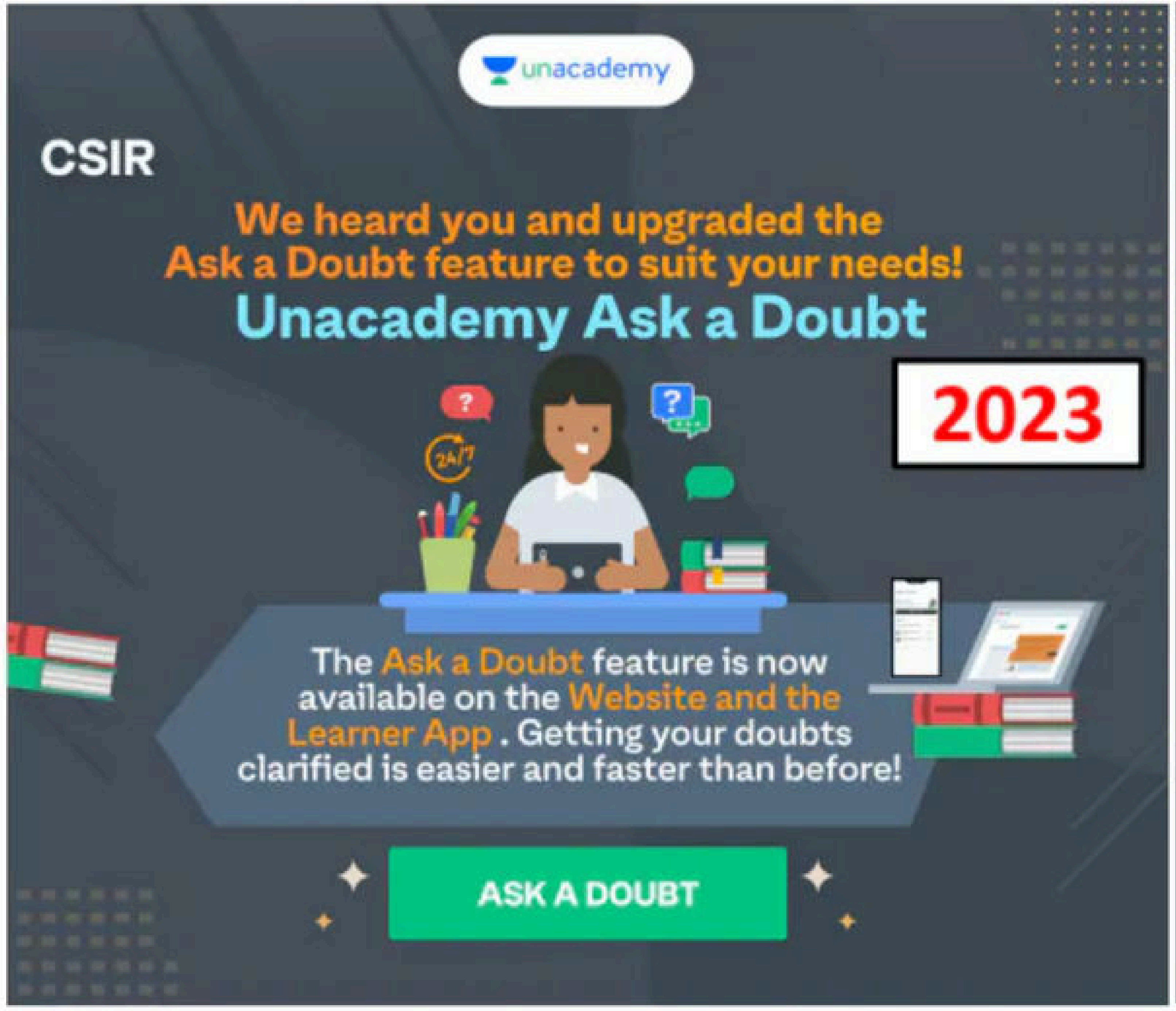
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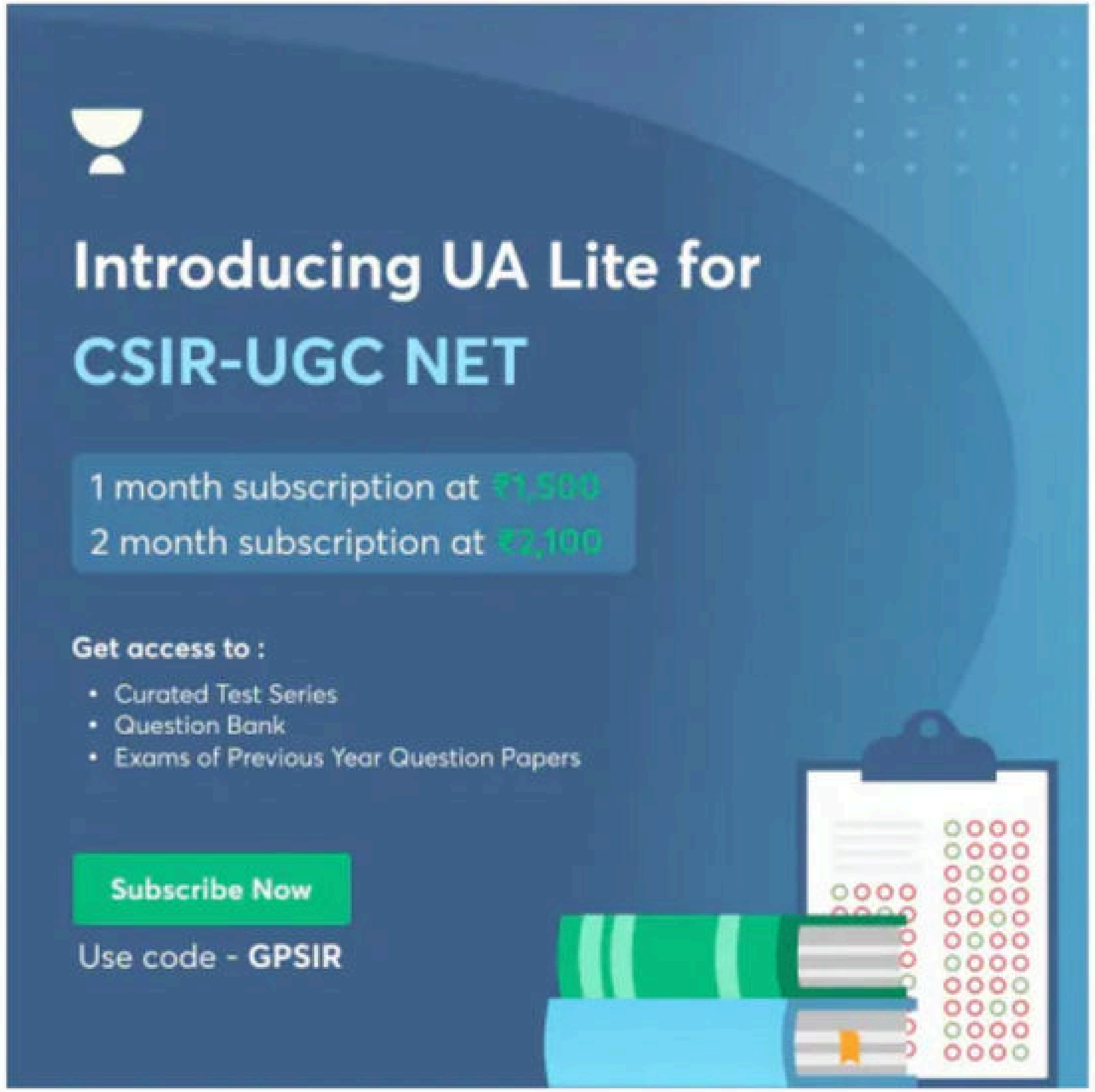
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Triple Integration

Dirichlet's theorem :

The theorem states that $\iiint x^{l-1} y^{m-1} z^{n-1} dxdydz = \dfrac{\gamma(l).\gamma(m).\gamma(n)}{\gamma(l+m+n+1)}$;

Where subject to condition x + y + z ≤ 1 and all variables are positive.

Note :

In general this theorem states that $\iint .....\int x_1^{m_1-1} x_2^{m_2-1} ......x_n^{m_{n-1}} dx_1.....dx_n = \dfrac{\gamma(m_1).\gamma(m_2)....\gamma(m_n)}{\gamma(m_1+m_2+....+1)}$.

Where subject to condition $x_1 + x_2 + ... + x_n \leq 1$

$$\iiint dx\,dy\,dz \qquad x^1+y^1+z^1\le 1$$

$$\iiint x^{1-1}\,y^{1-1}\,z^{1-1}\,dx\,dy\,dz = \frac{\Gamma 1\,\Gamma 1\,\Gamma 1}{\Gamma(1+1+1+1)} = \frac{1}{\Gamma 4} = \frac{1}{3!}$$

$$= 1/6$$

$$\iiint dx\,dy\,dz \qquad x^2+y^2+z^2 \le R^2$$

$$\frac{x^2}{R^2}+\frac{y^2}{R^2}+\frac{z^2}{R^2} \le 1$$

$$\Gamma\left(\tfrac{5}{2}\right) = \tfrac{3}{2}\,\tfrac{1}{2}\sqrt{\pi}$$

$$\frac{x^2}{R^2} = u \Rightarrow x = R\sqrt{u} \qquad dx = \frac{R}{2\sqrt{u}}\,du$$

$$\frac{y^2}{R^2} = v \qquad dy = \frac{R}{2\sqrt{v}}\,dv$$

$$\frac{z^2}{R^2} = w \qquad dz = \frac{1}{2\sqrt{w}}\,dw$$

$$\iiint \frac{R}{2\sqrt{u}}\,du\,\frac{R}{2\sqrt{v}}\,dv\,\frac{R}{2\sqrt{w}}\,dw$$

$$\frac{R^3}{8}\iiint u^{-1/2}\,v^{-1/2}\,w^{-1/2}\,du\,dv\,dw$$

$$\frac{R^3}{8}\,\frac{\Gamma\left(\tfrac12\right)\Gamma\left(\tfrac12\right)\Gamma\left(\tfrac12\right)}{\Gamma\left(\tfrac12+\tfrac12+\tfrac12+1\right)} = \frac{R^3}{8}\,\frac{\sqrt{\pi}\sqrt{\pi}\cancel{\sqrt{\pi}}}{\tfrac32\,\tfrac12\,\cancel{\sqrt{\pi}}} = \frac{R^3\pi}{6}\times 8$$

$$\frac{4\pi R^3}{3}$$

$$\iiint dx\,dy\,dz$$

$$2|x| + 6|y| + 3|z| \le 12$$

$$\frac{2x}{12} + \frac{6y}{12} + \frac{3z}{12} \le 1$$

$$\frac{x}{6} + \frac{y}{2} + \frac{z}{4} \le 1$$

$$u = \frac{x}{6} \qquad v = \frac{y}{2} \qquad w = \frac{z}{4}$$

$$dx = 6\,du \qquad dy = 2\,dv \qquad dz = 4\,dw$$

$$\iiint 6\,du \cdot 2\,dv\, 4\,dw$$

$$u + v + w \le$$

$$48 \iiint du\,dv\,dw$$

$$48 \iiint u^{1-1} v^{1-1} w^{1-1}\,du\,dv\,dw$$

$$48\,\frac{\Gamma 1\,\Gamma 1\,\Gamma 1\,\Gamma}{\Gamma 1+1+1+1} = \frac{48}{6} = 8 \times 8$$

Q.1. Evaluate $\iiint xyz\,dx\,dy\,dz$ taking throughout the ellipsoid $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}\le 1$ in which variable are positive.

(a) $\frac{abc}{8}$

(b) $\left(\frac{abc}{2}\right)^2$

(c) $\frac{abc}{4}$

(d) ~~$\frac{a^2b^2c^2}{48}$~~

$u = \frac{x^2}{a^2}$

$\frac{a^2}{2}du = x\,dx$

$\frac{b^2}{2}dv = y\,dy$

$\frac{c^2}{2}dw = z\,dz$

$\frac{a^2}{2}\frac{b^2}{2}\frac{c^2}{2}\iiint du\,dv\,dw = \frac{a^2b^2c^2}{8}\iiint u^{1-1}v^{1-1}w^{1-1}\,du\,dv\,dw$

$= \frac{a^2b^2c^2}{8}\,\frac{\Gamma(1)\Gamma(1)\Gamma(1)}{\Gamma(1+1+1+1)} = \frac{a^2b^2c^2}{8\times 6} = \frac{a^2b^2c^2}{48}$

Volume by Triple Integrals :

The volume by triple integral is $\iiint\limits_D dV$, where D is a solid region and dV = dxdydz.

$x = r\cos\theta,\ y = r\sin\theta$

Q.2. Consider the region $G = \{(x,y,z) \in R^3 : 0 < z < x^2 - y^2,\ x^2 + y^2 < 1\}$. Then the volume of G is equal to **IIT JAM 2022**

$$\int\int\int_0^{x^2-y^2} dz\,dx\,dy$$

(a) 1 (b) 0

(c) 2 (d) 1.4

$$\int\int (x^2 - y^2)\,dx\,dy$$

$$\int_0^{2\pi}\int_0^1 (r^2\cos^2\theta - r^2\sin^2\theta)\,r\,dr\,d\theta$$

$$\int_0^{2\pi} \cos 2\theta \left(\frac{r^4}{4}\right)_0^1 d\theta$$

$$\frac{1}{4}\int_0^{2\pi} \cos 2\theta\,d\theta$$

$$\frac{1}{4}\left(\frac{\sin 2\theta}{2}\right)_0^{2\pi} \qquad \theta = 0 \quad r = 0$$

$$= 0$$

Q.3. Volume of the solid $\left\{(x, y, z) \in R^3 \mid 1 \le x \le 2, 0 \le y \le \frac{2}{x}, 0 \le z \le x\right\}$ is expressible as **IIT – JAM 2017**

$0 \le z \le x \le 2$

(a) $\int_1^2 \int_0^{2/x} \int_0^x dz\,dy\,dx$ (b) $\int_1^2 \int_0^x \int_0^{2/x} dy\,dz\,dx$

(c) $\int_0^2 \int_1^z \int_0^{2/x} dy\,dx\,dz$ (d) $\int_0^2 \int_{\max(z,1)}^2 \int_0^{2/x} dy\,dx\,dz$


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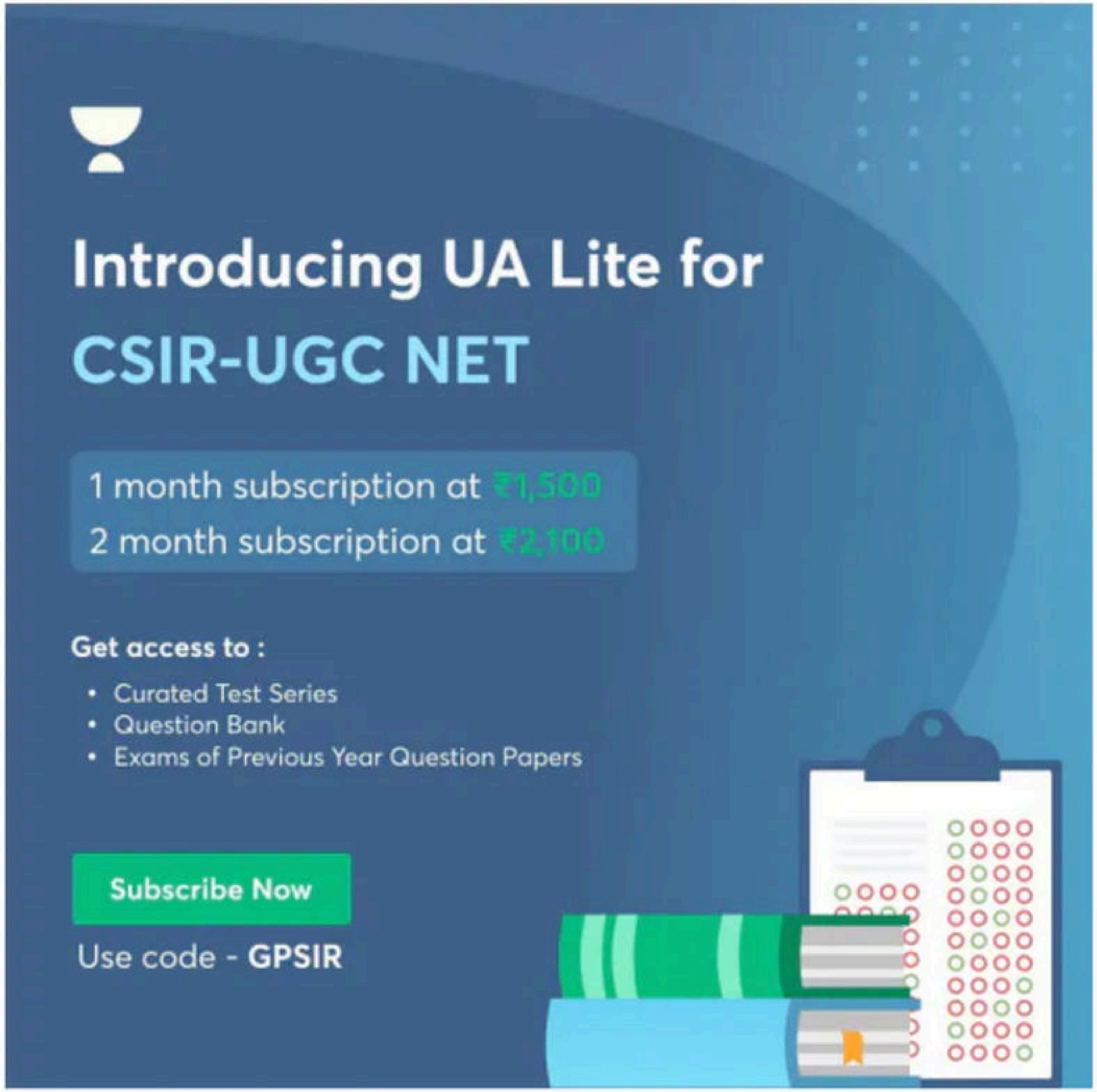
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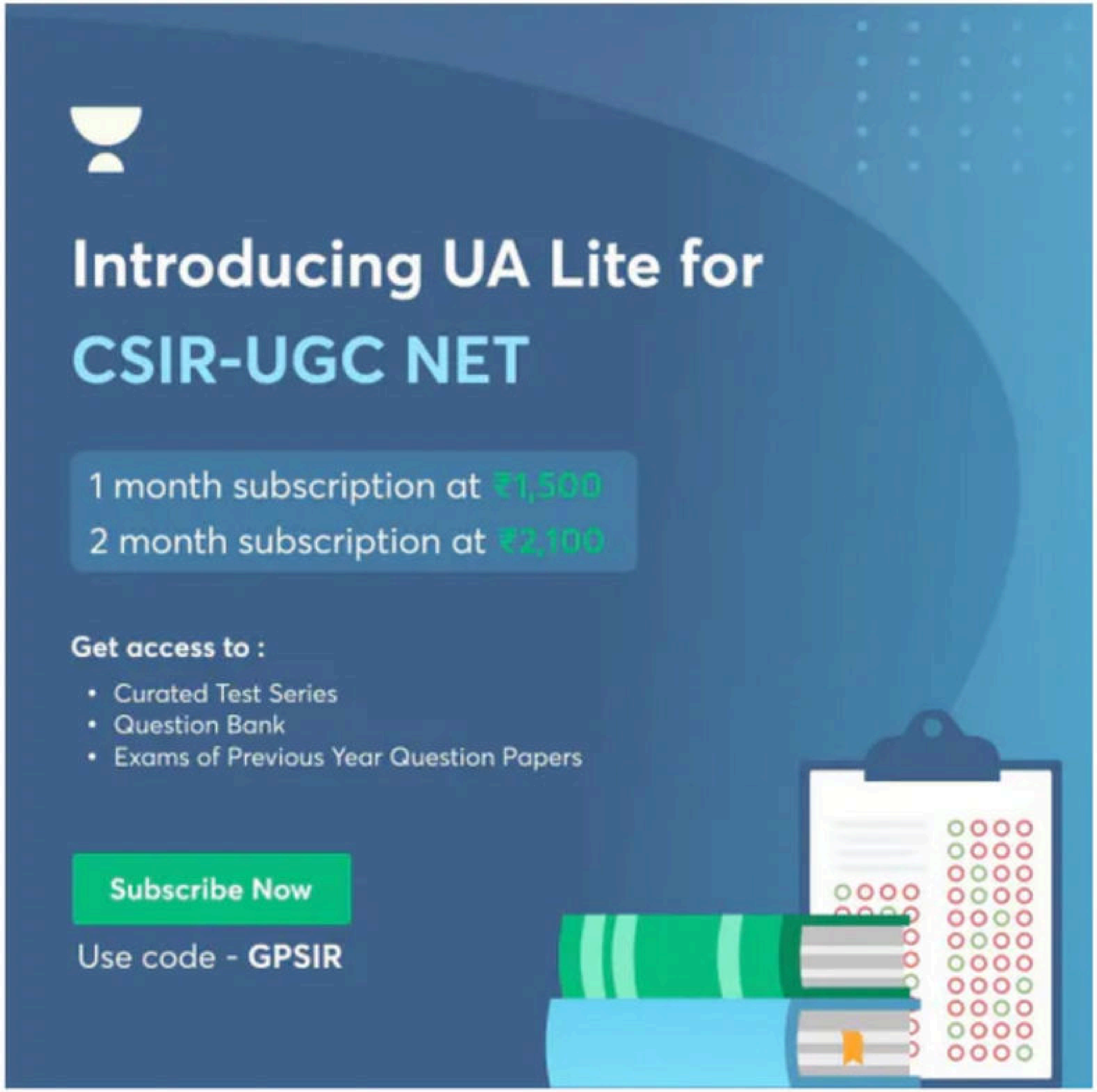
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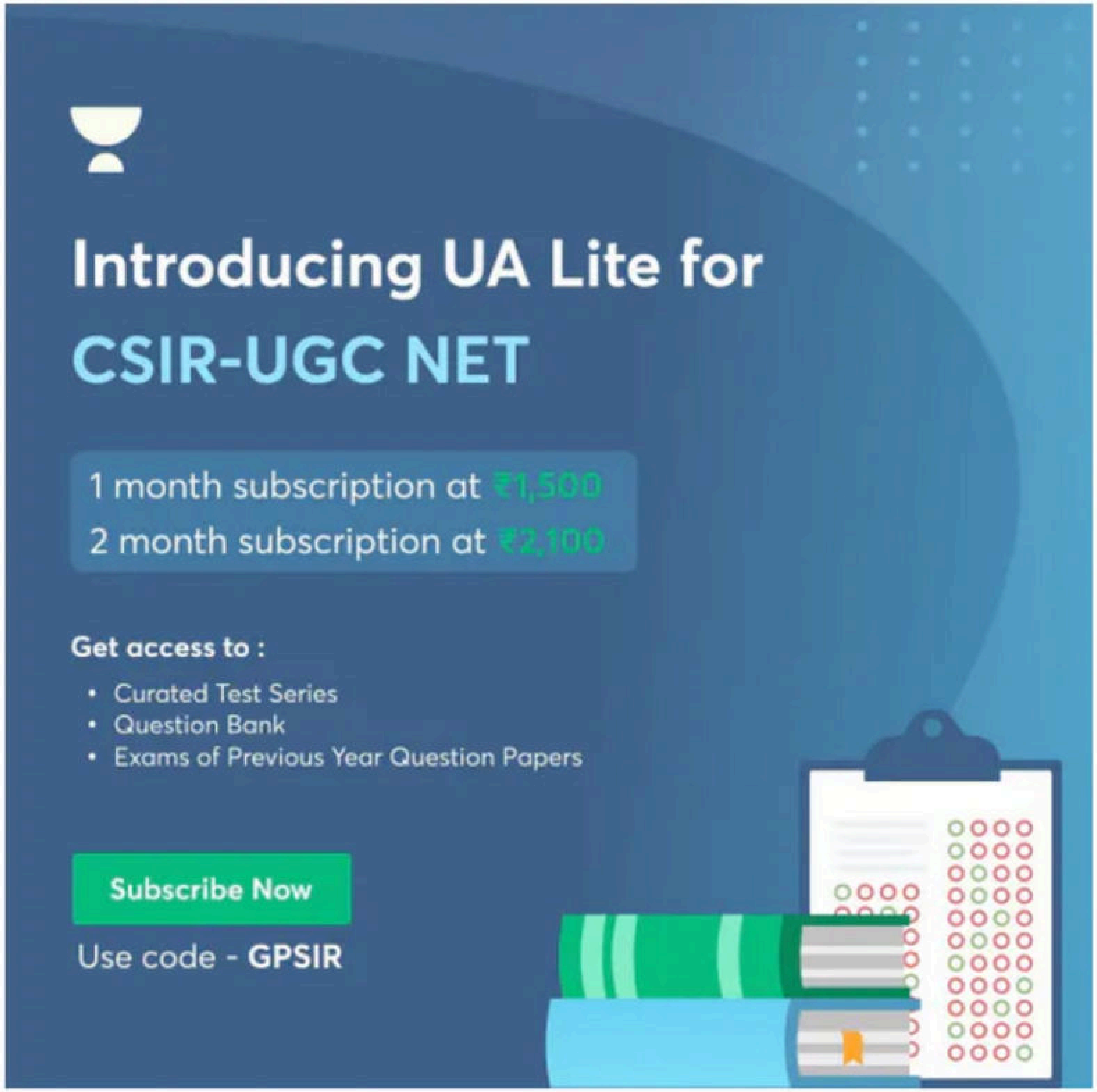
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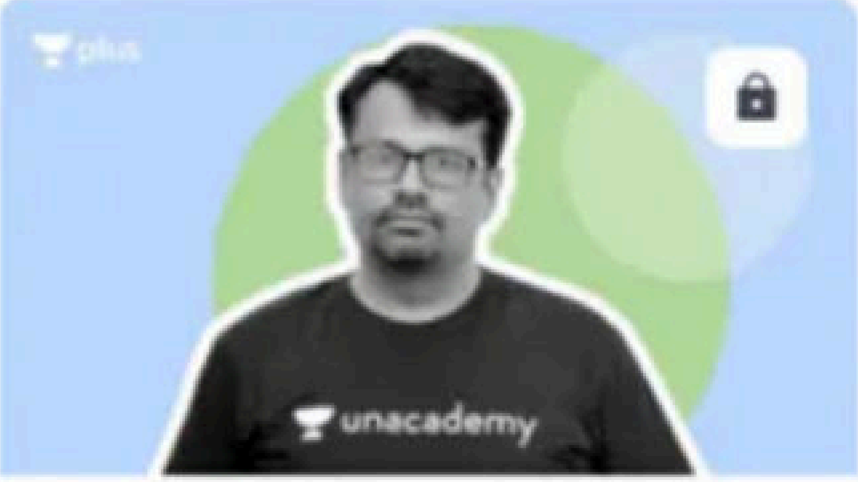

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- Lives in **Udaipur, Rajasthan, India**
- Unacademy Educator since

$$8-4\left[\frac{1}{2}+\sin^{-1}\frac{1}{\sqrt{2}}\right] = 8-2-\cancel{4}\frac{\pi}{\cancel{4}}$$

$$6-\pi$$

Q.4. If the volume of the solid in R^3 bounded by the surface by the surface ~~$x = -1, x = 1$~~, $y = -1$, $y = 1$, $z = 2$, $y^2 + z^2 = 2$ is $\alpha - \pi$, then α equal to **IIT JAM 2018**

(a) 4 (b) 5

(c) 6 (d) 7

$$\int\int\int dx\,dy\,dz$$

$$2\int_{-1}^{1}\int^{2} dy\,dz$$

$y=1$ $z=\sqrt{2-y^2}$

$$2\int_{-1}^{1}\left(2-\sqrt{2-y^2}\right)dy$$

$$4\int_{0}^{1}\left(2-\sqrt{2-y^2}\right)dy = 4\left[2y\right]_0^1 - 4\int_0^1\sqrt{2-y^2}\,dy$$

$$= 8-4\left[\frac{y}{2}\sqrt{2-y^2}+\frac{2}{2}\sin^{-1}\frac{y}{\sqrt{2}}\right]_0^1$$

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Q.5. The volume of the closed region bounded by the planes $x = 0$, $y = 0$, $z = 0$ and $2x + 5y + 10z = 10$ is **[JAM CA-2008]**

(a) 20/3 (b) 5

(c) 10/3 (d) 5/3

$$\frac{2}{10}x + \frac{5}{10}y + \frac{10z}{10} \Rightarrow \frac{x}{5} + \frac{y}{2} + \frac{z}{1} = 1$$

$$u = \frac{x}{5} \Rightarrow dx = 5du$$

$$v = \frac{y}{2} \Rightarrow dy = 2dv$$

$$w = z$$

$$dz = dw$$

$$\iiint 5du\, 2dv\, dw$$

$$10 \iiint u^{1-1} v^{1-1} w^{1-1}\, du\, dv\, dw$$

$$10\,\frac{\Gamma 1\, \Gamma 1\, \Gamma 1}{\Gamma(1+1+1+1)} = \frac{10}{\Gamma 4} = \frac{10}{6}$$

Q.6. The volume of the solid bounded by the planes $x + 2y + z = 2$, $x = 2y$, $x = 0$ and $z = 0$ is **[JAM CA 2010]**

(a) $\int_0^1 \int_0^{2-2y} \int_0^{2-x-2y} dz\, dx\, dy$

(b) $\int_0^1 \int_{x/2}^{1-\frac{x}{2}} \int_0^{2-x-2y} dz\, dy\, dx$

(c) $\int_0^1 \int_0^{2y} \int_0^{2-x-2y} dz\, dx\, dy$

(d) $\int_0^1 \int_0^{1/2} \int_0^{2-x-2y} dz\, dx\, dy$

Q.7. The volume of the region in R^3 given by $3|x| + 4|y| + 3|z| \leq 12$ is **[JAM CA-2011]**

(a) 64 (b) 48

(c) 32 (d) 24

$3x + 4y + 3z = 12$

$\frac{x}{4} + \frac{y}{3} + \frac{z}{4} = 1$

$48 \iiint du\, dv\, dw$

$8 \times 48 \frac{1}{3!} = 64$

Q.8. Find the volume of the region bounded by the plane $x = 0, y = 0, z = 0$ and $6x + 4y + 3z = 12$.

~~[JAM MS-2008]~~

(a) 1 (b) 2

(c) 3 (d) 4

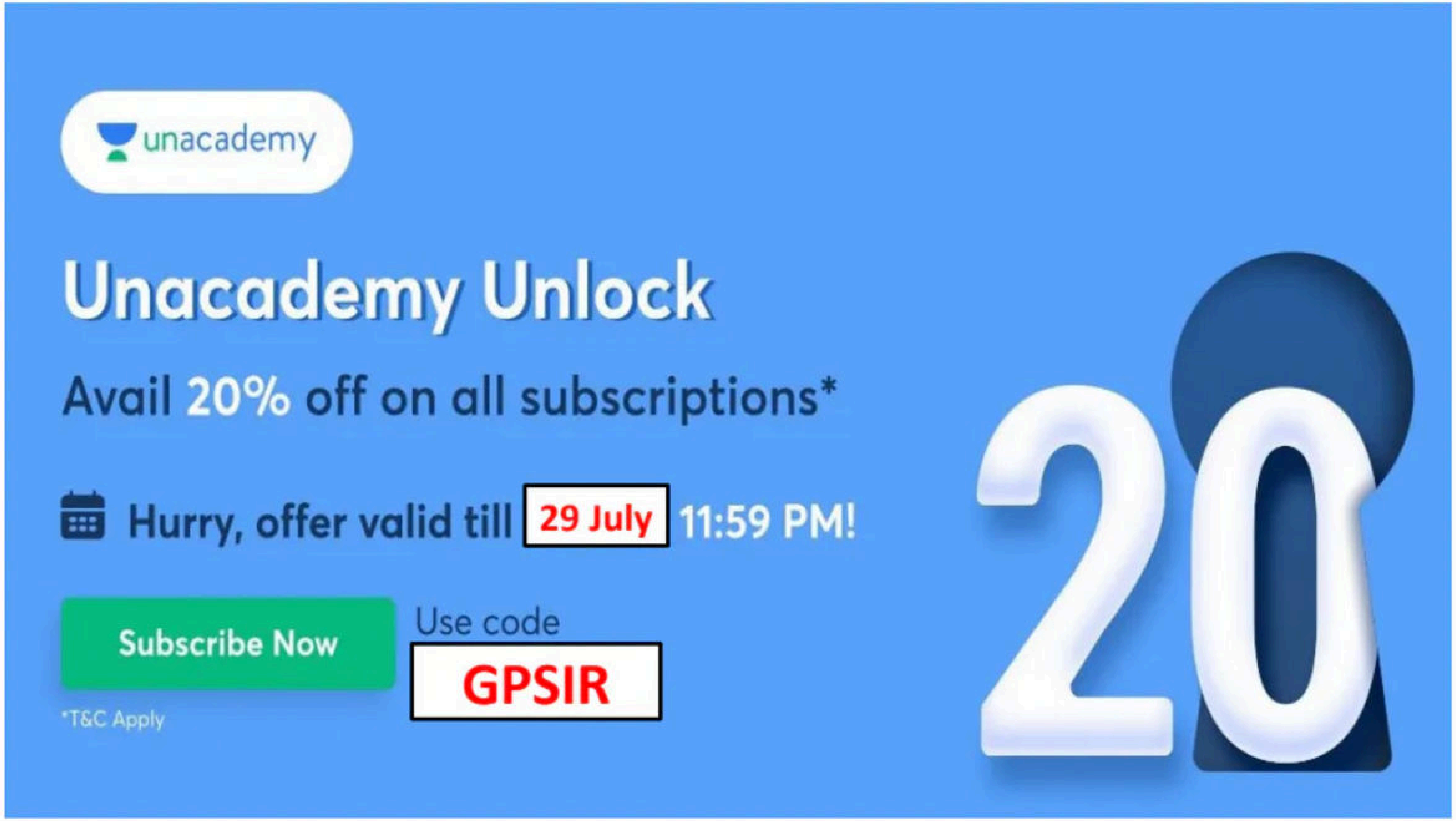
$\frac{x}{2} + \frac{y}{3} + \frac{z}{4}$

$\frac{24}{3}$

Q.9. Find the finite volume enclosed by the paraboloids $z = 2 - x^2 - y^2$ and $z = x^2 + y^2$. **IIT JAM – 2007**

(a) π (b) $-\pi$

(c) 2π (d) None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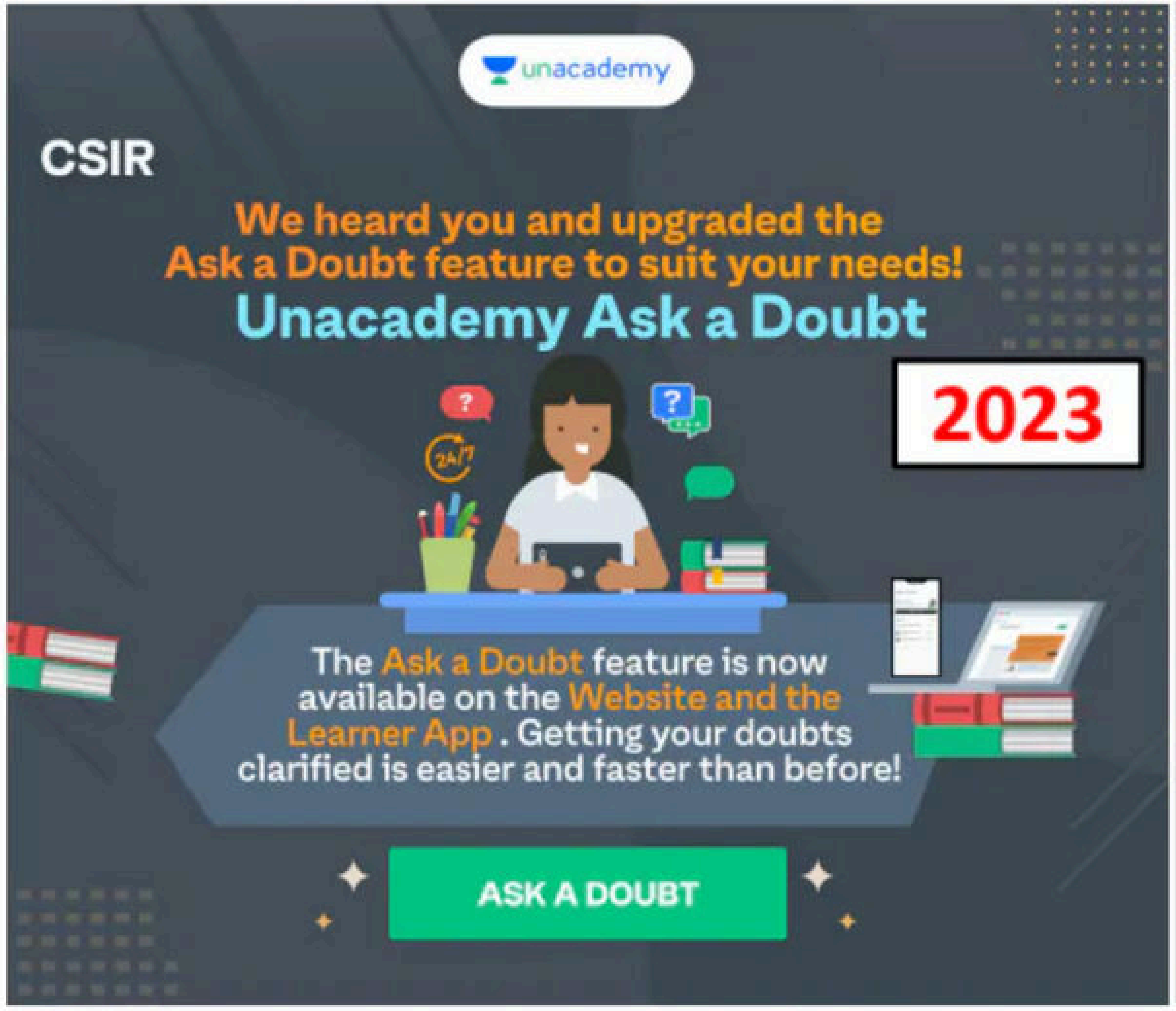
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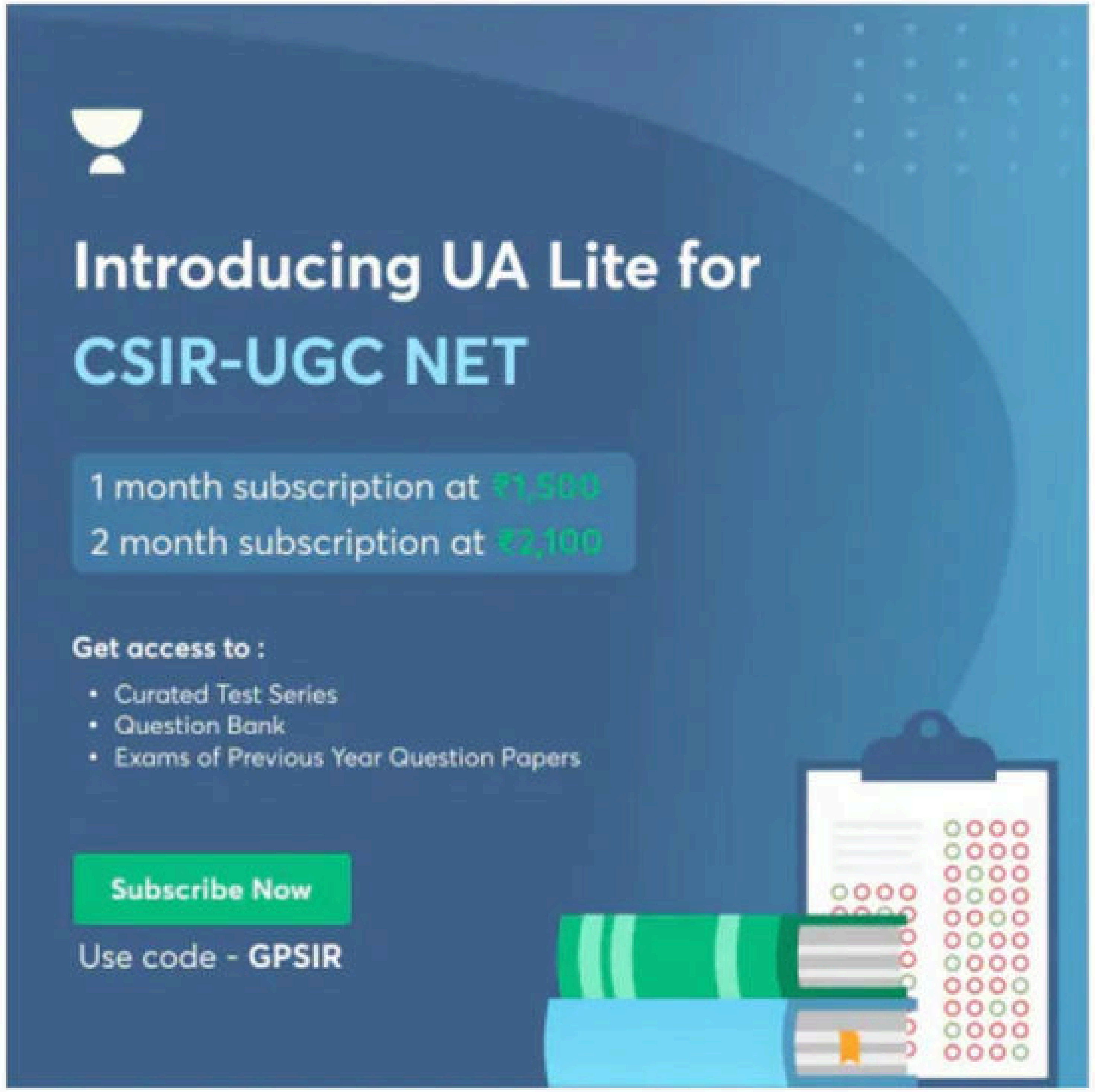
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