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Differential Equation

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Q4. The differential equation

$$\frac{d^2y}{dx^2} + \sin x \frac{dy}{dx} + ye^x = \sinh x \text{ is}$$

- (A) first order and linear
- (B) first order and non linear
- (C) second order and linear
- (D) second order and non linear



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Ans. (C)

Sol.

$$\frac{d^2y}{dx^2} + \sin x \frac{dy}{dx} + ye^x = \sinh x$$

Is of second order linear differential equation (each derivative being of one degree).

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Q10. The differential equation for the variation of the amount of salt x in a tank with time t is given by $\frac{dx}{dt} + \frac{x}{20} = 10$. x is in kg and t is in minute. Assuming that there is no salt in the tank initially, the time (in minute) at which the amount of salt increases to 100 kg is

- (A) $10 \ln 2$
- (B) $20 \ln 2$
- (C) $50 \ln 2$
- (D) $100 \ln 2$



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Ans. (B)

Sol.

Given Differential equation

$$\frac{dx}{dt} + \frac{x}{20} = 10$$

X is in kg t is in minute it is a linear differential equation of first order and first degree

Its integrating factor (IF)

$$\int \frac{1}{20} dt = e^{t/20}$$

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$$xe^{t/20} = \int e^{t/20} 10dt + c$$

$$xe^{t/20} = 10 \cdot \frac{e^{t/20}}{1/20} + c = 200e^{t/20} + c$$

$$\rightarrow X = 200 + x = 200 + ce^{-t/20}$$

C being constant of integration. When $t = 0$, $x = 0$ kg (given initial condition) with it gives

$$0 = 200 + c^{-0/20} = 200 + c$$

$$c = -200$$

Problem is to find t , when $x = 100$ kg using this value of x in which we have

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$$100 = 200 - 200e^{-\frac{t}{20}}$$

$$\rightarrow -100 = -200e^{-\frac{t}{20}}$$

or $e^{-t/20} = \frac{1}{2} \rightarrow \log e^{-t/20} = \log \frac{1}{2}$

$$\rightarrow -\frac{t}{20} = -\log 2$$

$$t = 20 \log 2$$

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Q12. The differential equations $\left(\frac{dy}{dx}\right)^2 + y \frac{d^2y}{dx^2} = 0$ can be reduced to
(where, α is a constant)

- (A) $\left(\frac{dy}{dx}\right)^3 = \alpha - \frac{3y^2}{2}$
- (B) $\left(\frac{dy}{dx}\right)^2 = \alpha - 2y$
- (C) $\frac{dy}{dx} = \frac{\alpha}{y^2}$
- (D) $\frac{dy}{dx} = \frac{\alpha}{y}$

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Ans. (D)

Sol.

We take,

On differentiating Eq. we get

$$\frac{dy}{dx} = \frac{\alpha}{y}$$

$\rightarrow y \frac{dy}{dx} = \alpha$

$$\frac{dy}{dx} \frac{dy}{dx} + y \frac{d^2y}{dx^2} = 0$$

$$\rightarrow \left(\frac{dy}{dx} \right)^2 + y \frac{d^2y}{dx^2} = 0$$

→ on integrating can be reduced to on integrating



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Q14. Match the following, where x is the spatial coordinate and t is time

Group I	Group II
P. Wave equation	1. $\frac{\partial c}{\partial t} = \alpha \frac{\partial c}{\partial x}$ 2. $\frac{\partial c}{\partial t} = \alpha^2 \frac{\partial^2 c}{\partial x^2}$ 3. $\frac{\partial^2 c}{\partial t^2} = \alpha^2 \frac{\partial c}{\partial x}$ 4. $\frac{\partial^2 c}{\partial t^2} = \alpha^2 \frac{\partial^2 c}{\partial x^2}$
Q. Heat equation	

(A) P - 4, Q - 2

(C) P - 3, Q - 1

(B) P - 2, Q - 4

(D) P - 1, Q - 3



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Ans. (A)

Sol.

Option (A) is correct.

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In a certain exchanger, both the fluid has identical mass flow rate specific heat product. The hot fluid enters at 76°C and leaves at 97°C and cold fluid entering at 26°C leaves at 55°C. The effectiveness of heat exchanger is
a) 0.16
b) 0.58
c) 0.72
d) 1.0
Answer: (b)
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Q22. What condition is to be satisfied so that the solution of the

differential equation $\frac{d^2y}{dx^2} + a\frac{dy}{dx} + by = 0$ is of the form $y =$

$(C_1 + C_2x)e^{mx}$ where C_1 & C_2 are constants of integration?

- (A) $a^2 = b$
- (B) $b^2 = a$
- (C) $a^2 = 4b$
- (D) $b^2 = 4a$



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Ans. (C)

Sol.

Given $\frac{d^2y}{dx^2} + a \frac{dy}{dx} + by = 0 \dots \dots \dots \text{(i)}$

Its solution is $y = (C_1 + xC_2)e^{mx}$

C_1 and C_2 being constants of integration. Problem is to find the condition for this solution the solution $y = (C_1 + xC_2)e^{mx}$ shows the roots of the auxiliary eq. (i) must be equal. Auxiliary Eq. (i) is

$$m^2 + am + b = 0$$

$$m = \frac{-a \pm \sqrt{a^2 - 4b}}{2a}$$



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Q24. If $f(x)$ is the solution of the equation $\frac{dy}{dx} + 2xy + 2x = 0$ and $g(x)$ is the solution of the equation $\frac{dy}{dx} + 2xy - 2x = 0$ and the constant of integration in $f(x)$ is equal to that in $g(x)$ then which of the following is true?

- (A) $g(x) = f(x) + 2$
- (B) $g(x) = f(x) + 1$
- (C) $g(x) = f(x) - 1$
- (D) $g(x) = f(x) - 2$



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Ans. (A)

Sol.

$$\frac{dy}{dx} + 2xy = -2x \quad \dots\dots(i)$$

If $= \int 2x dx = e^{x^2}$

Solution is $ye^{x^2} = \int e^{x^2} \cdot (-2x) dx + c$
 $= -e^{x^2} + c_1$

$$f(x) = y - 1 + c_1 e^{-x^2}$$

[Given. F(x) is solution of Eq. (i)]

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

$$\text{if } = \int 2x dx = e^{x^2}$$

$$\text{Solution is } ye^{x^2} = \int e^{x^2} \cdot 2x dx + c_2$$

$$= e^{x^2} + c_2$$

$$g(x) = y = 1 + c_2 e^{-x^2}$$

[given, $g(x)$ is solution of Eq]

Also, $c_1 = c_2$



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$$G(x) = c_2 e^{-x^2} = 1 + c_1 e^{-x^2}$$

$$= 1 + f(x) + 1$$

$$= 2 + f(x)$$

$$\text{Or } g(x) = f(x) + 2$$

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Q33. With $y = e^{ax}$,

if the sum $s = \frac{dy}{dx} + \frac{d^2y}{dx^2} + \dots + \frac{d^n y}{dx^n}$ approaches $2y$ as $n \rightarrow \infty$, then
the value of a is

- (A) $\frac{1}{3}$
- (B) $\frac{1}{2}$
- (C) $\frac{2}{3}$
- (D) 2

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Ans. (C)

Sol.

$$\begin{aligned} Y &= e^{ax} \\ S &= \frac{dy}{dx} + \frac{d^2y}{dx^2} + \dots + \frac{d^ny}{dx^n} \\ &= ae^{ax} + a^2e^{ax} + \dots + a^n e^{ax} \\ &= ae^{ax}(1 + a + a^2 + \dots + a^{n-1}) \\ &= ae^{ax} \frac{1 - a^n}{(1 - a)} \end{aligned}$$

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Given, $\lim_{x \rightarrow \infty} s = 2y = 2e^{ax}$

$$\Rightarrow \lim_{x \rightarrow \infty} ae^{ax} \frac{(1 - a^{an})}{(1 - a)} = 2e^{ax}$$

$$\Rightarrow \lim_{x \rightarrow \infty} \frac{(1 - a^n)}{1 - a} = \frac{2}{a}$$

this is possible when $0 < a < 1$.
and then

$$\frac{1}{1 - a} = \frac{2}{a} \quad (\text{as } \lim_{x \rightarrow \infty} a^n = 0)$$

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$$\Rightarrow a = 2(1 - a) = 2 - 2a$$

$$3a = 2 \Rightarrow a = \frac{2}{3}$$

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Q36. The solution to the following equation $x^2 \frac{d^3y}{dx^3} + 2x \frac{d^2y}{dx^2} - 2 \frac{dy}{dx} = 0$ is given by

- (A) $y = C_1x + C_2x^{-2} + C_3$
- (B) $y = C_1x^2 + C_2x^{-2} + C_3$
- (C) $y = C_1x^2 + C_2x^{-1} + C_3$
- (D) $y = C_1x + C_2x^{-1} + C_3$



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Ans. (C)

Sol.

$$x^2 \frac{d^3y}{dx^3} + 2x \frac{d^2y}{dx^2} - 2 \frac{dy}{dx} = 0 \dots\dots \text{(i)}$$

On multiplying Eq. (i) by x , we get

$$x^3 \frac{d^3y}{dx^3} + 2x^2 \frac{d^2y}{dx^2} - 2x \frac{dy}{dx} = 0 \dots\dots \text{(ii)}$$

It is homogeneous linear differential equation of 3rd order and first degree

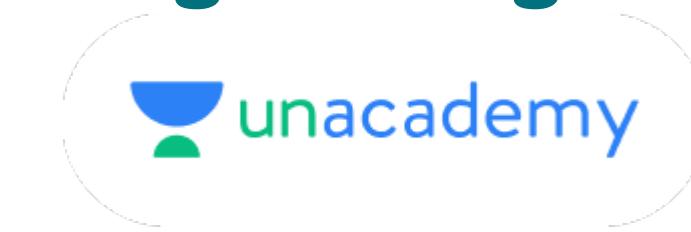
Putting $x = e^t$, then $x \frac{d}{dx} = \frac{d}{dt} = D$



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$$x^2 \frac{d^2}{dx^2} = D(D - 1) \Rightarrow x^3 \frac{d^3}{dx^3} = D(D - 1)(D - 2)$$

Using these in Eq. (ii) we get

$$\begin{aligned}[D(D - 1)(D - 2) + 2D(D - 1) - 2D]y &= 0 \\ \Rightarrow D[D^2 - 3D + 2 + 2D - 2 - 2]Y &= 0 \\ \Rightarrow D[D^2 - D - 2]y &= 0\end{aligned}$$

Its auxiliary equation is

$$m(m^2 - m - 2) = 0 \Rightarrow m = 0, -1, 2$$

$$\begin{aligned}CF &= a_1 e^{0t} + a_2 e^{-t} + a_3 e^{2t} \quad \text{So, } y = a_1 + a_2 e^{-t} + a_3 e^{2t} = a_1 + a_2 x^{-1} + a_3 x^2 \\ &= C_1 x^2 + C_2 x^{-1} + C_3 \quad \{\text{where, } a_3 = C_1, a_2 = C_2, a_1 = C_3 \text{ are constant}\}\end{aligned}$$

$$PI = 0$$

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Q43. The initial condition for which the following equation

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

has infinitely many solutions, is

- (A) $y(x = 0) = 5$
- (B) $y(x = 0) = 1$
- (C) $y(x = 2) = 1$
- (D) $y(x = -2) = 0$



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Ans. (D)

Sol.

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

$$\Rightarrow x(x + 2) \frac{dy}{dx} = (2xy + 2y)$$

$$\Rightarrow \frac{dy}{y} = \frac{2(x + 1)dx}{x(x + 2)}$$

$$\Rightarrow \frac{dy}{2y} = \frac{1}{2} \left[\frac{1}{2} + \frac{1}{x + 2} \right] dx$$

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Integrating on both sides,

$$\Rightarrow \frac{1}{2} \log y = \frac{1}{2} [\log x + \log(x+2)] + \frac{1}{2} \log C \Rightarrow \log y = \log x(x+2)C \Rightarrow \\ = y(x^2 + 2x)C$$

Given at $x = x_0 \Rightarrow y = y_0$

$$\Rightarrow y_0 = (x_0^2 + 2x_0)C \Rightarrow C = \frac{y_0}{x_0^2 + 2x_0}$$

From Eq (i), $y \frac{(x^2+2x)}{(x_0^2+2x_0)} y_0$

At $x = -2, y = 0$



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Q47. The solution of the following differential equation $x \frac{dy}{dx} +$

$y(x^2 - 1) = 2x^3$ is

- (A) 0
- (B) $2 + ce^{-\frac{x^2}{2}}$
- (C) $c_1x + c_2x^2$
- (D) $2x + Cxe^{-\frac{x^2}{2}}$

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Ans. (D)

Sol.

$$\begin{aligned}x \frac{dy}{dx} + (x^2 - 1)y &= 2x^3 \\ \Rightarrow \frac{dy}{dx} + \frac{x^2 - 1}{x}y &= 2x^2 \quad \dots\dots (i)\end{aligned}$$

Integrating factor,

$$\begin{aligned}\text{If } I.F. &= \int \frac{x^2 - 1}{x} dx = \int \left(x - \frac{1}{x}\right) dx \\ &= e^{\frac{x^2}{2}} - \log x = e^{\frac{x^2}{2}} e^{\log \frac{1}{x}} = \frac{e^{x^2/2}}{x}\end{aligned}$$

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solution of. (i)

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

$$= 2 \int e^{x^2/2} dx + c$$

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

So, $y \frac{e^{x^2/2}}{x} = 2 \int e^t dt + c = 2e^t + c$



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$$= 2e^{x^2/2} + C$$
$$y = 2X + CXe^{-x^2/2}$$

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Q52. Which one of the following is not an integrating factor for the differential equation $xdy - ydx = 0$?

- (A) $\frac{1}{x^2}$
- (B) $\frac{1}{y^2}$
- (C) $\frac{1}{xy}$
- (D) $\frac{1}{(x+y)}$

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Ans. (D)

Sol.

Given, differential equation

$$xdy - ydx = 0 \dots\dots (i)$$

$$\frac{\text{Eq.(i)}}{x^2} \Rightarrow \frac{xdy - ydx}{x^2} = 0 \Rightarrow d\left(\frac{y}{x}\right) = 0$$

$$\Rightarrow \frac{y}{x} = \text{constants } C_1$$

$\Rightarrow \frac{1}{x^2}$ is integrating factor

$$\frac{\text{Eq. (i)}}{y^2} \Rightarrow -\frac{(ydx - xdy)}{y^2} = 0$$

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$$\Rightarrow -d\left(\frac{x}{y}\right) = 0 \Rightarrow \frac{-x}{y} = C_2$$

$\Rightarrow \frac{1}{y^2}$ is integrating factor

$$\frac{\text{Eq.(i)}}{xy} \Rightarrow \frac{dy}{y} - \frac{dx}{x} = 0$$

$$\Rightarrow \log y - \log x = C_1$$

$\Rightarrow \frac{1}{xy}$ is integrating factor.

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$$\begin{aligned} \text{Eq} \cdot (i) \Rightarrow & \frac{x dy - y dx}{x + y} = 0 \\ \Rightarrow & \frac{x}{x + y} dy - \frac{y}{x + y} dx = 0 \\ M = & \frac{-y}{x + y} \\ \Rightarrow \frac{\partial M}{\partial y} = & \frac{-(1 \cdot (x + y) - y \cdot 1)}{(x + y)^2} = \frac{-x}{(x + y)^2} \end{aligned}$$

$$N = \frac{x}{x + y}$$
$$\Rightarrow \frac{\partial N}{\partial x} = \frac{1 \cdot (x + y) - x \cdot 1}{(x + y)^2} = \frac{y}{(x + y)^2}$$

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$$\text{As } \frac{\partial M}{\partial y} \neq \frac{\partial N}{\partial x}$$

$\Rightarrow \frac{x dy}{x+y} - \frac{y}{x+y} dx = 0$ is not integrable

$\Rightarrow \frac{1}{x+y}$ is not int integrating factor

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Q53. Which one of the following is not a solution of the differential equation $\frac{d^2y}{dx^2} + y = 1$?

- (A) $y = 1$
- (B) $y = 1 + \cos x$
- (C) $y = 1 + \sin x$
- (D) $y = 2 + \sin x + \cos x$

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Ans. (D)

Sol.

$$\frac{d^2y}{dx^2} + y = 1 \dots\dots (i)$$

We consider, $y = 2 + \sin x + \cos x$

$$\frac{dy}{dx} = \cos x - \sin x$$

$$\frac{d^2y}{dx^2} = -\sin x - \cos x \text{ LHS of Eq. (i)} \Rightarrow -\sin x - \cos x + 2\sin x + \cos x =$$

$2 \neq 1$ Thus, $y = 2 + \sin x + \cos x$ does not satisfy Eq. (i)
 \Rightarrow it is not the solution of Eq (i).



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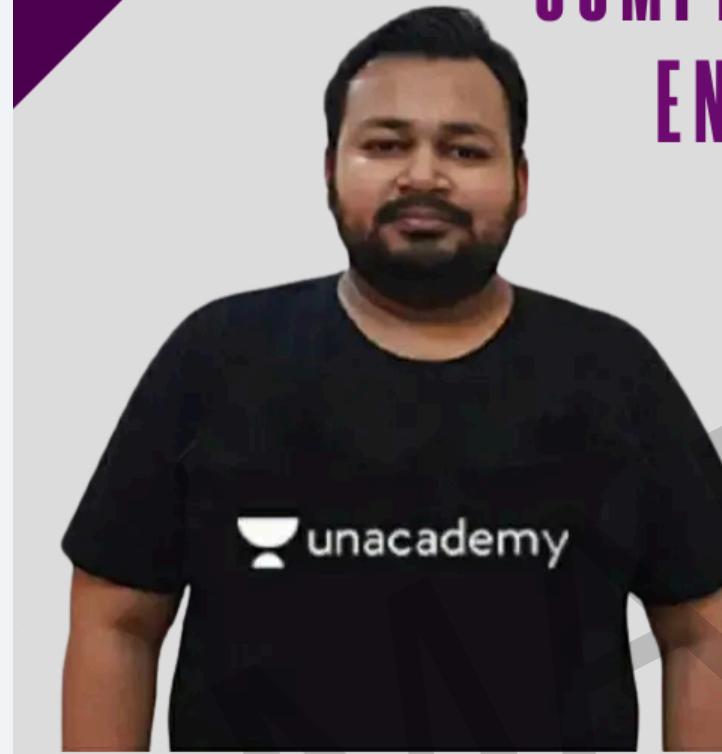
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- Q57. Which one of the following transformations reduces $\frac{dy}{dx} + Ay^3 + By = 0$ to a linear differential equation? (A & B are positive constants)
- (A) $u = y^{-3}$
 - (B) $u = y^{-2}$
 - (C) $u = y^{-1}$
 - (D) $u = y^2$



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Ans. (B)

Sol.

$$\frac{dy}{dx} + Ay^3 + By = 0$$

A and B being constant

Putting $u = 1/y^2 \Rightarrow \frac{du}{dx} = -2y^{-3} \frac{dy}{dx}$

Now, Eq (i) v

Using alone values in it, we get $-\frac{1}{2} \frac{du}{dx} + A + Bu = 0$

$$\text{or } \frac{du}{dx} - 2Bu = 2A$$

It is required linear differential equation.

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- Q68. The general solution of the differential equation $\frac{d^2y}{dx^2} - \frac{dy}{dx} - 6y = 0$, where C_1 and C_2 are constants of integration, is
- (A) $C_1 e^{-3x} + C_2 e^{-2x}$
 - (B) $C_1 e^{3x} + C_2 e^{-2x}$
 - (C) $C_1 e^{3x} + C_2 e^{2x}$
 - (D) $C_1 e^{-3x} + C_2 e^{2x}$

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Ans. (B)

Sol.

Given, $\frac{d^2y}{dx^2} - \frac{dy}{dx} - 6y$

Its auxiliary equation is $m^2 - m - 6 = 0$

$$\Rightarrow (m - 3)(m + 2) = 0 \Rightarrow m = 3 \cdot -2$$

$$CF = C_1 e^{3x} + C_2 e^{-2x}$$

$$PI = 0$$

$$So, y = CF + PI = C_1 e^{3x} + C_2 e^{-2x}$$



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Q81. The solution of the differential equation $\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 2y = 0$

With the initial conditions $y(0) = 0, \frac{dy}{dt}\Big|_{t=0} = -1$, is

- (A) $-ts \sin t$
- (B) $-e^{-t}(1 - \cos t)$
- (C) $-(t + \sin t/2)$
- (D) $-e^{-t} \sin t$

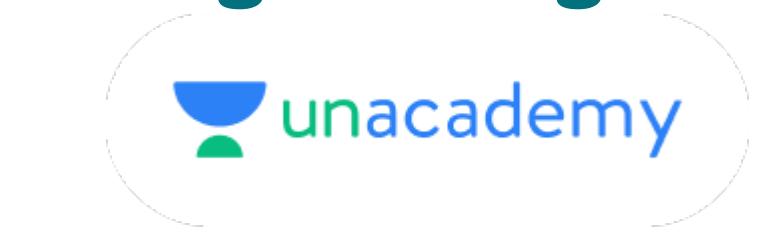
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Ans. (B)

Sol.

Given, $\frac{d^2y}{dt^2} + 2 \frac{dy}{dt} + 2y = 0$ (i)

With $y(0) = 0, \frac{dy}{dt} \Big|_{t=0} = -1$

Auxiliary eq. of (i)

$$m^2 + 2m + 2 = 0$$

$$\Rightarrow m = \frac{-2 + \sqrt{4 - 8}}{2} = -1 \pm i$$

$$CF = e^{-t}(C_1 \cos t + C_2 \sin t)$$

$$\text{so, } y(t) = e^{-t}(C_1 \cos t + C_2 \sin t)$$

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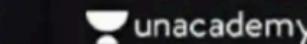
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$$\text{At } t = 0, y(0) = e^{-0}(C_1 \cos 0 + C_2 \sin 0)$$

$$0 = C_1$$

$$\begin{aligned} y'(t) &= e^{-t} - (t)(C_1 \cos t + C_2 \sin t) \\ &\quad + e^{-t}(-C_1 \sin t + C_2 \cos t) \end{aligned}$$

$$\text{At } t = 0, y'(0) = -1 \cdot (0) + e^{-0}C_2$$

$$-1 = C_2$$

$$\text{So } y(t) = -e^{-t} \sin t$$

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Q90. Which one of following choices is a solution of the differential equation given below? $\frac{dy}{dx} = \frac{y^2}{x} + \frac{y}{x} - \frac{2}{x}$. Note c is real constant.

- (A) $y = \frac{c-x^2}{c+2x^2}$
- (B) $y = \frac{c+2x^2}{c-x^2}$
- (C) $y = \frac{c-x^3}{c+2x^3}$
- (D) $y = \frac{c+2x^3}{c-x^3}$

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Ans. (D)

Sol.

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

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

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

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

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

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$$\Rightarrow \frac{1}{3} \left[\frac{1}{y-1} - \frac{1}{y+2} \right] dy = \frac{dx}{x}$$

On integrating

$$\frac{1}{3} [\log(y-1) - \log(y+2)] = \log x + \log c$$

$$\Rightarrow \log \frac{(y-1)}{(y+2)} = \log(c_1 x)^3$$

$$\Rightarrow \frac{y-1}{y+2} = (c_1 x)^3 = c_2 x^3 \quad [\text{putting } c_1^3 = c_2]$$

$$\Rightarrow y-1 = (y+2)c_2 x^3$$

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$$y - yc_2x^3 = 1 + 2c_2x^3$$

$$y(1 - c_2x^3) = 1 + 2c_2x^3$$

$$y = \frac{1 + 2c_2x^3}{1 - c_2x^3} = \frac{c_2\left(\frac{1}{c_2} + 2x^3\right)}{c_2\left(\frac{1}{c_2} - x^3\right)}$$

$$y = \frac{c + 2x^3}{c - x^3} = \left(\text{putting } \frac{1}{c_2} = c \right)$$

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Q94. If a and b are arbitrary constants, then the solution to the ordinary differential equation $\frac{d^2y}{dx^2} - 4y = 0$ is

- (A) $y = ax + b$
- (B) $y = ae^{-x}$
- (C) $y = a\sin 2x + b\cos 2x$
- (D) $y = a\cosh 2x + b\sinh 2x$

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In a certain exchanger, both the fluid has identical mass flow rate specific heat product. The hot fluid enters at 76°C and leaves at 97°C and cold fluid entering at 26°C leaves at 55°C. The effectiveness of heat exchanger is
a) 0.16
b) 0.58
c) 0.72
d) 1.0
Answer: (b)
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Ans. (D)

Sol.

We have

$$(D^2 - 4) = 0 \Rightarrow D^2 - 4 = 0$$

$$\Rightarrow D^2 = 4 \Rightarrow D = \pm 2$$

$$y = C_1 e^{2x} + C_2 e^{-2x}$$
$$= ae^{2x} + be^{-2x}$$

$$\cosh 2x = \frac{e^{2x} + e^{-2x}}{2}$$

$$\sinh 2x = \frac{e^{2x} - e^{-2x}}{2}$$

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Q104. Evaluate $\int \frac{dx}{e^x - 1}$ (Note: C is a constant of integration)

- (A) $\frac{e^x}{e^x + 1} + C$
- (B) $\ln \frac{(e^x - 1)}{e^x} + C$
- (C) $\ln \left(\frac{e^x}{e^x - 1} \right) + C$
- (D) $\ln(1 - e^{-x}) + C$

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Ans. (B)

Sol.

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

$$e^x - 1 = t$$

$$e^x dx = dt$$

$$dx = \frac{dt}{t+1}$$

$$\ln \frac{t}{t+1} + c = \ln \left| \frac{e^x - 1}{e^x} \right| + c$$

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Q106. The solution of the differential equation $\frac{dy}{dx} - y^2 = 0$, given $y = 1$ at $x = 0$ is

- (A) $\frac{1}{1+x}$
- (B) $\frac{1}{1-x}$
- (C) $\frac{1}{(1-x)^2}$
- (D) $\frac{x^3}{3} + 1$

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Ans. (B)

Sol.

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

$$y(0) = 1$$

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

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

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Q107. The solution of the differential equation $\frac{d^2y}{dx^2} - \frac{dy}{dx} + 0.25y = 0$, given $y = 0$ at $x = 0$ and $\frac{dy}{dx} = 1$ at $x = 0$ is

(A) $xe^{0.5x} - xe^{-0.5x}$
(B) $0.5xe^x - 0.5xe^{-x}$
(C) $xe^{0.5x}$
(D) $-xe^{0.5x}$

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Ans. (C)

Sol.

$$\frac{d^2y}{dx^2} - \frac{dy}{dx} + 0.25y = 0$$

$$(D^2 - D + .25)y = 0$$

$$D^2 - D + .25 = 0$$

$$D = 1 \pm \frac{\sqrt{1 - 4 \cdot 25}}{2}$$

$$= \frac{1}{2}, \frac{1}{2}$$

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$$y = (C_1 x + C_2) e^{1/2x}$$

$$y(0) = 0$$

$$y^1 = C_1 \left[x e^{1/2} \cdot \frac{1}{2} + e^{1/2} \cdot 1 \right] C_2 = 0$$

$$y^1(0) = 1$$

$$y = x e^{1/2x} \quad C_1 = 1$$

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Q114. The integrating factor for the differential equation $\frac{dy}{dx} - \frac{y}{1+x} =$
(1 + x) is

- (A) $\frac{1}{1+x}$
- (B) (1 + x)
- (C) $x(1 + x)$
- (D) $\frac{x}{1+x}$

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Ans. (A)

Sol.

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

I.F. = $e^{\int \frac{-1}{1+x} dx} = e^{\ln(1+x)^{-1}} = \frac{1}{1+x}$

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- Q115. The differential equation $\frac{d^2y}{dx^2} + x^2 \frac{dy}{dx} + x^3y = e^x$ is a
- (a) nonlinear differential equation of first degree
 - (b) linear differential equation of first degree
 - (c) linear differential equation of second degree
 - (d) nonlinear differential equation of second degree



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Ans. (B)

Sol.

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

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Q120. Consider a linear ordinary differential equation $\frac{dy}{dx} + p(x)y = r(x)$. Functions $p(x)$ and $r(x)$ are defined and have a continuous first derivative. The integrating factor of this equation is non zero. Multiplying this equation by its integrating factor converts this into a:

- (A) homogeneous differential equation
- (B) nonlinear differential equation
- (C) second order differential equation
- (D) exact differential equation



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Ans. (D)

Sol.

Option (D) is correct.

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Q129. What is the solution for the second order differential equation $\frac{d^2y}{dx^2} + y = 0$, with the initial conditions $y|_{x=0} = 5$ and $\frac{dy}{dx}|_{x=0} = 10$?

- (A) $y = 5 + 10\sin x$
- (B) $y = 5\cos x - 5\sin x$
- (C) $y = 5\cos x + 10x$
- (D) $y = 5\cos x + 10\sin x$



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Ans. (D)

Sol.

$$D^2 + 1 = 0$$

$$D = \pm i$$

$$Y = C_1 \cos x + C_2 \sin x$$

By using the boundary condition

$$y = 5 \cos x + 10 \sin x$$

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Q138. For the initial value problem

$$\frac{dx}{dt} = \sin(t), x(0) = 0$$

The value of x at $t = \pi/3$, is _____

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Ans. 0.5

Sol.

$$\frac{dx}{dt} = \sin t \Rightarrow \int dx = \int \sin t dt \Rightarrow x = -\cos t + C$$

Given,

$$x(0) \Rightarrow \text{at } t = 0 \Rightarrow x = 0 \Rightarrow 0 = -1 + C \Rightarrow C = 1$$

$$\therefore x = -\cos t + 1$$

$$\text{at } t = \frac{\pi}{3}, x = -\cos \frac{\pi}{3} + 1 = -\frac{-1}{2} + 1 = \frac{1}{2} = 0.5$$

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Q143. Consider the following two equations:

$$\frac{dx}{dt} + x + y = 0$$

$$\frac{dy}{dt} - x = 0$$

The above set of equations is represented by

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- (A) $\frac{d^2y}{dt^2} - \frac{dy}{dt} - y = 0$
- (B) $\frac{d^2x}{dt^2} - \frac{dx}{dt} - y = 0$
- (C) $\frac{d^2y}{dt^2} + \frac{dy}{dt} + y = 0$
- (D) $\frac{d^2x}{dt^2} + \frac{dx}{dt} + x = 0$

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Ans. (C)

Sol.

$$\frac{dx}{dt} - x = 0 \dots\dots (2)$$

From (2); $x = \frac{dy}{dt} \dots \dots \dots$ (3)

Differentiate both sides w. x. t ‘t’, then $\frac{dx}{dt} = \frac{d^2y}{dt^2}$

$$\frac{dx}{dt} = \frac{d^2y}{dt^2} \dots \dots \dots \dots \dots \dots \quad (4)$$

\therefore From (1); $\frac{d^2y}{dt^2} + \frac{dy}{dt} + y = 0$ $[\because x = \frac{dy}{dt} \text{ & } \frac{dx}{dt} = \frac{d^2y}{dt^2}]$

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Q145. If $y = e^{-x^2}$ then the value of

$$\lim_{x \rightarrow \infty} \frac{1}{x} \frac{dy}{dx}$$

is _____

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Ans. 0

Sol.

$$\begin{aligned}y &= e^{-x^2} \Rightarrow \frac{dy}{dx} = e^{-x^2}(-2x) \\ \therefore \lim_{x \rightarrow \infty} \frac{1}{x} \frac{dy}{dx} &= \lim_{x \rightarrow \infty} \frac{1}{x} [e^{-x^2}(-2x)] \left[\because \frac{dy}{dx} = e^{-x^2}(-2x) \right] \\ &= \lim_{x \rightarrow \infty} -2e^{-x^2} \\ &= -2 \times 0 \left[\because \lim_{x \rightarrow \infty} e^{-x^2} = 0 \right] = 0\end{aligned}$$



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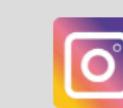
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Q153. Given $\frac{dy}{dx} = y - 20$, and $y|_{x=0} = 40$, the value of y at $x = 2$ is _____ (round off to nearest integer).

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Ans. (167.78)

Sol.

$$\frac{dy}{dx} = y - 20$$

$$\int_{40}^y \frac{dy}{y - 20} = \int_0^2 dx$$

$$\ln\left(\frac{y - 20}{40 - 20}\right) = 2$$

$$y - 20 = 20e^2 = 167.78$$

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Q158. The solution of the ordinary differential equation $\frac{dy}{dx} + 3y = 1$, subject to the initial condition $y = 1$ at $x = 0$, is
(GATE – 2019)

- (a) $\frac{1}{3}(1 + 2e^{-x/3})$
- (b) $\frac{1}{3}(5 - 2e^{-x/3})$
- (c) $\frac{1}{3}(5 - 2e^{-3x})$
- (d) $\frac{1}{3}(1 + 2e^{-3x})$



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Ans. (d)

Sol.

$$\begin{aligned} \frac{dy}{dx} + 3y &= 1 \\ \int \frac{dy}{1-3y} &= \int dx \\ -\frac{1}{3} \ln \left[\frac{1-3y}{1-3} \right] &= x \\ 3y - 1 &= 2e^{-3x} \\ y &= [1 + 2e^{-3x}] \cdot 1/3 \end{aligned}$$



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Q166. The value of y as $t \rightarrow \infty$ for the following differential equation for an initial value of $y(1) = 0$ is: $(4t^2 + 1)\frac{dy}{dt} + 8yt - t = 0$
(GATE – 2003)

- a) 1
- b) 1/2
- c) 1/4
- d) 1/8



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Ans. (d)

Sol.

$$(4t^2 + 1) \frac{dy}{dt} + 8yt - t = 0$$

$$\frac{dy}{dt} + \frac{8t}{(4t^2 + 1)}y = \frac{t}{(4t^2 + 1)}$$

$$IF = e^{\int \frac{8t}{(4t^2 + 1)} dt} = e^{\ln(4t^2 + 1)} = (4t^2 + 1)$$

$$y(4t^2 + 1) = \int \frac{t}{(4t^2 + 1)} \cdot (4t^2 + 1) dt + c$$



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$$y(4t^2 + 1) = \frac{t^2}{2} + c$$

$$y(1) = 0$$

$$0 = \frac{1}{2} + c \rightarrow c = -\frac{1}{2}$$

$$y = \frac{1}{(4t^2 + 1)}(t^2 - 1)\frac{1}{2}$$

$$y = \frac{1}{2} \cdot \frac{\left(1 - \frac{1}{t^2}\right)}{\left(4 + \frac{1}{t^2}\right)}$$

$$\lim_{t \rightarrow \infty} y = \frac{1}{2} \cdot \frac{1}{4} = \frac{1}{8}$$

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Q168. The differential equation, $\frac{d^2x}{dt^2} + 10 \frac{dx}{dt} + 25x = 0$ will have a solution of the form

(GATE – 2003)

- a) $(C_1 + C_2 t)e^{-5t}$
- b) $C_1 e^{-2t}$
- c) $C_1 e^{-5t} + C_2 e^{5t}$
- d) $C^5 t + C_2 e^{2t}$

where C_1 and C_2 are constants.



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Ans. (b)

Sol.

$$(D^2 + 10D + 25)x = 0$$

Characteristic equation = $m^2 + 10m + 25 = 0$

$$m = -5, -5$$

$x = C.F$

$$\alpha = c_1 e^{5t} + c_2 t e^{-5t}$$

$$\alpha = (c_1 + c_2 t) e^{-5t}$$

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Q175. (a) Reduce the following differential equation to linear form

$$\frac{dz}{dt} + Zt = Z^{-1}t$$

- (b) Find a general solution to the linearized equation
(c) Determine the integration constants if $z(0) = 0$

(GATE – 2002)

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Ans. (a) $\rightarrow \frac{da}{dt} + 2ta = 2t$, (b) $\rightarrow z = [1 + ce^{-t^2}]^{1/2}$, (c) $\rightarrow -1$

Sol.

$$\frac{dz}{dt} + zt = z^{-1}t$$

$$z \frac{dz}{dt} + z^2 t = t$$

$$z^2 = a \rightarrow 2z \frac{dz}{dt} = \frac{da}{dt}$$

$$\frac{1}{2} \frac{da}{dt} + at = t$$

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$$\frac{da}{dt} + 2ta = 2t$$

(Linear differential Equation)

$$IF = e^{\int 2t dt} = e^{t^2}$$

$$ae^{t^2} = \int 2t e^{t^2} dt + c$$

$$ae^{t^2} = e^{t^2} + c$$

$$a = 1 + ce^{-t^2}$$

$$z^2 = 1 + ce^{-t^2}$$

$$z = [1 + ce^{-t^2}]^{1/2}$$

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At $t = 0$

$$z = 0$$

$$0 = (1 + c)^{1/2} \rightarrow c = -1$$

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Q186. The integrating factor for the differential equation

$$(\cos^2 x) \frac{dy}{dx} + y = \tan x \text{ is}$$

(GATE – 2000)

- A) $e^{\tan x}$
- B) $\cos 2x$
- C) $e^{-\tan x}$
- D) $\sin 2x$

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Ans. (a)

Sol.

Standard 1st order D.E.

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

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

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

$$= e^{\tan x}$$

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Q190. The general solution of $\frac{d^4y}{dx^4} + 2 \frac{d^2y}{dx^2} + y = 0$

(GATE – 2000)

- (A) $(C_1x + C_2)e^x + (C_3 + C_4x)e^{-x}$
- (B) $C_1\cos x + C_2\sin x + C_3e^x + C_4e^{-x}$
- (C) $C_1e^{ix} + C_2e^{-ix}$
- (D) $(C_1 + C_2x)\cos x + (C_3 + C_4x)\sin x$

Where C_1, C_2, C_3 , and C_4 are constants.

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Ans. (a)

Sol.

$$(D^4 + 2D^2 + 1)y = 0$$

Characteristic equation

$$m^4 + 2m^2 + 1 = 0$$

$$(m^2 + 1)^2 = 0$$

$$m \pm i, \pm i$$

Two equal imaginary roots (pair)

General solution -

$$y = (c_1 + c_2x) \cdot e^{\alpha x} (c_3 \cos \beta x + c_4 \sin \beta x)$$

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$$\alpha = 0, \quad \beta = 1$$

$$y = (c_1 + c_2x)(c_3 \cos x + c_4 \sin x)$$

$$y = c_3(c_1 + c_2x) \cos x + c_4(c_1 + c_2x) \sin x$$

$$y = (c'_1 + c'_2x) \cos x + (c'_3 + c'_4x) \sin x$$

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Q200. Solve $\frac{dy}{dx} - 6xy = -6x$ by the following methods:

- (a) variation of parameters
- (b) separation of variables

(GATE – 1999)

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Ans. (a) $\rightarrow (y = 1 + ce^{3x^2})$, (b) $\rightarrow (y = 1 + c'e^{3x^2})$

Sol.

a) Variation of parameter

$$\frac{dy}{dx} - 6xy = -6x$$

$$IF = e^{\int pdx} = e^{-6 \int x dx} = e^{-3x^2}$$

$$ye^{-3x^2} = \int e^{-3x^2} (-6x) dx + c$$

$$y = 1 + ce^{3x^2}$$

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(b) Variable separable method -

$$\frac{dy}{dx} = 6x(y - 1)$$

$$\int \frac{dy}{(y - 1)} = \int 6x \, dx$$

$$\ln(y - 1) = 3x^2 + c$$

$$y - 1 = e^{3x^2} * e^c$$

$$y = 1 + e^c e^{3x^2}$$

$$y = 1 + c' e^{3x^2}$$

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Q206. The differential equation $\frac{d^2y}{dt^2} + 3 \frac{dy}{dt} + 2y = 0$ will have a solution of the form

(GATE – 1998)

- A) $C_1 e^{-t} + C_2 e^{2t}$
- B) $C_1 e^{-t} + C_2 e^{-2t}$
- C) $C_1 e^{-3t} + C_2 e^{-2t}$
- D) $C_1 e^{-5t}$

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Ans. (b)

Sol.

$$(D^2 + 3D + 2)Y = 0$$

Characteristic equation -

$$m^2 + 3m + 2 = 0$$

$$m^2 + 2m + m + 2 = 0$$

$$m(m+2) + (m+2) = 0$$

$$m = -1, -2$$

$Y = C.F.$

$$Y = c_1 e^{-x} + c_2 e^{-2x}$$

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Q216. Solve $\frac{d^2y}{dx^2} - m^2y = 0$ subject to $y = 1$ at $x = 0$ and $dy/dx = 0$ at $x = 1$.

(GATE – 1996)

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$$\text{Ans. } y = \frac{e^{mx}}{(1+e^{2m})} + \frac{e^{2m}}{(1+e^{2m})} e^{-mx}$$

Sol.

$$(D^2 - m^2)y = 0$$
$$D = +m, -m$$
$$= c_1 e^{mx} + c_2 e^{-mx}$$

@ x = 0, y = L

$$1 = c_1 + c_2 \dots$$

$$\frac{dy}{dx} = c_1 m e^{mx} + c_2 (-m) e^{-mx}$$

$$@ x = 1 \frac{dy}{dx} = 0$$

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$$0 = mc_1 e^m - mc_2 e^{-m} \rightarrow c_1 e^{2m} = c_2 \dots \dots \text{(ii)}$$

From (i) & (ii)

$$c_1(1 + e^{2m}) = 1$$

$$c_1 = \frac{1}{(1 + e^{2m})}$$

$$c_2 = \frac{e^{2m}}{(1 + e^{2m})}$$

$$y = \frac{e^{mx}}{(1 + e^{2m})} + \frac{e^{2m}}{(1 + e^{2m})} e^{-mx}$$



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Q218. Solve using $\frac{dy}{dx} + 0.6y = 6e^{-0.5x}$ the integrating factor method
given $y = 1$ at $x = 0$.

(GATE – 1996)

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Ans. $y = 60e^{-0.5x} - 59e^{-0.6x}$

Sol.

$$\frac{dy}{dx} + 0.6y = 6e^{-0.5x}$$

$$IF = e^{\int 0.6 dx} = e^{0.6x}$$

$$y \cdot e^{0.6x} = \int 6e^{-0.5x} e^{0.6x} dx + c$$

$$y \cdot e^{0.6x} = 6 \int e^{0.1x} dx + c$$



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$$y \cdot e^{0.6x} = \frac{6e^{0.1x}}{0.1} + c$$

$$y(0) = 1$$

$$1 = 60 + c \rightarrow c = -59$$

$$y = 60e^{0.1x}e^{-0.6x} - 59e^{-0.6x}$$

$$y = 60e^{-0.5x} - 59e^{-0.6x}$$

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Q225. Match the items in the left column with the appropriate items in the right column.

- (I) $y = x^2$
- (II) $dy/dx = 2x$

- (A) linear O.D.E.
- (B) nonlinear O.D.E.
- (C) linear algebraic equation
- (D) nonlinear algebraic equation

(GATE – 1995)

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Ans. (I) \rightarrow (D), (II) \rightarrow (A)

Sol.

(i) $y = x^2$ non linear algebraic equation

(ii) $\frac{dy}{dx} = 2x$ linear O.D.E.

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Q226. Match the items in the left column with the appropriate items in the right column.

- (I) $\frac{dy}{dx} + 5y = 0, y(0) = y_0$
(II) $\frac{dy}{dx} + 5 = 0, y(0) = y_0$

- (A) $y = y_0 + 5x$
(B) $y = y_0 - 5x$
(C) $y = y_0 e^{-5x}$
(D) $y = y_0 e^{5x}$

(GATE – 1995)

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Ans. (I) $\rightarrow y = y_0 e^{-5x}$ (II) $\rightarrow y = y_0 - 5x$

Sol.

$$(I) \frac{dy}{dx} + 5y = 0$$

$$-\int \frac{dy}{y} = \int 5dx + c$$

$$-\ln y = 5x + c$$

$$x = 0 \quad y = y_0$$

$$-\ln y_0 = c$$

$$\ln \frac{y_0}{y} = 5x \rightarrow y = y_0 e^{-5x}$$



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$$(II) \frac{dy}{dx} + 5 = 0$$

$$\int dy = - \int 5dx + c$$
$$y = -5x + c$$
$$y(0) = y_0$$
$$y_0 = c$$
$$y = y_0 - 5x$$

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Q230. Integrating factor for the differential equation, $\frac{dy}{dx} + P(x)y = Q(x)$ (GATE – 1994)

- (a). $\exp[\int pdx]$
- (b). $\exp[-\int pdx]$
- (c). $\int Pdx$
- (d). dP/dx

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Ans. (a)

Sol.

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

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

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Q231. The solution for the differential equation $\frac{d^2y}{dt^2} + 5\frac{dy}{dt} + 6y = 0$
(GATE – 1994)

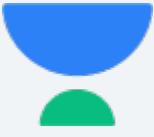
- (a). $C_1 e^{-2t} + C_2 e^{3t}$
- (b). $C_1 \sin 2t + C_2 \cos 2t$
- (c). $C_1 e^{2t} + C_2 e^{-3t}$
- (d). $C_1 e^{-2t} + C_2 e^{-3t}$

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Ans. (d)

Sol.

$$\frac{d^2y}{dx^2} + 5 \frac{dy}{dx} + 6y = 0$$

$$(D^2 + 5D + 6)y = 0$$

$$M^2 + 5M + 6 = 0$$

$$M = -3, -2$$

Solution –

$$y = CF$$

$$y = c_1 e^{-3x} + c_2 e^{-2x}$$



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