

# 8

## Differential Equations and Applications



### Let's Study

- Differential Equation
- Ordinary differential equation
- Order and degree of a differential equation
- Solution of a differential equation
- Formation of a differential equation
- Applications of differential equations



### Let's Recall

- Independent variable
- Dependent variable
- Equation
- Derivatives
- Integration



### Let's Learn

#### 8.1 Differential Equations:

**Definition:** An equation involving dependent variable(s), independent variable and derivative(s) of dependent variable(s) with respect to the independent variable is called a differential equation.

For example :

- 1)  $\frac{dy}{dx} + y = x$
- 2)  $x^2 \frac{d^2 y}{dx^2} + x \frac{dy}{dx} + y = 0$
- 3)  $\frac{d^2 y}{dt^2} = 2t$

$$4) \quad r \frac{dr}{d\theta} + e^\theta = 8$$

$$5) \quad \sqrt{1 + \frac{dy}{dx}} = \frac{d^2 y}{dx^2}$$

$$6) \quad x dx + y dy = 0$$

#### 8.1.1 Ordinary differential equation

A differential equation in which the dependent variable, say  $y$ , depends only on one independent variable, say  $x$ , is called an ordinary differential equation.

#### 8.1.2 Order of a differential equation

It is the order of the highest order derivative occurring in the differential equation.

$$\frac{dy}{dx} + y = x \text{ is of order 1}$$

$$x^2 \frac{d^2 y}{dx^2} + x \frac{dy}{dx} + y = 0 \text{ is of order 2}$$

$$\left( \frac{d^2 y}{dx^2} \right)^2 + x \frac{dy}{dx} = 2y \text{ is of order 2}$$

$$\frac{2dy}{dx} = e^x \text{ is of order 1}$$

#### 8.1.3 Degree of a differential equation

It is the power of the highest order derivative when all the derivatives are made free from fractional indices and negative sign, if any.

For example -

$$1) \quad x^2 \left( \frac{d^2 y}{dx^2} \right)^1 + x \frac{dy}{dx} + y = 0$$

In this equation, the highest order derivative is  $\frac{d^2 y}{dx^2}$  and its power is one. Therefore this

equation has degree one.

$$2) \quad \frac{d^2 y}{dx^2} = \sqrt[3]{1 + \left(\frac{dy}{dx}\right)^2}$$

In this equation, the highest order derivative is  $\frac{d^2 y}{dx^2}$  but to determine the degree of this equation, first we have to remove the cube root by raising both sides to the power 3.

$$\left(\frac{d^2 y}{dx^2}\right)^3 = 1 + \left(\frac{dy}{dx}\right)^2 \therefore \text{the degree of this}$$

equation is 3.

$$3) \quad \frac{dy}{dx} = \frac{2x+7}{\frac{dy}{dx}}$$

The equation can be written as

$$\left(\frac{dy}{dx}\right)^2 = 2x+7. \text{ Now highest order derivative is}$$

$\frac{dy}{dx}$  and its power is two. Hence the equation has degree two.

#### **We have learnt:**

To find the degree of the differential equation, make all the derivatives free from fractional indices and negative sign, if any.

### **8.1.4 Solution of a Differential Equation:**

A function of the form  $y = f(x) + c$  which satisfies the given differential equation is called the solution of the differential equation.

Every differential equation has two types of solutions: 1) General and 2) Particular

#### **1) General Solution:**

A solution of the differential equation in which the number of arbitrary constants is equal to order of differential equation is called a general solution.

#### **2) Particular Solution:**

A solution of the differential equation which can be obtained from the general solution by giving particular values to the arbitrary constants is called a particular solution.

### **SOLVED EXAMPLES**

- 1) Verify that the function  $y = ae^x + be^{-2x}$ ,  $a, b \in \mathbb{R}$  is a solution of the differential equation  $\frac{d^2 y}{dx^2} + \frac{dy}{dx} = 2y$ .

**Solution:** Consider the function

$$y = ae^x + be^{-2x} \quad \dots\dots\dots \text{(I)}$$

Differentiating both sides of equation I with respect to  $x$ , we get

$$\frac{dy}{dx} = ae^x - 2be^{-2x} \quad \dots\dots\dots \text{II and}$$

Differentiating both sides of equation II with respect to  $x$ , we get

$$\frac{d^2 y}{dx^2} = ae^x + 4be^{-2x} \quad \dots\dots\dots \text{III}$$

$$\text{Now, L.H.S} = \frac{d^2 y}{dx^2} + \frac{dy}{dx}$$

$$= (ae^x + 4be^{-2x}) + (ae^x - 2be^{-2x}) \quad \text{(from II and III)}$$

$$= 2ae^x + 2be^{-2x}$$

$$= 2(ae^x + be^{-2x}) = 2y \text{ (from I)}$$

$$= \text{R.H.S.}$$

Therefore, the given function is a general solution of the given differential equation.

- 2) Verify that the function  $y = e^{-x} + ax + b$ , where  $a, b \in \mathbb{R}$  is a solution of the

$$\text{differential equation } e^x \left( \frac{d^2 y}{dx^2} \right) = 1$$

**Solution:**  $y = e^{-x} + ax + b \quad \dots\dots\dots \text{I}$

Differentiating both sides of equation I with respect to  $x$ , we get

$$\therefore \frac{dy}{dx} = -e^{-x} + a \dots\dots\dots \text{II}$$

Differentiating both sides of equation II with respect to  $x$ , we get

$$\frac{d^2y}{dx^2} = e^{-x}$$

$$\begin{aligned} \text{Consider L.H.S.} &= e^x \frac{d^2y}{dx^2} = e^x (e^{-x}) \\ &= e^0 = 1 = \text{R.H.S.} \end{aligned}$$

Therefore, the given function is a general solution of the given differential equation.

### EXERCISE 8.1

1. Determine the order and degree of the following differential equations.

i)  $\frac{d^2x}{dt^2} + \left(\frac{dx}{dt}\right)^2 + 8 = 0$

ii)  $\left(\frac{d^2y}{dx^2}\right)^2 + \left(\frac{dy}{dx}\right)^2 = a^x$

iii)  $\frac{d^4y}{dx^4} + \left[1 + \left(\frac{dy}{dx}\right)^2\right]^3$

iv)  $(y''')^2 + 2(y'')^2 + 6y' + 7y = 0$

v)  $\sqrt{1 + \frac{1}{\left(\frac{dy}{dx}\right)^2}} = \left(\frac{dy}{dx}\right)^{3/2}$

vi)  $\frac{dy}{dx} = 7 \frac{d^2y}{dx^2}$

vii)  $\left(\frac{d^3y}{dx^3}\right)^{1/6} = 9$

2. In each of the following examples, verify that the given function is a solution of the corresponding differential equation.

	Solution	D.E.
i)	$xy = \log y + k$	$y'(1 - xy) = y^2$
ii)	$y = x^n$	$x^2 \frac{d^2y}{dx^2} - n \times \frac{xdy}{dx} + n y = 0$

iii)	$y = e^x,$	$\frac{dy}{dx} = y$
iv)	$y = 1 - \log x$	$x^2 \frac{d^2y}{dx^2} = 1$
v)	$y = ae^x + be^{-x}$	$\frac{d^2y}{dx^2} = y$
vi)	$ax^2 + by^2 = 5$	$xy \frac{d^2y}{dx^2} + x \left(\frac{dy}{dx}\right)^2 = y \cdot \frac{dy}{dx}$

### 8.1.5 Formation of a differential equation:

#### By eliminating arbitrary constants

If the order of a differential equation is  $n$ , differentiate the equation  $n$  times to eliminate arbitrary constants.

#### SOLVED EXAMPLES

1. Form the differential equation of the line having  $x$ -intercept 'a' and  $y$ -intercept 'b'.

**Solution:** The equation of a line is given by,

$$\frac{x}{a} + \frac{y}{b} = 1 \dots\dots\dots \text{I}$$

Differentiating equation I with r. t.  $x$  we get,

$$\frac{1}{a} + \frac{1}{b} \frac{dy}{dx} = 0, \therefore \frac{1}{b} \frac{dy}{dx} = -\frac{1}{a}$$

$$\therefore \frac{dy}{dx} = \frac{-b}{a} \dots\dots\dots \text{II}$$

Differentiating equation II with r. t.  $x$  we get,  $\frac{d^2y}{dx^2} = 0$  is the required differential equation.

2. Obtain the differential equation from the relation  $Ax^2 + By^2 = 1$ , where  $A$  and  $B$  are constant.

**Solution:** The given equation is

$$Ax^2 + By^2 = 1 \dots\dots\dots \text{I}$$

Differentiating equation I twice with respect to  $x$ , we get,

$$2Ax + 2By \frac{dy}{dx} = 0$$

$$Ax + By \frac{dy}{dx} = 0 \quad \dots\dots\dots \text{II and}$$

$$A + B \left( y \frac{d^2y}{dx^2} + \left( \frac{dy}{dx} \right)^2 \right) = 0 \quad \dots\dots\dots \text{III}$$

since the equations I, II & III are consistent in A and B,

$$\therefore \begin{vmatrix} x^2 & y^2 & 1 \\ x & y \frac{dy}{dx} & 0 \\ 1 & y \frac{d^2y}{dx^2} + \left( \frac{dy}{dx} \right)^2 & 0 \end{vmatrix} = 0$$

$$\therefore \left\{ x \left[ y \frac{d^2y}{dx^2} + \left( \frac{dy}{dx} \right)^2 \right] - 1 \times y \cdot \frac{dy}{dx} \right\} = 0$$

$$\therefore xy \frac{d^2y}{dx^2} + x \left( \frac{dy}{dx} \right)^2 - y \frac{dy}{dx} = 0$$

is the required differential equation.

3. Form the differential equation whose general solution is  $x^3 + y^3 = 4ax$

**Solution:** Given equation is

$$x^3 + y^3 = 4ax \quad \dots\dots\dots \text{I}$$

Since the given equation contains only one arbitrary constant, the required differential equation will be of order one.

Differentiating equation I with respect to  $x$ , we get,

$$3x^2 + 3y^2 \frac{dy}{dx} = 4a \quad \dots\dots\dots \text{II}$$

To eliminate  $a$  from the equations I & II, substitute the value of  $4a$  from equation II

in I

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

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

$$\text{that is } 2x^3 - y^3 + 3xy^2 \frac{dy}{dx} = 0.$$

is the required differential equation.

### We have learnt:

To form a differential equation by eliminating arbitrary constants, if 'n' arbitrary constants are present in the given equation then differentiate the given equation 'n' times.

## EXERCISE 8.2

- Obtain the differential equation by eliminating arbitrary constants from the following equations.
  - $y = Ae^{3x} + B.e^{-3x}$
  - $y = c_2 + \frac{c_1}{x}$
  - $y = (c_1 + c_2x) e^x$
  - $y = c_1e^{3x} + c_2e^{2x}$
  - $y^2 = (x + c)^3$
- Find the differential equation by eliminating arbitrary constants from the relation  $x^2 + y^2 = 2ax$
- Form the differential equation by eliminating arbitrary constants from the relation  $bx + ay = ab$ .
- Find the differential equation whose general solution is  $x^3 + y^3 = 35ax$ .
- Form the differential equation from the relation  $x^2 + 4y^2 = 4b^2$ .

### 8.2.1 Solution of a Differential Equation:

#### Variable Separable Method.

Sometimes, a differential equation of first order and first degree can be written in the form  $f(x) dx + g(y) dy = 0 \quad \dots\dots\dots \text{I}$

where  $f(x)$  and  $g(y)$  are functions of  $x$  and  $y$  respectively.

This is said to be Variable Separable form, whose solution is obtained by integrating equation I and is given by

$\int f(x)dx + \int g(y)dy = c$ , where  $c$  is the constant of integration.

Now, we solve some examples using variable separable method.

### SOLVED EXAMPLES

1. Solve the differential equation  $\frac{dy}{dx} = \frac{1+y}{1+x}$

**Solution :** Separating the variables, the given equation can be written as,

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

Integrating both sides we get,

$$\int \frac{dy}{1+y} = \int \frac{dx}{1+x} + c$$

$$\log(1+y) = \log(1+x) + \log c$$

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

$$\therefore \frac{1+y}{1+x} = c$$

2. Solve the differential equation  $3e^x dx + (1 + e^x) dy = 0$

**Solution :** Given equation is

$$3e^x dx + (1 + e^x) dy = 0$$

This equation can be written as

$$\frac{3e^x}{1+e^x} dx + dy = 0.$$

Integrating both sides we get,

$$\int \frac{3e^x}{1+e^x} dx + \int 1 dy = 0$$

$$\therefore 3 \log(1 + e^x) + y = c$$

3. Solve  $y - x \frac{dy}{dx} = 0$

**Solution:** Given equation is  $y - x \frac{dy}{dx} = 0$ .

Separating the variables we get,

$$\frac{dx}{x} = \frac{dy}{y} \text{ Integrating both sides we get,}$$

$$\int \frac{dx}{x} = \int \frac{dy}{y}$$

$$\log x = \log y + \log c$$

$$\log x - \log y = \log c$$

$$\log(x/y) = \log c \therefore \frac{x}{y} = c$$

**Note -** When variables are not separated we use the method of substitution

### SOLVED EXAMPLES

1. Solve

$(2x - 2y + 3) dx - (x - y + 1) dy = 0$ , hence find the particular solution if  $x = 0, y = 1$ .

**Solution :** The given equation is

$$(2x - 2y + 3) dx - (x - y + 1) dy = 0$$

$$(x - y + 1) dy = (2x - 2y + 3) dx$$

$$\frac{dy}{dx} = \frac{2x - 2y + 3}{x - y + 1} = \frac{2(x - y) + 3}{x - y + 1}$$

This equation cannot be written in variable separable form.

Use the method of substitution.

Put  $x - y = t$

$$\therefore \frac{dt}{dx} = 1 - \frac{dy}{dx} \therefore \frac{dy}{dx} = 1 - \frac{dt}{dx}$$

Using these in given equation we get,

$$1 - \frac{dt}{dx} = \frac{2t + 3}{t + 1}$$

$$1 - \frac{2t + 3}{t + 1} = \frac{dt}{dx}$$

$$\frac{dt}{dx} = \frac{t+1-2t-3}{t+1} = \frac{-t-2}{t+1}$$

$$\frac{t+1}{t+2} dt = -dx$$

$$\text{Integrating we get, } \int \frac{t+1}{t+2} dt = -\int 1 dx$$

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

$$= \int \left( 1 - \frac{1}{t+2} \right) dt = \int -1 dx + c$$

$$t - \log(t+2) = -x + c,$$

Resubstituting the value of t, we get,

$$x - y - \log(x-y+2) = -x + c$$

$$2x - y - \log(x - y + 2) = c \dots\dots\dots I$$

which is the required general solution.

To determine the particular solution

we have  $x = 0$  and  $y = 1$ , Substitute in I

$$2(0) - 1 - \log(0 - 1 + 2) = c,$$

$$c = -1$$

$2x - y - \log(x - y + 2) + 1 = 0$  is the particular solution.

### We have learnt:

To solve a differential equation of first order and first degree, separate the variables and integrate the equation.

## EXERCISE 8.3

1. Solve the following differential equations

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

ii)  $\frac{d\theta}{dt} = -k(\theta - \theta_0)$

iii)  $(x^2 - yx^2) dy + (y^2 + xy^2) dx = 0$

iv)  $y^3 - \frac{dy}{dx} = x \frac{dy}{dx}$

2. For each of the following differential equations find the particular solution.

i)  $(x - y^2x)dx - (y + x^2y) dy = 0,$

when  $x = 2, y = 0$

ii)  $(x + 1) \frac{dy}{dx} - 1 = 2e^{-5},$

when  $y = 0, x = 1$

iii)  $y(1 + \log x) dx/dy - x \log x = 0,$

when  $x = e, y = e^2.$

iv)  $\frac{dy}{dx} = (4x + y + 1),$  when  $y = 1, x = 0$

### 8.3.1 Homogeneous Differential Equation:

**Definition :** A differential equation

$f(x, y) dx + g(x, y) dy = 0$  is said to be Homogeneous Differential Equation

if  $f(x, y)$  and  $g(x, y)$  are homogeneous functions of the same degree.

**For example:**

1)  $x^3dx + y^3dy = 0$  is homogeneous differential equation because  $x^3$  and  $y^3$  are homogeneous functions of the same degree.

2)  $x^2ydx + 8y^3dy = 0$  is homogeneous differential equation because  $x^2y$  and  $y^3$  are homogeneous functions of the same degree.

### 8.3.2 Solution of Homogeneous Differential Equation:

Method to solve Homogeneous Differential Equation:

To solve homogeneous differential equation

$$f(x,y)dx + g(x,y) dy = 0, \dots\dots\dots$$

we write it as

$$\frac{dy}{dx} = \frac{f(x,y)}{g(x,y)} \dots\dots\dots II$$

To solve this equation we substitute

$$y = tx$$

$$\frac{dy}{dx} = t + x \frac{dt}{dx}$$

Then equation II is converted into variable separable form and hence it can be solved.

**Let's note :** After solving equation II, resubstitution  $t = \frac{y}{x}$  will give the required solution of the given equation.

### SOLVED EXAMPLES

1. Solve :  $\left(1 + 2e^{\frac{x}{y}}\right)dx + 2e^{\frac{x}{y}}\left(1 - \frac{x}{y}\right)dy = 0$

**Solution:** The given equation can be written as

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

This is Homogeneous Differential Equation

To solve it, substitute  $y = tx$

differentiating with respect to  $x$  we get,

$$\frac{dy}{dx} = t + x \frac{dt}{dx}$$

equation I can be written as

$$\begin{aligned} t + x \frac{dt}{dx} &= -\frac{1 + 2e^{\frac{1}{t}}}{2e^{\frac{1}{t}}\left(1 - \frac{1}{t}\right)} \\ x \frac{dt}{dx} &= -\frac{1 + 2e^{\frac{1}{t}}}{2e^{\frac{1}{t}}\left(1 - \frac{1}{t}\right)} - t \\ &= \frac{-\left(1 + 2e^{\frac{1}{t}} + (t-1)2e^{\frac{1}{t}}\right)}{2e^{\frac{1}{t}}\left(1 - \frac{1}{t}\right)} \\ &= -\frac{\left(1 + 2te^{\frac{1}{t}}\right)}{2e^{\frac{1}{t}}\left(1 - \frac{1}{t}\right)} \\ \therefore \frac{2e^{\frac{1}{t}}\left(1 - \frac{1}{t}\right)}{1 + 2te^{\frac{1}{t}}} dt &= -\frac{dx}{x} \end{aligned}$$

Integrating both sides, we get

$$\int \frac{2e^{\frac{1}{t}}(1 - 1/t)}{1 + 2te^{\frac{1}{t}}} dt = -\int \frac{dx}{x}$$

$$\log [1 + 2t(e^{1/t})] + \log x = \log c$$

$$\log [1 + 2te^{1/t}] x = \log c$$

$$x(1 + 2te^{1/t}) = c$$

Resubstitute the value of  $t = \frac{y}{x}$  We get

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

$$x + 2ye^{x/y} = c$$

which is the required general solution.

2. Solve :  $(x^2 + y^2) dx - 2xy dy = 0$

**Solution:** The given equation can be written as

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

$$\frac{dy}{dx} = \frac{(x^2 + y^2)}{2xy} \dots\dots\dots \text{I}$$

To solve it, substitute  $y = tx$ .

Differentiating with respect to  $x$  we get,

$$\frac{dy}{dx} = t + x \frac{dt}{dx}$$

Equation I can be written as

$$t + x \frac{dt}{dx} = \frac{(x^2 + t^2 x^2)}{2xtx} = \frac{x^2(1 + t^2)}{2x^2 t} = \frac{1 + t^2}{2t}$$

$$x \frac{dt}{dx} = \frac{1 + t^2}{2t} - t = \frac{1 - t^2}{2t}$$

$$\therefore \frac{2t}{1 - t^2} dt = \frac{dx}{x}$$

which is variable separable form.

Integrating both sides, we get,

$$\int \frac{2t}{1 - t^2} dt = \int \frac{dx}{x}$$

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

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

$\log x (1 - t^2) = \log c$ ,  
 $x(1 - t^2) = c$ . Resubstitute the value of  $t = \frac{y}{x}$ ,  
 we get

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

$$(x^2 - y^2) = cx$$

which is the required general solution.

### We have learnt :

To solve a homogeneous differential equation, separate the variables using substitution  $\frac{y}{x} = t$  and integrate it.

## EXERCISE 8.4

Solve the following differential equations.

1.  $x dx + 2y dy = 0$
2.  $y^2 dx + (xy + x^2) dy = 0$
3.  $x^2 y dx - (x^3 + y^3) dy = 0$
4.  $\frac{dy}{dx} + \frac{x-2y}{2x-y} = 0$
5.  $(x^2 - y^2) dx + 2xy dy = 0$
6.  $xy \frac{dy}{dx} = x^2 + 2y^2$
7.  $x^2 \frac{dy}{dx} = x^2 + xy - y^2$

### 8.4.1 Linear Differential Equation :

#### General Form

The general form of a linear differential equation of first degree is

$$\frac{dy}{dx} + P y = Q \dots\dots\dots I,$$

where P and Q are functions of x only or constants.

### 8.4.2 Solution of Linear Differential Equation:

To solve  $\frac{dy}{dx} + P y = Q \dots\dots\dots I$

The solution of equation I is given by

$$y \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dx + c$$

where I.F. (Integrating factor) =  $e^{\int p dx}$

**Let's Note:** If given equation is linear in x,

that is  $\frac{dx}{dy} + P \cdot x = Q$ , where P and Q are functions

of y only then its solution is given by

$$x \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dy + c,$$

where I.F. =  $e^{\int p dy}$

Working rule to solve first order Linear Differential Equation.

- i. Write the equation in the form  $\frac{dy}{dx} + P y = Q$ .
- ii. Find I.F. =  $e^{\int p dx}$
- iii. The solution of the given differential equation is  $y \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dx + c$

## SOLVED EXAMPLES

1. **Solve**  $\frac{dy}{dx} = x + y$

**Solution :** Given equation can be written

as  $\frac{dy}{dx} - y = x$

Here  $P = -1$  and  $Q = x$

$$\text{I.F.} = e^{\int p dx} = e^{\int -1 dx} = e^{-x}$$

Hence the solution of the given equation is given by

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

$$y \cdot e^{-x} = \frac{x e^{-x}}{-1} - \int \frac{e^{-x}}{-1} dx + c$$

$$y \cdot e^{-x} = -e^{-x} (x + 1) + c$$

$$x + y + 1 = c e^x$$

2. **Solve**  $\frac{dy}{dx} + \frac{y}{x} = x^3 - 3$

**Solution :** Given equation is of the type.

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



where  $P = \frac{1}{x}$  and  $Q = x^3 - 3$

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

The solution of the above equation is given by

$$y \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dx + c$$

$$y \cdot x = \int (x^3 - 3) \cdot x dx + c$$

$$xy = \int (x^4 - 3x) dx + c$$

$$xy = \frac{x^5}{5} - \frac{3x^2}{2} + c, \text{ which is the solution of}$$

the given differential equation.

### We have learnt:

To solve first order Linear Differential Equation

i. write the equation in the form  $\frac{dy}{dx} + P y = Q$ .

ii. Find I.F. =  $e^{\int P dx}$

iii) The solution of the given differential equation is  $y \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dx + c$

### EXERCISE 8.5

Solve the following differential equations

i.  $\frac{dy}{dx} + y = e^{-x}$

ii.  $\frac{dy}{dx} + y = 3$

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

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

v.  $y dx + (x - y^2) dy = 0$

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

vii.  $(x + a) \frac{dy}{dx} = -y + (a)$

viii.  $dr + (2r)d\theta = 8d\theta$

## 8.5.1 Applications of Differential Equations

### 1) Population Growth and Growth of Bacteria.

If the population (P) increases at time t then the rate of change of P is proportional to the population present at that time.

$$\text{This is } \frac{dp}{dt} \propto p, \quad \frac{dp}{dt} = kp$$

where k is the constant of proportionality.

$$\text{Integrating } \int \frac{dp}{p} = \int k dt + c$$

$$\log P = kt + c$$

$$\therefore P = e^{kt+c} = a \cdot e^{kt} \text{ where } e^c = a,$$

which gives the population at any time t.

### SOLVED EXAMPLES

1. Bacteria increase at the rate proportional to the number of bacteria present. If the original number N doubles in 3 hours, find in how many hours the number of bacteria will be 4N.

**Solution:** Let x be the number of bacteria at time t. Since the rate of increase of x is proportional to x, the differential equation

$$\text{can be written as } \frac{dx}{dt} \propto x$$

$\frac{dx}{dt} = kx$ , where k is constant of proportionality. Integrating we get,

$$\int \frac{dx}{x} = k \int 1 \cdot dt + c$$

Solving this differential equation we get,

$$\log x = kt + c,$$

$$x = a e^{kt}, \text{ where } a = e^c \dots\dots\dots \text{I}$$

given that when  $t = 0$ ,  $x = N$ .

From equation I we get  $N = a \cdot 1$ ,

$$a = N, \quad x = N e^{kt} \dots\dots\dots \text{II}$$

Also when  $t = 3$ ,  $x = 2N$ ,

$$\text{From equation II, we have } 2N = N e^{3k}$$

$$e^{3k} = 2 \text{ i.e. } e^k = 2^{1/3} \quad \text{III}$$

Now we have to find out  $t$  when  $x = 4N$

From equation II, we get  $4N = N e^{kt}$

$$4 = e^{kt}, \quad 2^2 = 2^{t/3}, \quad t/3 = 2, \quad t = 6.$$

Hence number of bacteria will be  $4N$  in 6 hours.

2. The population of a country doubles in 60 years, in how many years will it be triple when the rate of increase is proportional to the number of inhabitants

(given  $\log_2 3 = 1.5894$ )

### Solution:

Let  $P$  be the population at time  $t$ .

Since the rate of increase of  $P$  is proportional to  $P$  itself, the differential equation can be

written as  $\frac{dp}{dt} \propto p$

$$\frac{dp}{dt} = kp$$

where  $k$  is the constant of proportionality

$$\text{Integrating } \left[ \int \frac{dp}{p} = \int k dt \right],$$

$$\therefore \log P = kt + c \dots\dots\dots(1)$$

$$\text{i) } t = 0, P = N \text{ from I}$$

$$\text{we get } \log N = 0 + c, c = \log N$$

$$\text{ii) when } t = 60, P = 2N,$$

$$\log 2N = 60k + \log N$$

$$\log 2N - \log N = 60k$$

$$\log 2N/N = 60k, k = \frac{\log 2}{60}$$

$$\text{iii) Now } P = 3N, t = ?$$

$$\text{from (I) } \log P = \frac{\log 2}{60}t + \log N$$

$$\log 3N - \log N = t \frac{\log 2}{60}$$

$$\frac{\log 3}{\log 2} \times 60 = t,$$

$$\therefore t = 1.5894 \times 60 = 95.36 \text{ years.}$$

### We have learnt :

#### For growth

If the population ( $P$ ) increases at time  $t$  then the rate of change in  $P$  is proportional to

the population present at that time  $\frac{dp}{dt} \propto p$ .

$\frac{dp}{dt} = kP$ , where  $k$  is the constant of proportionality. Integrating  $\int \frac{dp}{p} = \int k dt$ ,

we get  $\log P = kt + c$ ,  $P = e^{kt+c} = a.e^{kt}$   
(where  $e^c = a$ )

### Radio Active Decay:

We know that the radio active substances like radium, uranium etc. disintegrate with time. It means the mass of the substance decreases with time.

The rate of disintegration of such elements is proportional to the amount present at that time.

If  $x$  is the amount of radioactive material present at time  $t$  then

$\frac{dx}{dt} = -kx$ , where  $k$  is the constant of proportionality and  $k \neq 0$ . The negative sign appears because  $x$  decreases as  $t$  increases.

Integrating we get,

$$\int \frac{dx}{x} = - \int k dt + c$$

$$\log x = -kt + c, x = e^{-kt+c} = e^{-kt} \cdot e^c$$

$$x = a.e^{-kt}, \text{ (where } a = e^c) \dots\dots\dots \text{I}$$

If  $x_0$  is the initial amount of radio active substance at time  $t = 0$ , then from equation I

$$x_0 = a.1, a = x_0,$$

$$x = x_0 \cdot e^{-kt} \dots\dots\dots \text{II}$$

### SOLVED EXAMPLES

- The rate of disintegration of a radio active element at time  $t$  is proportional to its mass at that time. The original mass of 800 gm will disintegrate into its mass of 400 gm after 5 days. Find the mass remaining after 30 days.

### Solution:

If  $x$  is the amount of material present at time  $t$  then

$\frac{dx}{dt} = -kt$ , where  $k$  is constant of proportionality

$$\int \frac{dx}{x} = -\int k dt + c$$

$$\log x = -kt + c$$

$$x = e^{-kt+c} = e^{-kt} \cdot e^c$$

$$x = a \cdot e^{-kt}, \text{ where } a = e^c. \dots\dots\dots \text{I}$$

Given when  $t = 0$ ,  $x = 800$

From I we get,  $800 = a \cdot 1 = a$

$$x = 800 e^{-kt} \dots\dots\dots \text{II}$$

when  $t = 5$ ,  $x = 400$  from II

$$400 = 800 e^{-5k}$$

$$e^{-5k} = \frac{1}{2}$$

Now we have to find  $x$ , when  $t = 30$

From II we have

$$x = 800 e^{-30k} = 800 (e^{-5k})^6$$

$$= 800 \left(\frac{1}{2}\right)^6 = \frac{800}{64} = 12.5$$

The mass remaining after 30 days will be 12.5 mg.

### We have learnt :

#### For decay

If  $x$  is the amount of any decaying material present at time  $t$  then

$\frac{dx}{dt} = -kx$ , where  $k$  is constant of proportionality and  $k \neq 0$ . The negative sign appears because  $x$  decreases as  $t$  increases, Integrating we get

$$\int \frac{dx}{x} = \int -k dt \text{ that is } \log x = -kt + c$$

$$\therefore \log x = -kt + c, x = e^{-kt+c} = e^{-kt} \cdot e^c$$

$$\therefore x = a \cdot e^{-kt}, \text{ where } a = e^c.$$

### EXERCISE 8.6

1. In a certain culture of bacteria, the rate of increase is proportional to the number present. If it is found that the number doubles in 4 hours, find the number of times the bacteria are increased in 12 hours.
2. If the population of a town increases at a rate proportional to the population at that time. If the population increases from 40 thousands to 60 thousands in 40 years, what will be the population in another 20 years?  
(Given :  $\sqrt{\frac{3}{2}} = 1.2247$ )
3. The rate of growth of bacteria is proportional to the number present. If initially, there were 1000 bacteria and the number doubles in 1 hour, find the number of bacteria after  $5/2$  hours.  
(Given :  $\sqrt{2} = 1.414$ )
4. Find the population of a city at any time  $t$  given that the rate of increase of population is proportional to the population at that instant and that in a period of 40 years the population increased from 30000 to 40000.
5. The rate of depreciation  $\frac{dv}{dt}$  of a machine is inversely proportional to the square of  $t + 1$ , where  $V$  is the value of the machine  $t$  years after it was purchased. The initial value of the machine was Rs. 8,00,000 and its value decreased Rs. 1,00,000 in the first year.

Find its value after 6 years.



### Let's Remember

1. An equation which involves polynomials of differentials of dependent variables with respect to the independent variable is called a differential equation.

2. A differential equation in which the dependent variable, say  $y$ , depends only on one independent variable, say  $x$ , is called an ordinary differential equation.

3. Order of a differential equation : It is the order of highest-order derivative occurring in the differential equation.

4. Degree of a differential equation : It is the power of the highest-order derivative when all the derivatives are made free from negative and / or fractional indices, if any.

5. **(i) General Solution :** A solution of differential equation in which the number of arbitrary constants is equal to the order of differential equation is called a general solution.

**(ii) Particular Solution :** A solution of a differential equation which can be obtained from the general solution by giving particular values to the arbitrary constants.

6. Order and degree of a differential equation are always positive integers.

7. Homogeneous Differential Equation: Definition : A differential equation  $f(x,y)dx + g(x,y)dy = 0$  is said to be Homogeneous Differential Equation if  $f(x,y)$  and  $g(x,y)$  are homogeneous functions of the same degree.

8. The general form of a linear differential equation of the first order is  $\frac{dy}{dx} = Py + Q$  (I), Where  $P$  and  $Q$  are functions of  $x$  only or constants.

The solution of the above equation (I) is given by  $y \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dx + c$  where  $\text{I.F. (Integrating factor)} = e^{\int P dx}$

9. If given equation is not linear in  $y$  that is  $\frac{dy}{dx} + P \cdot x = Q$  then its solution is given by  $x \cdot (\text{I.F.}) = \int Q \cdot (\text{I.F.}) dy + c$ , where  $\text{I.F.} = e^{\int P dy}$ .

## MISCELLANEOUS EXERCISE - 8

### I) Choose the correct alternative.

1. The order and degree of  $\left(\frac{dy}{dx}\right)^3 - \frac{d^3y}{dx^3} + ye^x$  are respectively.

- a) 3,1                                      b) 1,3  
c) 3,3                                      d) 1,1

2) The order and degree of

$$\left[1 + \left(\frac{dy}{dx}\right)^3\right]^{\frac{2}{3}} = 8 \frac{d^3y}{dx^3} \text{ are respectively}$$

- a) 3,1                                      b) 1,3  
c) 3,3                                      d) 1,1

3) The differential equation of  $y = k_1 + \frac{k_2}{x}$  is

- a)  $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} = 0$     b)  $x \frac{d^2y}{dx^2} + 2\frac{dy}{dx} = 0$   
c)  $\frac{d^2y}{dx^2} - 2\frac{dy}{dx} = 0$     d)  $x \frac{d^2y}{dx^2} - 2\frac{dy}{dx} = 0$

4. The differential equation of  $y = k_1 e^x + k_2 e^{-x}$  is

- a)  $\frac{d^2y}{dx^2} - y = e^x$     b)  $\frac{d^2y}{dx^2} + \frac{dy}{dx} = 0$   
c)  $\frac{d^2y}{dx^2} + y \frac{dy}{dx} = 0$     d)  $\frac{d^2y}{dx^2} + y = 0$

5. The solution of  $\frac{dy}{dx} = 1$  is

- a)  $x + y = c$   
b)  $xy = c$   
c)  $x^2 + y^2 = c$   
d)  $y - x = c$

6) The solution of  $\frac{dy}{dx} + \frac{x^2}{y^2} = 0$  is

- a)  $x^3 + y^3 = 7$   
b)  $x^2 + y^2 = c$   
c)  $x^3 + y^3 = c$   
d)  $x + y = c$

- 7) The solution of  $x \frac{dy}{dx} = y \log y$  is
- $y = ae^x$
  - $y = be^{2x}$
  - $y = be^{-2x}$
  - $y = e^{ax}$
- 8) Bacterial increases at the rate proportional to the number present. If the original number M doubles in 3 hours, then the number of bacteria will be 4M in
- 4 hours
  - 6 hours
  - 8 hours
  - 10 hours
- 9) The integrating factor of  $\frac{dy}{dx} + y = e^{-x}$  is
- $x$
  - $-x$
  - $e^x$
  - $e^{-x}$
- 10) The integrating factor of  $\frac{d^2y}{dx^2} - y = e^x$  is  $e^{-x}$  then its solution is
- $ye^{-x} = x + c$
  - $ye^x = x + c$
  - $ye^x = 2x + c$
  - $ye^{-x} = 2x + c$

## II. Fill in the blanks.

- The order of highest derivative occurring in the differential equation is called ..... of the differential equation.
- The power of the highest ordered derivative when all the derivatives are made free from negative and / or fractional indices if any is called ..... of the differential equation.
- A solution of differential equation which can be obtained from the general solution by giving particular values to the arbitrary constants is called ..... solution.
- Order and degree of a differential equation are always ..... integers.
- The integrating factor of the differential equation  $\frac{dy}{dx} - y = x$  is .....
- The differential equation by eliminating arbitrary constants from  $bx + ay = ab$  is .....

## III State whether each of the following is True or False.

- The integrating factor of the differential equation  $\frac{dy}{dx} - y = x$  is  $e^{-x}$ .
- Order and degree of a differential equation are always positive integers
- The degree of a differential equation is the power of the highest ordered derivative when all the derivatives are made free from negative and / or fractional indices if any.
- The order of highest derivative occurring in the differential equation is called degree of the differential equation.
- The power of the highest ordered derivative when all the derivatives are made free from negative and / or fractional indices if any is called order of the differential equation.
- The degree of the differential equation  $e^{\frac{dy}{dx}} = \frac{dy}{dx} + c$  is not defined.

## IV. Solve the following.

- Find the order and degree of the following differential equations:
  - $\left[ \frac{d^3y}{dx^3} + x \right]^{3/2} = \frac{d^2y}{dx^2}$
  - $x + \frac{dy}{dx} = 1 + \left( \frac{dy}{dx} \right)^2$
- Verify  $y = \log x + c$  is a solution of the differential equation  $x \frac{d^2y}{dx^2} + \frac{dy}{dx} = 0$ .
- Solve the differential equations
  - $\frac{dy}{dx} = 1 + x + y + xy$
  - $e^{dy/dx} = x$
  - $dr = a r d\theta - \theta dr$
  - Find the differential equation of family of curves  $y = e^x (ax + bx^2)$  where A and B are arbitrary constant.

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

when  $x = \frac{2}{3}$  and  $y = \frac{1}{3}$

5) Solve  $ydx - xdy = -\log x dx$

6) Solve  $y \log y \frac{dx}{dy} + x - \log y = 0$

7) Solve  $(x+y)dy = a^2 dx$

8) Solve  $\frac{dy}{dx} + \frac{2}{x}y = x^2$

9) The rate of growth of population is proportional to the number present.

If the population doubled in the last 25 years and the present population is 1 lac, when will the city have population 4,000,000?

10) The resale value of a machine decreases over a 10 year period at a rate that depends on the age of the machine. When the machine is  $x$  years old, the rate at which its value is changing is ₹ 2200  $(x - 10)$  per year. Express the value of the machine as a function of its age and initial value. If the machine was originally worth ₹ 1,20,000 how much will it be worth when it is 10 years old?

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

12)  $x^2 ydx - (x^3 + y^3)dy = 0$

13)  $yx \frac{dy}{dx} = x^2 + 2y^2$

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

15)  $ydx - xdy + \log x dx = 0$

16)  $\frac{dy}{dx} = \log x$

17)  $y \log y \frac{dy}{dx} = \log y - x$

### Activities

1) Complete the following activity.

The equation  $\frac{dy}{dx} - y = 2x$  is of the form

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

Where  $P =$   and,  $Q =$

$\therefore$  I.F. =  $e^{\int P dx} =$

$\therefore$  the solution of the linear differential equation is

$y$   =  $\int 2x$  (I.F.)  $dx + c$ .

$\therefore ye^{-x} = \int 2x$    $dx + c$

$ye^{-x} = 2 \int x$    $dx$

=  $2 \{ x \int e^{-x} dx - \int$    $dx \frac{d}{dx}$    $dx \} + c$

=  $2 \{ x \frac{e^{-x}}{\square} - \int \frac{e^{-x}}{\square} . 1 dx$

$\therefore e^{\frac{-x}{y}} = -2xe^{-x} + 2 \int$    $dx + c_1$

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

$y +$    $+ \frac{2}{e^{-x}} = ce^x$  is the required general solution of the given differential equation.

2) Verify  $y = a + \frac{b}{x}$  is a solution of

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

$y = a + \frac{b}{x}$

$\frac{dy}{dx} =$

$\frac{d^2 y}{dx^2} =$

**Consider**  $x \frac{d^2 y}{dx^2} + 2 \frac{dy}{dx}$

=  $x$    $+ 2$

=

Hence  $y = a + \frac{b}{x}$  is a solution of



# Answers

## 1. Mathematical logic

### Exercise : 1.1

Sentences (ii), (x), (xiii), (xvi), (xvii), (xviii), (xix), (xx), (xxiv) are statements and their truth value is T.

Sentences (i), (v), (vi), (xi), (xii), (xiv), (xv) are statements and their truth value is F.

Sentences (iii), (iv), (vii), (viii), (ix), (xxi), (xxii), (xxiii), (xxv) are not statements in logic.

### Exercise : 1.2

- 1) i)  $p \vee q$     ii)  $p \wedge q$     iii)  $p \vee q$   
iv)  $p \wedge q$     v)  $p \wedge q$

2) truth values are

- i) F    ii) F    iii) F  
iv) T

### Exercise : 1.3

- 1) i) Some men are not animals.  
ii)  $-3$  is not a natural number.  
iii) Nagpur is capital of Maharashtra  
iv)  $2 + 3 = 5$

2) Truth values are

- i) F    ii) F    iii) T

### Exercise : 1.4

- 1) i)  $p \rightarrow q$     ii)  $\sim P$     iii)  $\sim P \wedge q$   
iv)  $p \leftrightarrow \sim q$     v)  $p \leftrightarrow q$     vi)  $p \rightarrow q$

2) Truth values are

- i) T    ii) F    iii) F  
iv) T    v) T

3) Truth values are

- i) F    ii) T    iii) T  
iv) F    v) T    vi) F

4) Truth values are

- i) F    ii) T    iii) F

5) i) He swims if and only if water is not warm.

ii) It is not true that he swims or water is warm.

iii) If water is warm then he swims.

iv) water is warm and he does not swim.

### Exercise : 1.5

- 1) i)  $\exists x \in \mathbb{N}$ , such that  $x^2 + 3x - 10 = 0$

It is true statement, since  $x = 2 \in \mathbb{N}$  satisfies it.

- ii)  $\exists x \in \mathbb{N}$ , such that  $3x - 4 < 9$

It is a true statement, since  $x = 2, 3, 4 \in \mathbb{N}$  satisfy  $3x - 4 < 9$ .

- iii)  $\forall n \in \mathbb{N}$ ,  $n^2 \geq 1$

It is true statement, since all  $n \in \mathbb{N}$  satisfy it.

- iv)  $\exists n \in \mathbb{N}$ , such that  $2n - 1 = 5$

It is true statement, since  $n = 3 \in \mathbb{N}$  satisfy  $2n - 1 = 5$ .

- v)  $\exists y \in \mathbb{N}$ , such that  $y + 4 > 6$

It is true statement, since  $y = 3, 4, \dots \in \mathbb{N}$  satisfy  $y + 4 > 6$ .



- v)  $\exists y \in \mathbb{N}$ , such that  $3y - 2 \leq 9$   
It is true statement, since  $y = 1, 2, 3, \dots \in \mathbb{N}$  satisfy it.

2) Truth value are

- i) F      ii) T      iii) F  
iv) F      v) F

### Exercise : 1.6

- 1) i) TFFT      ii) FFTT  
iii) TTTTTTTT      iv) TTFTFTFT
- 2) i) tatology      ii) contradiction  
iii) contingency      iv) tautology

### Exercise : 1.7

- 1) i)  $(p \wedge q) \wedge r$   
ii)  $\sim (p \wedge q) \vee [p \wedge \sim (q \vee \sim r)]$   
iii)  $p \wedge (q \wedge r) \equiv (p \wedge q) \wedge r$   
iv)  $\sim (p \vee q) \equiv \sim p \wedge \sim q$
- 2) i) 13 is a prime number or India is a democratic country.  
ii) Karina is very good and everybody likes her.  
iii) Radha or Sushmita can not read Urdu.  
iv) A number is real number or the square of the numbers is non negative.

### Exercise : 1.8

- 1) i) Some stars are shining and it is night.  
ii)  $\exists n \in \mathbb{N}$ , such that  $n + 1 \leq 0$   
iii)  $\forall n \in \mathbb{N}$ ,  $(n^2 + 2)$  is not odd number  
iv) All continuous functions are not differentiable.
- 2) i)  $(p \wedge \sim r) \vee \sim q$   
ii)  $(\sim p \wedge \sim q) \wedge \sim r$   
iii)  $(p \vee \sim q) \vee (q \wedge r)$

- 3) i) Converse : If they do not drive the car then it snows.

Inverse : If it does not snow then they drive the car.

Contrapositive : If they drive the car then it does not snow.

- ii) Converse : If he will go to college then he studies.

Inverse : If he does not study, then he will not go to college.

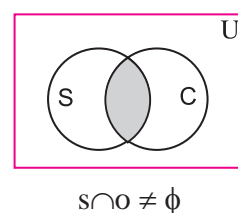
Contrapositive : If he will not go to college then he does not study.

- 4) i)  $(p \wedge \sim q) \wedge (p \wedge \sim r)$   
ii)  $(p \wedge \sim q) \wedge r$   
iii)  $(p \wedge \sim q) \vee \sim r$

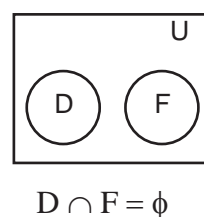
### Exercise : 1.10

- 1) Venn diagrams.

- i) U : The set of all students  
S : The set of all hard working students.  
O : The set of all obedient students.

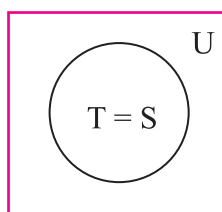


- ii) U : The set of closed geometrical figures in plane.  
D : The set of all polygons.  
F : The set of all circles.



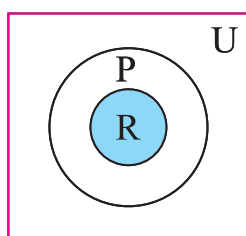


- iii) U : The set of all human beings.  
 T : The set of all teachers.  
 S : The set of all scholars.



.....

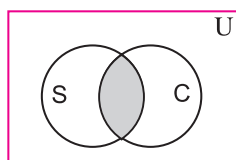
- iv) U : The set of all quadrilaterals.  
 P : The set of all parallelograms.  
 R : The set of all rhombus.



$$R \subset P$$

## 2) Venn diagrams

i)

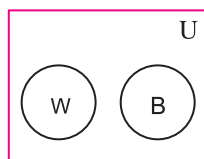


$$S \cap C \neq \phi$$

Where

- U : The set of all human beings.  
 S : The set of all share brokers.  
 C : The set of all chartered accountants.

ii)

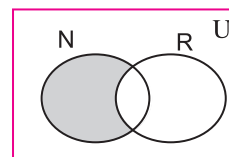


$$W \cap B = \phi$$

Where

- U : The set of all human beings.  
 W : The set of all wicket keepers.  
 B : The set of all bowlers.

3) i)

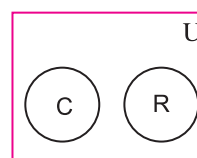


$$N - R \neq \phi$$

Where

- U : The set of all human beings.  
 N : The set of all non resident Indians.  
 R : The set of all rich people.

ii)

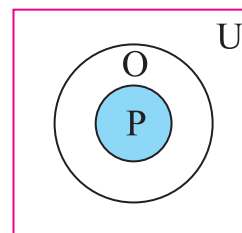


$$C \cap R = \phi$$

Where

- U : The set of all geometrical polygons.  
 C : The set of all circles.  
 R : The set of all rectangles.

iiii)



$$P \subset O$$

Where

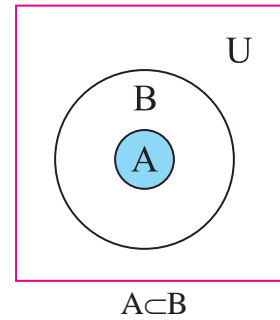
- U : The set of all real numbers.  
 P : The set of all prime numbers and  $n \neq 2$ .  
 O : The set of all odd numbers.

## MISCELLANEOUS EXERCISE - 1

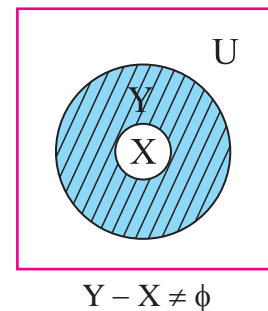
- I. 1) d    2) a    3) d    4) b  
 5) c    6) c    7) b    8) d  
 9) c    10) a    11) b    12) d  
 13) b    14) c    15) c
- II. i) Converse    ii)  $p \wedge q$     iii) F  
 iv) No men are animals    v) F  
 vi)  $\sim p \rightarrow \sim q$     vii) different  
 viii) If the problem is not easy then it is not challenging.  
 ix) T
- III. i) False    ii) True    iii) False  
 iv) False    v) False    vi) True  
 vii) True    viii) False    ix) False  
 x) True.
- IV. 1) sentence (i), (ii), (iv), (v), (vi), (ix), (x), (xi) are statements. in logic  
 sentence (iii), (vii), (viii), (xii), (xiii) are not statements in logic  
 2) sentence (ii), (iii), (iv), (vi), (vii), (ix) are statement and truth value of each is T.  
 Sentence (x) is a statement and its truth value is F.  
 Sentence (i), (v), (viii) are not statement.  
 3) i)  $p \wedge q$     ii)  $p \wedge q$     iii)  $p \leftrightarrow q$   
 iv)  $p \wedge q$     v)  $p \rightarrow q$     vi)  $p \leftrightarrow q$   
 vii)  $p \leftrightarrow q$     viii)  $p \leftrightarrow q$     ix)  $p \rightarrow q$   
 x)  $p \rightarrow q$     xi)  $\sim(p \wedge q)$     xii)  $q \rightarrow p$   
 xiii)  $\sim p$     xiv)  $p \rightarrow q$   
 4) i)  $p \wedge \sim q$     ii)  $p \rightarrow q$     iii)  $\sim(p \wedge q)$   
 iv)  $q \leftrightarrow p$   
 5) i) Sachin wins the match or he is the member of Rajya Sabha or Sachin is happy.
- ii) If Sachin wins the match then he is happy.  
 iii) Sachin does not win the match or he is the member of Rajya Sabha.  
 iv) If sachin wins the match, then he is the member of Rajyasabha or he is happy.  
 v) Sachin wins the match if and only if he is happy.  
 vi) Sachin wins the match and he is the member of Rajyasabha but he is not happy.  
 vii) It is false that sachin wins the match or he is the member of Rajyasabha but he is happy.
- 6) i) F    ii) T    iii) F  
 iv) T
- 7) i) T    ii) T    iii) F  
 iv) T
- 8) i) Demand does not fall or price does not increase.  
 ii) Price increase or demand does not falls.
- 9) i) F    ii) F    iii) F  
 iv) T    v) T
- 10) i)  $\Delta ABC$  is not equilateral and it is equiangular.  
 ii) Ramesh is not intelligent or he is not hard working.  
 iii) An angle is a right angle and it is not of measure  $90^\circ$ , or an angle is of measure  $90^\circ$  and it is a right angles.  
 iv) Kanchanganga is not in India or Everest is not in Nepal.  
 v)  $x \in (A \cap B)$  and  $x \notin A$  or  $x \notin B$ .

- ii) i) FTTF                      ii) FFFT  
       iii) TTTTTTTT    iv) FTTTFTTT  
       v) TFTFTTFF
- 13) i) tautology                      ii) contradiction  
       iii) contradiction              iv) contingency  
       v) contradiction
- 15) i) Converse : If  $4 + 10 = 20$ , then  $2 + 5 = 10$   
       Inverse : If  $2 + 5 \neq 10$ , then  $4 + 10 \neq 20$   
       Contrapositive : If  $4 + 10 \neq 20$ , then  $2 + 5 \neq 10$
- ii) Converse : If a man is happy, then he is bachelor  
       Inverse : If a man is not bachelor, then he is not happy.  
       Contrapositive : If a man is not happy, then he is not bachelor.
- iii) Converse : If I do not prosper, then I do not work hard.  
       Inverse : If I work hard then I prosper.  
       Contrapositive : If I prosper then I work hard.
- 16) i)  $(p \vee \sim q) \wedge (\sim p \vee q) \equiv (p \wedge q) \vee \sim(p \vee q)$   
       ii)  $p \wedge (q \wedge r) \equiv \sim[(p \vee q) \wedge (r \wedge s)]$   
       iii) 2 is even number and 9 is a perfect square.
- 17) i) A quadrilateral is not a rhombus or it is not a square.  
       ii)  $10 - 3 \neq 7$  or  $10 \times 3 \neq 30$   
       iii) It does not rain or the principal declares a holiday.
- 18) i)  $(\sim p \vee q) \wedge (p \vee \sim q) \wedge (\sim p \vee \sim q)$   
       ii)  $(p \vee q) \vee r \equiv p \vee (q \vee r)$   
       iii)  $p \wedge (q \vee r) \equiv (p \wedge q) \vee (p \wedge r)$   
       iv)  $\sim(p \wedge q) \equiv \sim p \vee \sim q$

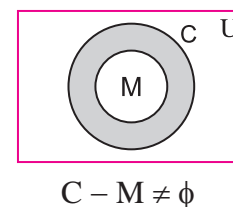
- 19) Statement (i) and (iii) are identical  
       Statement (ii) and iv) are identical
- 20) i) U : The set of all human being  
       A : The set of all men  
       B : The set of all mortal



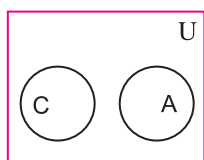
- ii) U : The set of all human beings.  
       X : The set of all persons.  
       Y : The set of all politician



- iii) U : The set of all human beings.  
       X : The set of all members of the present Indian cricket.  
       Y : The set of all committed members of the present Indian cricket.



- iv) U : Set of all human beings.  
       C : Set of all child.  
       A : Set of all Adult.



$$C \cap A = \phi$$

- 21) i) T      ii) F      iii) T  
iv) F
- 22) i) 7 is not prime number or Tajmahal is not in Agra  
ii)  $10 < 5$  or  $3 > 8$   
iii) I will have not tea and cofee.  
iv)  $\exists n \in \mathbb{N}$ , such that  $n + 3 \leq 9$   
v)  $\forall x \in A$ ,  $x + 5 \geq 11$ .

## 2. Matrices

### Exercise : 2.1

1) i)  $A = \begin{bmatrix} 0 & \frac{1}{4} \\ \frac{1}{3} & 0 \\ 2 & \frac{1}{2} \end{bmatrix}$       ii)  $A = \begin{bmatrix} -2 & -5 \\ -1 & -4 \\ 0 & -3 \end{bmatrix}$

iii)  $A = \frac{1}{5} \begin{bmatrix} 8 & 27 \\ 27 & 64 \\ 64 & 125 \end{bmatrix}$

- 2) i) Upper Triangular Matrix  
ii) Column Matrix  
iii) Row Matrix  
iv) Scalar Matrix  
v) Lower Triangular Matrix  
vi) Diagonal Matrix  
vii) Identity Matrix

- 3) i) Singular Matrix  
ii) Singular Matrix  
iii) Non Singular Matrix  
iv) Non singular Matrix

- 4) i)  $k = \frac{-6}{7}$       ii)  $k = 6$   
ii)  $k = \frac{49}{8}$

### Exercise : 2.2

2)  $A - 2B + 6I = \begin{bmatrix} 5 & 4 \\ -3 & 23 \end{bmatrix}$

3)  $C = \begin{bmatrix} -10 & -1 & 1 \\ 7 & -9 & 3 \\ -4 & 6 & 2 \end{bmatrix}$

4)  $X = \begin{bmatrix} -1 & \frac{2}{5} \\ \frac{6}{5} & \frac{19}{5} \\ \frac{19}{5} & \frac{26}{5} \end{bmatrix}$

5)  $(A^T)^T = A$       6)  $(A^T)^T = A$

7)  $a = -4$ ,  $b = \frac{3}{5}$ ,  $c = -7$

8)  $x = \frac{-3}{2}$ ,  $y = 5i$ ,  $z = \sqrt{2}$

- 9) i)  $A = A^T \therefore A$  is a symmetric matrix,  
ii) Neither  $A = A^T$  nor  $A = -A^T \therefore A$  is neither symmetric nor skew symmetric matrix.  
iii)  $A = -A^T \therefore A$  is a skew symmetric matrix.

$$10) A = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$$

$\therefore A$  is a skew symmetric matrix.

$$11) X = \begin{bmatrix} \frac{3}{8} & \frac{-1}{4} \\ \frac{-3}{8} & \frac{1}{2} \end{bmatrix}, Y = \begin{bmatrix} \frac{1}{8} & \frac{1}{4} \\ \frac{-1}{8} & \frac{1}{2} \end{bmatrix}$$

$$12) A = \begin{bmatrix} 3 & \frac{-14}{3} & \frac{-8}{3} \\ -2 & 1 & 3 \end{bmatrix},$$

$$B = \begin{bmatrix} 0 & \frac{-10}{3} & \frac{-16}{3} \\ 0 & 0 & 5 \end{bmatrix}$$

$$13) x = \frac{-1}{4}, y = \frac{9}{2}$$

$$14) a = 1, b = 0, c = \frac{2}{5}, d = \frac{9}{5}$$

15) i) Suresh book shop : Rs. 1050/- in Physics Rs. 305/- in Chemistry and Rs. 405/- in Maths.

Ganesh book shop : Rs. 350/- in Physics Rs. 445/- in Chemistry and Rs. 1295/- in Maths.

ii) The profit for Suresh book shop are Rs. 665/- in Physics Rs. 705.50/- in Chemistry and Rs. 890.50/- in Maths.

For Ganesh book shop are Rs. 700/- in Physics Rs. 750/- in Chemistry and Rs. 1020/- in Maths.

### Exercise : 2.3

$$1) i) \begin{bmatrix} 6 & -12 & 9 \\ 4 & -8 & 6 \\ 2 & -4 & 3 \end{bmatrix} \quad ii) [8]$$

2)

$$AB = \begin{bmatrix} 2 & 1 & -1 \\ 13 & 2 & 14 \\ -6 & 3 & -1 \end{bmatrix} \text{ and } BA = \begin{bmatrix} 4 & -7 & 6 \\ -1 & -3 & 5 \\ 4 & 4 & 2 \end{bmatrix}$$

$\therefore AB \neq BA$

$$7) (A + I)(A - I) = \begin{bmatrix} 9 & 6 & 4 \\ 15 & 32 & -2 \\ 35 & -7 & 29 \end{bmatrix}$$

$$9) k = -7$$

$$11) a = 2, b = -1$$

$$12) k = 1$$

$$13) x = 19, y = 12$$

$$14) x = -3, y = 1, z = -1$$

$$15) \text{ Jay Rs. 104 and Ram Rs. 150}$$

### Exercise : 2.4

$$1) i) A^T = \begin{bmatrix} 1 & -4 \\ 3 & 5 \end{bmatrix}$$

$$ii) A^T = \begin{bmatrix} 2 & -4 \\ -6 & 0 \\ 1 & 5 \end{bmatrix}$$

$$2) A = \begin{bmatrix} 0 & -2 & -4 \\ 2 & 0 & -2 \\ 4 & 2 & 0 \end{bmatrix} \text{ and } A^T = \begin{bmatrix} 0 & 2 & 4 \\ -2 & 0 & 2 \\ -4 & -2 & 0 \end{bmatrix}$$

$\therefore$  Both are skew symmetric.

$$6) C^T = \begin{bmatrix} -16 & 14 \\ -6 & -10 \end{bmatrix}$$

$$7) i) \begin{bmatrix} 7 & 8 \\ -5 & 8 \\ 12 & -18 \end{bmatrix} \quad ii) \begin{bmatrix} 35 & -10 \\ 25 & 15 \\ -15 & 10 \end{bmatrix}$$

$$11) i) \begin{bmatrix} 4 & \frac{1}{2} \\ \frac{1}{2} & -5 \end{bmatrix} + \begin{bmatrix} 0 & \frac{-5}{2} \\ \frac{5}{2} & 0 \end{bmatrix}$$

$$\text{ii) } \frac{1}{2} \begin{bmatrix} 6 & 1 & -5 \\ 1 & -4 & -4 \\ -5 & -4 & 4 \end{bmatrix} + \frac{1}{2} \begin{bmatrix} 0 & 5 & 3 \\ -5 & 0 & 6 \\ -3 & -6 & 0 \end{bmatrix}$$

$$9) \frac{1}{6} \begin{bmatrix} 4 & 4 & 2 \\ 11 & 8 & -5 \\ 10 & 10 & 2 \end{bmatrix} \quad 10) \begin{bmatrix} -\frac{1}{3} \\ -\frac{7}{3} \\ 2 \end{bmatrix}$$

### Exercise : 2.5

$$1) \quad \text{i) } \begin{bmatrix} 2 & 2 \\ 3 & -4 \end{bmatrix} \quad \text{ii) } \begin{bmatrix} 4 & 2 \\ -5 & 1 \end{bmatrix}$$

$$\text{iii) } \begin{bmatrix} 3 & 1 & -1 \\ 3 & 9 & 3 \\ -1 & 1 & 3 \end{bmatrix} \text{ and } \begin{bmatrix} 3 & -11 & -1 \\ 1 & -1 & 1 \\ -1 & 5 & 3 \end{bmatrix}$$

$$2) \begin{bmatrix} 1 & -1 & 2 \\ 0 & 1 & \frac{-1}{3} \\ 0 & 0 & \frac{-1}{3} \end{bmatrix}$$

$$3) \quad \text{i) } \begin{bmatrix} -8 & -5 \\ -2 & 1 \end{bmatrix} \quad \text{ii) } \begin{bmatrix} -3 & -1 & 5 \\ -1 & 19 & -21 \\ 22 & -12 & -2 \end{bmatrix}$$

$$4) \quad \text{i) } \begin{bmatrix} 5 & 3 \\ -3 & 2 \end{bmatrix} \quad \text{ii) } \begin{bmatrix} -3 & -1 & -11 \\ -12 & 3 & -9 \\ 6 & 2 & 1 \end{bmatrix}$$

$$5) \quad \text{i) } \begin{bmatrix} 1 & -1 \\ 2 & -3 \end{bmatrix} \quad \text{ii) } \frac{1}{18} \begin{bmatrix} 5 & 2 \\ -4 & 2 \end{bmatrix}$$

$$\text{iii) } \frac{1}{10} \begin{bmatrix} 10 & -10 & 2 \\ 0 & 5 & -4 \\ 0 & 0 & 2 \end{bmatrix}$$

$$6) \quad \text{i) } \frac{1}{5} \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix} \quad \text{ii) } \begin{bmatrix} 3 & -1 & 1 \\ -15 & 6 & -5 \\ 5 & -2 & 2 \end{bmatrix}$$

$$7) \frac{1}{6} \begin{bmatrix} 4 & -2 & 2 \\ -3 & 0 & 3 \\ 3 & 2 & -2 \end{bmatrix} \quad 8) \begin{bmatrix} 13 & 2 & -7 \\ -3 & -1 & 2 \\ -2 & 0 & 1 \end{bmatrix}$$

### Exercise : 2.6

$$1) \quad \text{i) } x=0, y=1 \quad \text{ii) } x=4, y=-3$$

$$\text{iii) } x=1, y=2, z=1$$

$$\text{iv) } x = \frac{5}{2}, y = \frac{-1}{2}, z = -1$$

$$2) \quad \text{i) } x = \frac{1}{2}, y = \frac{1}{2} \quad \text{ii) } x=1, y=2$$

$$\text{iii) } x=3, y=2, z=1$$

$$\text{iv) } x=-2, y=0, z=3$$

3) Cost price T.V. Rs. 3000 and cost price of V.C. Rs. 13000. Selling price of T.V. Rs. 4000 and Selling price of V.C.R. Rs. 13500.

4) Cost of one Economics book is Rs. 300, Cost of one Co-operation book is Rs. 60 and Cost of one Account book is Rs. 60.

### MISCELLANEOUS EXERCISE - 2

I. 1) c    2) b    3) d    4) c  
5) a    6) a    7) b    8) d  
9) c    10) a    11) b    12) b  
13) d    14) c    15) b

II. 1) Column    2)  $2 \times 3$     3) 2  
4) -1    5) 3    6) -2  
7) |A|    8) A    9) -1  
10)  $\begin{bmatrix} a_1 & b_1 \\ a_2 & b_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix}$

- III. 1) True      2) False      3) True  
 4) False      5) False      6) False  
 7) False      8) False      9) False  
 10) True

$$\text{iv)} \begin{bmatrix} 3 & -1 & 1 \\ -15 & 6 & -5 \\ 5 & -2 & 2 \end{bmatrix}$$

IV. 1)  $k = \frac{15}{7}$       2)  $x = 3, y = 5, z = 5$

$$17) A^{-1} = \frac{1}{40} \begin{bmatrix} 19 & 5 & -27 \\ -2 & 10 & -14 \\ -3 & -5 & 19 \end{bmatrix}$$

$$4) A - 4B + 7I = \begin{bmatrix} 5 & -23 \\ 15 & 14 \end{bmatrix}$$

$$18) \text{ i) } x = \frac{26}{7}, y = \frac{30}{7}$$

$$9) a = \frac{-2}{7}, b = \frac{-2}{7}$$

$$\text{ii) } x = 3, y = 1, z = 2$$

$$\text{iii) } x = 2, y = -1, z = 1$$

$$10) A^3 = \begin{bmatrix} -9 & 22 \\ -11 & 13 \end{bmatrix}$$

$$19) \text{ i) } x = 4, y = -3$$

$$\text{ii) } x = \frac{-5}{7}, y = \frac{6}{7}, z = 2$$

$$\text{iii) } x = \frac{1}{6}, y = -\frac{1}{3}, z = \frac{5}{6}$$

14) i) Shantaram Kantaram  
 $\begin{pmatrix} \text{Rs.33000} & \text{Rs.39000} \\ \text{Rs.28000} & \text{Rs.31500} \\ \text{Rs.20000} & \text{Rs.24000} \end{pmatrix} \begin{matrix} \text{Rice} \\ \text{Wheat} \\ \text{Groundnut} \end{matrix}$

20) Three number  $x = 1, y = 2, z = 3$

ii) Shantaram Kantaram  
 $\begin{pmatrix} \text{Rs.3000} & \text{Rs.3000} \\ \text{Rs.2000} & \text{Rs.1500} \\ \text{Rs.0} & \text{Rs.8000} \end{pmatrix} \begin{matrix} \text{Rice} \\ \text{Wheat} \\ \text{Groundnut} \end{matrix}$

15) i) Invertible      ii) Not Invertible  
 iii) Invertible      iv) Not Invertible

16) i)  $\begin{pmatrix} \frac{3}{5} & \frac{1}{5} \\ \frac{-2}{5} & \frac{1}{5} \end{pmatrix}$       ii)  $\begin{pmatrix} 4 & -1 \\ -7 & 2 \end{pmatrix}$

$$\text{iii) } \begin{bmatrix} \frac{-2}{5} & 0 & \frac{3}{5} \\ \frac{-1}{5} & \frac{1}{5} & 0 \\ \frac{2}{5} & \frac{1}{5} & \frac{-2}{5} \end{bmatrix}$$

### 3. Differentiation

#### Exercise : 3.1

I. 1)  $\frac{1}{2} \left( x + \frac{1}{x} \right)^{\frac{-1}{2}} \left( 1 - \frac{1}{x^2} \right)$

$$2) \frac{2x}{3} (a^2 + x^2)^{\frac{-2}{3}}$$

$$3) 9(5x^3 - 4x^2 - 8x)^8 (15x^2 - 8x - 8)$$

II. 1)  $\frac{1}{x \log x}$

$$2) \frac{(40x^3 + 15x^2 - 6x)}{(10x^4 + 5x^3 - 3x^2 + 2)}$$

$$3) \frac{2ax + b}{ax^2 + bx + c}$$

III. 1)  $(10x-2).e^{5x^2-2x+4}$

2)  $a^{(1+\log x)} \log a. \frac{1}{x}$

3)  $5^{(x+\log x)} \log 5. \left(1 + \frac{1}{x}\right)$

### Exercise : 3.2

I. 1)  $\frac{1}{10+50x}$

2)  $\frac{x-4}{18x-71}$

3)  $\frac{1+x^2}{25x^2+2x+25}$

II. 1)  $\frac{e^x}{1-x}$

2)  $\frac{(x^2+1)^2}{1-4x-x^2}$

3)  $\frac{-(2x-10)^2}{68}$

### Exercise : 3.3

I. 1)  $x^{x^{2x}} x^{2x} \log x \left[ 2(1+\log x) + \frac{1}{x \log x} \right]$

2)  $x^{e^x} e^x \left[ \frac{1}{x} + \log x \right]$

3)  $e^{x^x} x^x [1+\log x]$

II. 1)  $\left(1 + \frac{1}{x}\right)^x \left[ \log \left(1 + \frac{1}{x}\right) - \frac{1}{1+x} \right]$

2)  $(2x+5)^x \left[ \log(2x+5) + \frac{2x}{2x+5} \right]$

3)  $\frac{1}{3} \sqrt[3]{\frac{(3x-1)}{(2x+3)(5-x)^2}} \left[ \frac{3}{3x-1} - \frac{2}{2x+3} + \frac{2}{5-x} \right]$

III. 1)  $(\log x)^x \left[ \frac{1}{\log x} + \log(\log x) \right] \times x^{\log x} \left[ \frac{2 \log x}{x} \right]$

2)  $x^x (1+\log x) + a^x \log a$

3)  $10^{x^x} . x^x . \log 10 (1+\log x) + 10^{x^{10}}$

$(10.x^9) \log 10 + 10^{10^x} . 10^x (\log 10)^2$

### Exercise : 3.4

I. 1)  $-\sqrt{\frac{y}{x}}$  2)  $-\frac{3x^2(1+4y)}{3y^2+4x^3}$

3)  $-\frac{3x^2+2xy+y^2}{x^2+2xy+3y^2}$

II. 1)  $-\frac{e^y + ye^x}{e^x + xe^y}$  2)  $\frac{\log x}{(1+\log x)^2}$

3)  $-\frac{y}{x}$

III. 1)  $\frac{y}{x}$  2)  $-\frac{y^2}{x^2}$

3)  $-e^{y-x}$

### Exercise : 3.5

I. 1)  $\frac{1}{t}$  2)  $t^2$  3)  $\frac{4}{3} e^{t+5}$

II. 1)  $\frac{y \log 2}{2\sqrt{x}}$  2)  $\frac{2}{\sqrt{1+u^2}}$

3)  $x.5^x (\log 5)$

### Exercise : 3.6

I. 1)  $-\frac{1}{4} x^{\frac{-3}{2}}$  2)  $20x^3$  3)  $56x^{-9}$

II. 1)  $e^x$  2)  $4.e^{(2x+1)}$  3)  $0$



### MISCELLANEOUS EXERCISE - 3

I.

- 1) a    2) c    3) a    4) b    5) c  
6) b    7) b    8) a    9) d    10) c

II.

- 1) -1    2) y    3) x    4) y    5)  $\frac{1}{x}$

- 6)  $\frac{-1}{x^2}$     7)  $\frac{y^2}{y^2-1}$     8)  $axy$

- 9) y    10) my

III.

- 1) True    2) False    3) True  
4) False    5) True    6) False  
7) True    8) False

IV.

- 1)  $10(6x^3 - 3x^2 - 9x)^4(18x^2 - 6x - 9)$

- 2)  $\frac{4}{5}(3x^2 + 8x + 5)^{\frac{-1}{5}}(6x + 8)$

- 3)  $\frac{2\log[\log(\log x)]}{x.\log x.\log(\log x)}$     4)  $\frac{1}{30-2x}$

- 5)  $-\frac{(2x-13)^2}{79}$     6)  $x^x.(1+\log x)$

- 7)  $2^{x^x} x^x \log 2.(1+\log x)$

- 8)  $\sqrt{\frac{(3x-4)^3}{(x+1)^4(x+2)}} \frac{1}{2} \left[ \frac{9}{3x-4} - \frac{4}{x+1} - \frac{1}{x+2} \right]$

- 9)  $x^x(1+\log x) + (7x-1)^x \left[ \log(7x-1) + \frac{7x}{7x-1} \right]$

- 10)  $\frac{-3(x^2 + y^2 + 2xy)}{(6xy + 3x^2 - 1)}$     11)  $\frac{-(y+3x^2)}{(2y+x)}$

- 12)  $\frac{x}{y} \left[ \frac{2-3xy^3}{2+3x^3y} \right]$     13)  $\frac{1}{t}$     14)  $\frac{1}{6\sqrt{t}} e^{(\sqrt{t}-3t)}$

15)  $\frac{2x}{a^x \cdot \log a \cdot (1+x^2)}$

16)  $\frac{e^{(4x+5)}}{10^{4x} \cdot \log 10}$

17)  $\frac{-1}{x^2}$

18)  $\frac{-1}{2at^3}$

19)  $e^x(x^2 + 4x + 2)$

### 4. Applications of Derivatives

#### Exercise : 4.1

- 1) i)  $5x - y - 2 = 0$ ;  $x + 5y - 16 = 0$   
ii)  $2x + 3y - 5$ ;  $3x - 2y - 1$   
iii)  $x + y = 2$ ;  $x - y = 0$   
2)  $4x - y + 7 = 0$  &  $x + 4y - 38 = 0$   
3)  $3x - y - 8 = 0$  &  $x + 3y + 14 = 0$

#### Exercise : 4.2

- 1) i) Increasing,  $x \in \mathbb{R} - \{2\}$   
ii) Increasing,  $x \in \mathbb{R}$ ,  $x \neq 0$   
iii) Decreasing,  $x \in \mathbb{R}$ ,  $x \neq 0$   
2) i)  $(-\infty, 2) \cup (3, \infty)$   
ii)  $x > -1$  i.e.  $(-1, \infty)$   
iii)  $(-\infty, -3) \cup (8, \infty)$   
3) i)  $-3 < x < 8$   
ii)  $-\infty < x < \frac{3}{2}$   
iii)  $-2 < x < 7$

#### Exercise : 4.3

- 1) i) maximum at  $x = 1$ , max value = -3 & minimum at  $x = 6$ , min value = -128  
ii) minimum at  $x = \frac{1}{e}$ , min value =  $-\frac{1}{e}$   
ii) minimum at  $x = 2$ , min value = 12

- 2) first part = 10, second part = 10  
 3) Length = breadth = 9 cm  
 4) 30

#### Exercise : 4.4

- 1) Decreasing function    2)  $D < 20$   
 3)  $x > 100$   
 4) i)  $x < 120$                       ii)  $x < 118$   
 5) i)  $x < 27$                       iii)  $x < 30$   
 6) i)  $x < 10$ ,  $C_A$  increasing.  
     ii)  $x > 10$ ,  $C_A$  decreasing  
 7) i)  $R_A = 36$                       ii)  $P = 42$   
     iii)  $\eta = 3$   
 8) 3.6                                  9)  $P = \frac{3}{2}$   
 10) i)  $\eta = 6.5$  elastic    ii)  $\frac{7}{20}$  inelastic  
 11) i)  $\eta = 2$  elastic    ii)  $\frac{18}{41}$  inelastic  
 12) i)  $R$  increasing,  $x < 60$   
     ii) Profit increasing,  $x < 59$   
     ii)  $\eta = 2$   
 13) i)  $MPC = 0.675$ ,  $MPS = 0.325$   
     ii)  $APC = 0.375$ ,  $APS = 0.625$

#### MISCELLANEOUS EXERCISE - 4

I.

- 1) a    2) a    3) c    4) b    5) a    6) c

II.

- 1) gradient                      2)  $6(x - 1)$   
 3)  $14x^{-3}$                       4)  $x = 27$ ,  $y = 27$   
 5)  $\frac{-1}{e}$

III.

- 1) True                      2) False    3) True

IV.

- 1) i)  $\left(y - \frac{c}{t}\right) = \frac{1}{t^2} (x - ct)$  ;  
      $\left(y - \frac{c}{t}\right) = -t^2 (x - ct)$   
     ii) for  $(-3, -3)$   $2x + y + 9 = 0$  ;  $x - 2y - 3 = 0$  and for  $(-1, -3)$   $2x - y - 1 = 0$  ;  
      $x + 2y + 7 = 0$   
     iii)  $10x + 2y - 8 = 0$  ;  $2x - 10y + 14 = 0$   
     iv)  $16x - y + 19 = 0$  ;  $x + 16y + 210 = 0$   
     v)  $x - 2y - 2 = 0$   
     vi) max at 2 and min at 4

#### 5. Integration

#### Exercise : 5.1

- i)  $\frac{2}{15} \left( (5x-4)^{3/2} + (5x-2)^{3/2} \right) + c$   
 ii)  $x + \frac{x^2}{2} + \frac{x^3}{6}$   
 iii)  $x^3 - 4\sqrt{x}$   
 iv)  $\left(\frac{9x^5}{5}\right) - 10x^3 + 25x + c$   
 v)  $\log \left| \frac{x-1}{x} \right| + c$   
 vi)  $f(x) = x^2 + 5$  and  $f(0) = -1$   $f(x) = \frac{x^3}{3} + 5x + c$   
     If  $x = 0$ , then  $f(0) = c \Leftrightarrow c = -1$  Hence  
      $f(x) = \frac{x^3}{3} + 5x - 1$  .  
 vii)  $f(x) = x^4 - x^3 + x^2 + 2x + 1$   
 viii)  $f(x) = \frac{x^3}{6} - \frac{x^2}{2} + x + 2$

**Exercise : 5.2**

i)  $\frac{1}{3}(1+x^2)^{\frac{3}{2}} + c$

ii)  $\frac{1}{2}\sqrt{(1+x^4)} + c$

iii)  $\frac{(e^x + e^{-x})^3}{3} + c$

iv)  $\log|xe^x + 1| + c$

v)  $\frac{(x+2)^{10}}{10} - \frac{(x+2)^8}{8} + c$

vi)  $\log|\log x| + c$

vii)  $\frac{1}{4}(x^1+1)^2 - (x^2+1) + \frac{1}{2}\log(x^2+1) + c$

viii)  $2\sqrt{x^2+6x+3} + c$

ix)  $2\log|\sqrt{x}+1| + c$

x)  $\frac{1}{6}\log\left|\frac{x^6}{x^6+1}\right| + c$

**Exercise : 5.3**

i)  $-t + \frac{7}{8}\log|4e^{2t} - 5| + c$

ii)  $5x + \log|3e^x - 4| + c$

iii)  $\frac{-1}{2}x + 2\log|2e^x - 8| + c$

iv)  $5x - 8\log|2e^x + 1| + c$

**Exercise : 5.4**

i)  $\frac{1}{4}\log\left|\frac{2x-1}{2x+1}\right| + c$

ii)  $\frac{1}{6}\log\left|\frac{x-1}{x+5}\right| + c$

iii)  $\frac{1}{8\sqrt{2}}\log\left|\frac{2x-5-2\sqrt{2}}{2x-5+2\sqrt{2}}\right| + c$

iv)  $\frac{1}{4\sqrt{13}}\log\left|\frac{4x^2-1-\sqrt{13}}{4x^2-1+\sqrt{13}}\right| + c$

v)  $\frac{1}{16}\log\left|\frac{4x^4-5}{4x^4+5}\right| + c$

vi)  $\frac{1}{2ab}\log\left|\frac{a+bx}{a-bx}\right| + c$

vii)  $\frac{1}{8}\log\left|\frac{1+x}{7-x}\right| + c$

viii)  $\frac{1}{\sqrt{3}}\log|\sqrt{3}x + \sqrt{3x^2+8}| + c$

ix)  $\log|(x+2) + \sqrt{x^2+4x+29}| + c_1$

x)  $\frac{1}{\sqrt{3}}\log|\sqrt{3}x + \sqrt{3x^2-5}| + c$

xi)  $\log|(x-4) + \sqrt{(x-4)^2-6^2}| + c$

xi)  $\log|(x-4) + \sqrt{x^2-8x-20}| + c$

**Exercise : 5.5**

i)  $\frac{x^2}{2}\log x - \frac{x^2}{4} + c$

ii)  $\frac{e^{4x}}{4}\left[x^2 - \frac{x}{2} + \frac{1}{8}\right] + c$

iii)  $\frac{1}{3}x^2e^{3x} - \frac{2}{9}xe^{3x} + \frac{2}{27}e^{3x} + c$

iv)  $\frac{1}{2}\{(x^2-1)e^{x^2} + c\}$

v)  $e^x \frac{1}{x} + c$

vi)  $e^x \frac{1}{x+1} + c$

vii)  $e^x \frac{1}{(x+1)^2} + c$

viii)  $e^x (\log x)^2 + c$

ix)  $\frac{x}{\log x} + c$

x)  $\frac{x}{1+\log x} + c$

### Exercise : 5.6

i)  $\frac{1}{3} \log|x+1| + \frac{5}{3} \log|x-2| + c$

ii)  $\frac{1}{4} \log|x| - \log|x-1| + \frac{3}{4} \log|x-4| + c$

iii)  $x - \log|x+3| + \log|x-2| + c$

iv)  $\frac{2}{9} \log \left| \frac{x-1}{x+2} \right| - \frac{1}{3(x-1)} + c$

v)  $\frac{11}{4} \log \left| \frac{x+1}{x+3} \right| + \frac{5}{2(x+1)} + c$

vi)  $\frac{1}{5} \log \left| \frac{x^5}{x^5+1} \right| + c$

vii)  $\frac{1}{n} \log \left| \frac{x^n}{x^n+1} \right| + c$

viii)  $6 \log|x| - \log|x+1| - \frac{9}{x+1} + c$

### MISCELLANEOUS EXERCISE - 5

- I. 1) b    2) a    3) b    4) c    5) a  
6) c    7) b    8) a    9) b    10) a

II. 1)  $x^5 - \frac{5}{3}x^3 + 5x + c$

2)  $x + 4 \log(x-1) + c$

3)  $f(x) = \log x + \frac{x^2}{2} + c$

4)  $1 + \log x = t$

5)  $p = \frac{1}{3}$

III. 1) True    2) False    3) True

4) True    5) False

IV. 1) i)  $\frac{5x^2}{4} + \frac{3x}{4} + \frac{21}{8} \log|2x-3| + c$

ii)  $\frac{9}{65} (5x+1)^{13/9} + c$

iii)  $\frac{\log|2x+3|}{2} + c$

iv)  $\frac{2}{3} (x+4)^{3/2} - 10\sqrt{x+4} + c$

v)  $\frac{2x^{3/2}}{3} + \frac{4}{3}$

vi)  $-\frac{x^2}{2} + c$

2) i)  $-\log|e^{-x}+1| + c$

ii)  $\frac{1}{2(ae^x - be^{-x})} + c$

iii)  $\frac{\log|2+3 \log x|}{3} + c$

iv)  $2 \log|1+\sqrt{x}| + c$

v)  $-3x + \frac{7}{2} \log|4e^x+1| + c$

3) i)  $\frac{1}{2} \log \left| x + \sqrt{x^2 - \frac{5}{4}} \right| + c$

ii)  $\frac{1}{4} \log \left| \frac{3+x}{1-x} \right| + c$

$$\text{iii)} \quad \frac{1}{30} \log \left| \frac{3x-5}{3x+5} \right|$$

$$\text{iv)} \quad \log \left| e^x + 2 + \sqrt{e^{2x} + 4e^x + 13} \right| + c$$

$$\text{v)} \quad \frac{1}{2\sqrt{5}} \log \left| \frac{\log x + 2 - \sqrt{5}}{\log x + 2 + \sqrt{5}} \right| + c$$

$$\text{vi)} \quad \frac{1}{8\sqrt{5}} \log \left| \frac{\sqrt{5} + 4x}{\sqrt{5} - 4x} \right| + c$$

$$\text{vii)} \quad \frac{1}{10} \log \left| \frac{5 + \log x}{5 - \log x} \right|$$

$$\text{viii)} \quad \frac{1}{4} \log \left| \frac{e^x - 1}{e^x + 1} \right| + c$$

$$4) \quad \text{i)} \quad x(\log x)^2 - 2x \log x + 2x + c$$

$$\text{ii)} \quad \frac{e^x}{2+x} + c$$

$$\text{iii)} \quad \frac{(2x-1)}{4} e^{2x}$$

$$\text{iv)} \quad x \left[ \log(x^2 + x) \right] - 2x + \log|x+1| + c$$

$$\text{v)} \quad 2(\sqrt{x} - 1)e^{\sqrt{x}} + c$$

$$\text{vi)} \quad \frac{x+1}{2} \sqrt{x^2 + 2x + 5} + 2 \log \left| (x+1) + \sqrt{x^2 + 2x + 5} \right| + c$$

$$\text{vii)} \quad \frac{(x-4)}{2} \sqrt{x^2 - 8x + 7} - \frac{9}{2} \log \left| (x-4) + \sqrt{x^2 - 8x + 7} \right| + c$$

$$5) \quad \text{i)} \quad \frac{2}{3} \log|x-1| + \frac{5 \log|2x+1|}{3} + c$$

$$\text{ii)} \quad \frac{x^2}{2} - x + \log \left( \frac{x+2}{2x+5} \right) + c$$

$$\text{iii)} \quad \frac{2}{7} \log(3 + \log x) + \frac{1}{21} \log(2 + 3 \log x) + c$$

## 6. Definite Integrals

### Exercise : 6.1

$$1) \quad 2 \quad 2) \quad \log\left(\frac{8}{3}\right) \quad 3) \quad \frac{1}{2} \log\left(\frac{8}{3}\right)$$

$$4) \quad \frac{32}{5} \quad 5) \quad \log\left(\frac{3456}{3125}\right) \quad 6) \quad \frac{1}{4} \log\left(\frac{9}{7}\right)$$

$$7) \quad a = -2 \text{ or } 1 \quad 8) \quad a = 2 \quad 9) \quad \frac{4}{3}(\sqrt{2} - 1)$$

$$10) \quad \frac{1}{6} \log\left(\frac{35}{8}\right)$$

$$11) \quad \log 27 - 4 \text{ or } 3 \log 3 - 4$$

### Exercise : 6.2

$$1) \quad 0 \quad 2) \quad \frac{16}{315} a^{9/2} \quad 3) \quad 1$$

$$4) \quad \frac{3}{2} \quad 5) \quad \frac{1}{2} \quad 6) \quad \frac{5}{2}$$

$$7) \quad 0 \quad 8) \quad \frac{1}{4^2}$$

## MISCELLANEOUS EXERCISE - 6

I.

$$1) \quad a \quad 2) \quad b \quad 3) \quad c \quad 4) \quad c$$

$$5) \quad a \quad 6) \quad d \quad 7) \quad d \quad 8) \quad c$$

$$9) \quad c \quad 10) \quad b$$

II.

$$1) \quad \text{i)} e^2 - 1 \quad 2) \quad \frac{211}{5} \quad 3) \quad \frac{1}{2} \log\left(\frac{7}{2}\right)$$

$$4) \quad 2 \quad 5) \quad 2 \quad 6) \quad \frac{1}{2} \log\left(\frac{8}{3}\right)$$

$$7) \quad \log\left(\frac{8}{3}\right) \quad 8) \quad 0$$

III.

- 1) True      2) True      3) False  
 4) False      5) True      6) True  
 7) False      8) True

IV.

- 1)  $3\log|x+3| - 2\log|x+2| + c$   
 2)  $\frac{\log 6}{2}$       3)  $9\log 3 - \frac{26}{9}$   
 4)  $\frac{1}{2}$       5)  $\frac{e^4}{4} - \frac{e^2}{2}$   
 6) 2      7)  $\log \frac{8}{3}$   
 8)  $\frac{1}{2} \log \frac{8}{3}$       9)  $\frac{32}{5}$   
 10)  $\frac{1}{9}(28 - 3\sqrt{3} - 7\sqrt{7})$       11)  $\log \sqrt{2}$   
 12)  $\frac{7}{3}$       13)  $-\log 4$   
 14)  $\frac{4}{3}(\sqrt{2} - 1)$       15)  $\log \left( \frac{5+3\sqrt{3}}{1+\sqrt{3}} \right)$   
 16)  $\frac{1}{2} \log \left( \frac{17}{5} \right)$       17)  $-\frac{1}{2} \log 3$   
 18)  $5 + \frac{1}{2}(5\log 3 + 85\log 2 - 45\log 2)$   
 19)  $\frac{\log 2}{1+\log 2}$       20)  $6 - 4\log 2$

## 7. Applications of Definite Integral

### Exercise : 7.1

- 1) i)  $\frac{3124}{5}$  sq. units      ii)  $\frac{56}{3}$  sq. units  
 iii)  $4\pi$  sq. units      iv) 96 sq. units

v) 5 sq. units      vi) 12 sq. units

vii)  $\frac{10}{3}$  sq. units

- 2)  $8\sqrt{3}$  sq. units  
 3)  $25\pi$  sq. units  
 4)  $10\pi$  sq. units

## MISCELLANEOUS EXERCISE - 7

I. 1) a      2) c      3) c      4) b      5) c

- II. 1)  $\frac{3124}{5}$  sq. units  
 2)  $49\pi$  sq. units  
 3)  $\frac{56}{3}$  sq. units  
 4)  $\frac{70}{3}$  sq. units  
 5)  $\frac{28}{3}$  sq. units

III. 1) True      2) False  
 3) True      4) False  
 5) True

- IV. 1)  $c^2 \log 2$  sq. units  
 2)  $\frac{49}{3}$  sq. units  
 3)  $\frac{40\sqrt{10}}{3}$  sq. units  
 4)  $12\pi$  sq. units  
 5) 21 sq. units  
 6)  $\frac{70}{3}$  sq. units

$$7) \quad A = 2 \int_0^5 y \, dx = 2 \int_0^5 5\sqrt{x} \, dx \\ = \frac{100\sqrt{5}}{3} \text{ sq. units}$$

## 8. Differential Equations and Applications

### Exercise : 8.1

1.

	order	Degree
i	2	1
ii	2	2
iii	4	1
iv	3	2
v	1	5
vi	2	1
vii	3	1

### Exercise : 8.2

- 1) i)  $\frac{dy^2}{dx^2} = 9y$
- ii)  $x^2 \frac{dy^2}{dx^2} + 2x \frac{dy}{dx} = 0$
- iii)  $\frac{dy^2}{dx^2} - 2 \frac{dy}{dx} + y = 0$
- iv)  $\frac{d^2y}{dx^2} - 5 \frac{dy}{dx} + 6y = 0$
- v)  $\frac{dy}{dx} = \frac{3}{2} \sqrt[3]{y}$
- 2)  $2xy \frac{dy}{dx} = y^2 - x^2$
- 3)  $\frac{d^2y}{dx^2} = 0$
- 4)  $2x^3 - y^3 + 3xy^2 \frac{dy}{dx} = 0$
- 5)  $x + 4y \frac{dy}{dx} = 0$

### Exercise : 8.3

1. i)  $\log y = \frac{x^3}{3} + x + c$
- ii)  $\theta - \theta_0 = e^{-kt+c}$
- iii)  $\log x - \log y = \frac{1}{x} + \frac{1}{y} + c$
- iv)  $2y^2 \log|1+x| = -1 + 2y^2c$
2. i)  $|1+x^2||1-y^2| = 5$
- ii)  $3x - 2e^y - 1 = 0$
- iii)  $\log x = y$
- iv)  $\log \left| \frac{4x+y+5}{6} \right| = x+c$

### Exercise : 8.4

- 1)  $x^2 + 2y^2 = c$
- 2)  $\log x + \frac{1}{4} \log \left| \frac{2y^2 + xy}{x^2} \right| + \frac{3}{4} \log \left| \frac{2y}{x+2y} \right| = c$
- 3)  $\frac{x^3}{3y^3} = \log yc$
- 4)  $\log \left| \frac{x+y}{x-y} \right| - \frac{1}{2} \log |x^2 - y^2| + 2 \log x = \log c$
- 5)  $x^2 + y^2 = xc$
- 6)  $x^2 + y^2 = cx^4$
- 7)  $\frac{x+y}{x-y} = cx^2$

### Exercise : 8.5

- 1)  $ye^x = x + c$
- 2)  $ye^x = 3e^x + c$

- 3)  $yx^2 = \log x \cdot \frac{x^4}{4} - \frac{x^4}{16} + c$
- 4)  $x + y + 1 = c \cdot e^y$
- 5)  $3xy = y^3 + c$
- 6)  $ye^{x^2} = \frac{1}{2}e^{x^2} + c$
- 7)  $y(x + a) = ax + c$
- 8)  $ye^{2x} = 4e^{2x} + c$

### Exercise : 8.6

- 1) 8
- 2) 73482
- 3) 45248
- 4)  $30000 \left(\frac{4}{3}\right)^{\frac{t}{40}}$
- 5) Rs. 628571

### MISCELLANEOUS EXERCISE - 8

- I. 1) a 2) c 3) b 4) a 5) d 6) c 7) d 8) b  
9) c 10) a

II.

- 1) Order of the differential equation
- 2) Degree of the differential equation
- 3) Particular solution
- 4) Positive
- 5)  $e^{-x}$
- 6)  $\frac{d^2y}{dx^2} = 0$

III.

- 1) True
- 2) True
- 3) True
- 4) False
- 5) False
- 6) True

IV.

- 1) i) Order : 3 , Degree : 3  
ii) Order : 1 , Degree : 3
- 2)  $x \frac{d^2y}{dx^2} + \frac{dy}{dx} = 0$
- 3) i)  $\log|1+y| = x + \frac{x^2}{2} + c$   
ii)  $y = x(\log x - 1) + c$   
iii)  $\log r = a \log|1+\theta| + c$   
iv)  $\frac{x^2 d^2y}{dx^2} - 2x^2 \frac{dy}{dx} - 2x \frac{dy}{dx} + x^2y + 2y + 2xy = 0$
- 4)  $\log|x+y| = y - x + \frac{1}{3}$
- 5)  $\log|x+y+1| = cx$
- 6)  $2xlogy = (logy)^2 + c$
- 7)  $a^3 + x + y = ce^{\frac{y}{a^2}}$
- 8)  $5x^2y = x^5 + c$
- 9) 50 years
- 10) Rs. 10,000
- 11)  $xy^2 = c^2(x+2y)$
- 12)  $logy - \frac{x^3}{3y^3} = c$
- 13)  $x^2 + y^2 = c^2x^4$
- 14)  $x = y(c+y^2)$
- 15)  $y = c \cdot x - (1 + \log x)$
- 16)  $y = x \log x - x + c$
- 17)  $xlogy = \frac{1}{2}(\log y)^2 + c$





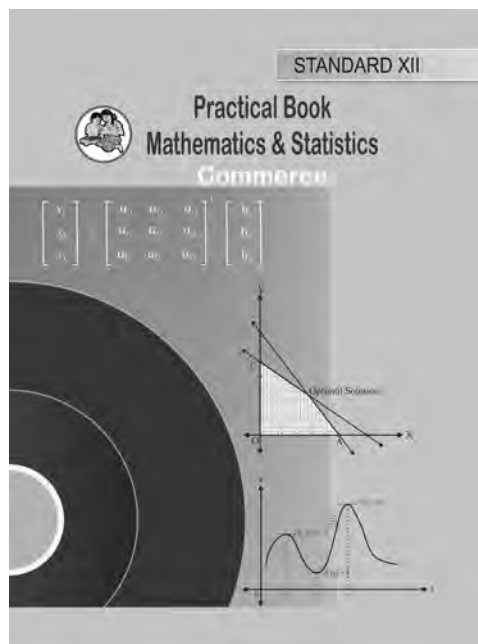
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$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

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

$$x dy + y dx = 0$$

$$\int e^x dx = e^x + C$$

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c, n \neq -1$$



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