Differential Equations

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. The order and degree of the differential equation $(y')^3 + 9y + 9 = 0$ are:

(a) order 1, degree 3 **(b)** order 3, degree 1

(c) order 1, degree 4 **(d)** order 2, degree 3

2. The general solution of $dy/dx = 2x$ is:

(a) $y = (2/3)x^3 + C$ **(b)** $y = 2 + C$

(c) $y = x^2 + C$ **(d)** $y = 2x^2 + C$

3. The integrating factor of $dy/dx - (1/x)y = x^5$ is:

(a) $-\log x$ **(b)** x **(c)** $1/x$ **(d)** e^{-x}

4. The number of arbitrary constants in the general solution of a differential equation of order 3 is:

(a) 0 **(b)** 3 **(c)** 4 **(d)** 2

5. The order of a differential equation is the order of:

(a) the lowest derivative in it **(b)** the highest power of y

(c) the highest derivative in it **(d)** the number of terms

6. Which function is a solution of $y'' + 16y = 0$?

(a) $y = x^4$ **(b)** $y = e^{4x}$ **(c)** $y = 5 \sin 4x$ **(d)** $y = \sin 16x$

7. The differential equation $dy/dx = (8x^2 + 7y^2)/(2xy)$ is:

(a) linear in y **(b)** variable separable

(c) homogeneous **(d)** of order 2

8. Assertion (A): $y = Ce^{-9x}$ is the general solution of $dy/dx = 9y$.
Reason (R): Separating the variables, $dy/y = k\,dx$ gives $\log|y| = kx + c$.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. Solve $dy/dx = 7x^2/(9y^3)$.

10. Solve $dy/dx = 5y$, given $y = 8$ when $x = 0$.

11. Solve $dy/dx + y = 4$.

12. Solve $dy/dx + (1/x)y = x^4$, $x > 0$.

13. Form the differential equation of the family $y = A \sin 3x + B \cos 3x$, where A and B are arbitrary constants.

14. Solve the homogeneous equation $x\, dy/dx = y - 7x$.

15. Solve $dy/dx = 24x^2 + 4$, given $y = -6$ when $x = 0$.

16. A population grows at a rate proportional to its size. It doubles in 16 years. In how many years will it become 16 times its present size?

Section C — Word problems — 4 × 4 = 16 marks

17. Solve $dy/dx + 4y = -9e^{2x}$, given $y = 1$ when $x = 0$.

18. Solve $x\, dy/dx - y = 5x^2$, given $y = 7$ when $x = 1$.

19. Solve $dy/dx = (x + 8)/(y - 7)$, given $y = 0$ when $x = 0$.

20. A radioactive substance decays at a rate proportional to the amount present, and its half-life is 55 years. What fraction remains after 165 years? After how many years will only 1/8 of it remain?

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Answer key

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Q	Answer	Working
1	**(a) order 1, degree 3**	highest derivative y', raised to the power 3
2	**(c) $y = x^2 + C$**	integrate both sides
3	**(c) 1/x**	e^(∫P dx) with P = −1/x
4	**(b) 3**	one constant for each order
5	**(c) the highest derivative in it**	—
6	**(c) $y = 5 \sin 4x$**	$(\sin 4x)'' = -16 \sin 4x$
7	**(c) homogeneous**	every term has degree 2, so dy/dx is a function of y/x
8	**(d) A is false, but R is true.**	A is false: the solution is $y = Ce^{9x}$, not Ce^{-9x}. R is true.
9	**$(9/4)y^4 = (7/3)x^3 + C$**	$9y^3\,dy = 7x^2\,dx$
10	**$y = 8e^{5x}$**	$y = Ce^{5x}$; x = 0 gives C = 8
11	**$y = 4 + Ce^{-x}$**	integrating factor e^x; $ye^x = 4e^x + C$
12	**$y = (1/6)x^5 + C/x$**	integrating factor x; $d/dx(xy) = x^5$
13	**$y'' + 9y = 0$**	differentiate twice and eliminate the constants
14	**$y = -7x \log\|x\| + Cx$**	put y = vx: $x\,dv/dx = -7$, so $v = -7 \log\|x\| + C$
15	**$y = 8x^3 + 4x - 6$**	$y = 8x^3 + 4x + C$; C = −6
16	**64 years**	$P = P_0 e^{(kt)}$ with $e^{(16k)} = 2$, so $16 = 2^4$ needs $t = 4 \times 16$
17	**$y = -(3/2)e^{2x} + (5/2)e^{-4x}$**	integrating factor e^{4x}: $ye^{4x} = -(3/2)e^{6x} + C$; $C = 1 - (-3/2) = 5/2$
18	**$y = 5x^2 + 2x$**	divide by x^2: $d/dx(y/x) = 5$, so $y/x = 5x + C$; C = 2
19	**$y^2 - 14y = x^2 + 16x$**	$(y - 7)\,dy = (x + 8)\,dx \Rightarrow y^2/2 - 7y = x^2/2 + 8x + C$; C = 0
20	**1/8 remains after 165 years; 1/8 remains after 165 years**	$A = A_0 e^{(-\lambda t)}$ with $e^{(-55\lambda)} = 1/2$, so $A = A_0(1/2)^{(t/55)}$

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