1. Classify the following differential equations completely by specifying:
   i) The dependent variable
   ii) The independent variable
   iii) The order of the equation
   iv) Linear or nonlinear
   v) If linear, homogeneous or inhomogeneous
   vi) If there are additional conditions, initial value or boundary value
   a) \( y''' + x^2 y'' - \sin x \ y' + 3 \ y = 0 \)
   b) \( t^2 \theta'' + t \theta' + \frac{1}{t} \theta = e^{5t} \) subject to \( \theta(0) = \theta_0 \) and \( \theta'(0) = 0 \)
   c) \( (x')^3 + 5 t \ x = 0 \) subject to \( x(0) = x(L) = 1 \)
   d) \( x'' - 2 t \ x' + x = e^x \)

2. Solve the following differential equations
   a) \( y' = x \ e^{x^2} \) subject to \( y(0) = 1 \)
   b) \( y'' + 4 \ y' + y = 0 \)
   c) \( D \ (D-2)^2 \ (D^2 + 6D + 10) \ y = 0 \)
   d) \( (D^2 - 2D - 2)^2 \ y = 0 \)

3. Given the following equation, write the correct guess for \( y_p \) using the method of undetermined coefficients. Do not plug the guess back into the equation to solve for the coefficients
   \[ (D^2 + 4D + 5) \ (D-3) \ y = x \ e^{3x} + 2 \ e^{-2x} \sin x \]

4. Given the following equation
   \[ y'' - 3 \ y' + 2 \ y = -x^2 \ e^x \]
   a) Solve using the method of undetermined coefficients
   b) Solve using the variation of parameters method
5. Solve the following differential equations
   a) $x^2 y'' + 7x y' + 9y = 0$
   b) $x^2 y' - 3x y = 0$
   c) $x y' + 2y = \frac{5}{2}\sqrt{x}$ subject to $y(1) = 1$
   d) $x^2 y'' + 5x y' + 8y = 0$
   e) $\frac{1}{x} y' - 2y = 1$ subject to $y(0) = \frac{1}{2}$

6. Solve the following nonlinear equations
   a) $x y'^2 - 2y - xy = 0$
   b) $x^2 (y')^2 - 4y^2 = 0$
   c) $(x^2 y - 2y^2) \frac{dy}{dx} + (x y^2 + 3x^2) = 0$

7. Given the differential equation

   $$x^2 y'' + x y' - y = 1 - 6x^2$$

   find the solution, $y(x)$, using the series form for the guess $y_g(x)$, or:

   $$y_g(x) = \sum_{i=0}^{\infty} a_i x^i$$

8. Solve the initial value problem using Laplace transforms

   $$y'' + y = 2e^x$$ subject to $y(0) = 2, \ y'(0) = 3$

9. The mass-spring system with friction is governed by the equation

   $$m y'' + \delta y' + k y = 0$$

   Given that $\delta = c m$ and $k = 1$, for what values of $c$ is the solution non-oscillatory