1. Initial conditions. Real form and complex form of solutions.

2. Qualitative behavior of solutions: periodicity, oscillation (spiraling), decay/growth, convergent/divergent.

3. Separation of variables. For example, with unknown \( y(t) \),
   \[ y' + y^2 - ty^2 = 0 \]

4. Integrating factors. For example, with unknown \( y(t) \),
   \[ 2y' = \frac{y}{t} + f(t). \]

5. Linear System of equations. For example, with unknowns \( x(t) \), \( y(t) \)
   \[
   \begin{cases}
   x' = -9y \\
   y' = 4x 
   \end{cases}
   \]

6. Let \( A \) be some constant, \( n \)-by-\( n \) matrix and consider \( \frac{d}{dt}\vec{x} = A\vec{x} \) for the unknown vector \( \vec{x}(t) \). Find fundamental matrix. Derive a solution formula for this system with initial condition \( \vec{x}(0) = \vec{x}_0 \).

7. Nonhomogeneous system. For example, with unknowns, \( x(t) \), \( y(t) \)
   \[
   \begin{cases}
   x' = y - e^t \\
   y' = 3x - 2y + 3e^t 
   \end{cases}
   \]

8. Nonhomogeneous 2nd order equation. For example, with unknown \( x(t) \)
   \[ 2x'' - x' - x = 2t^2 - 10e^{5t} \]

9. Laplace transform. For example, with unknown \( x(t) \)
   \[ x'' - x' - x = u(t - 1) \] with \( x(0) = 2 \) and \( x'(0) = 1 \).
10. Nonlinear system. Problem will be similar to HW12. For example, with unknowns $x(t), y(t)$

\[
\begin{cases}
  x' = y^2 - x \\
  y' = 2x + 2y^2 - 4
\end{cases}
\]

11. Spring-mass system with damping. For example

Find the value for $k$ so that the system is critically damped $x'' = -kx - 4x'$