MATH 250
FALL 2020
EXAM 3

NAME:

1. $\boxed{\text{10 pts.}}$ Solve the nonlinear ODE

$$yy'' + (y')^2 - y' = 0$$

starting with the substitution $u = y'$.

2. $\boxed{\text{10 pts.}}$ Obtain the first five nonzero terms of a Taylor series solution (centered at 0) to the initial-value problem

$$y'' - 2y^2 = 4x, \quad y(0) = -1, \quad y'(0) = 2.$$

3. Consider the initial-value problem

$$y'' + 4y = 4\cos x + 3\sin x - 8, \quad y(0) = 0, \quad y'(0) = -2.$$

(a) $\boxed{\text{12 pts.}}$ Use the Method of Undetermined Coefficients to find a particular solution to the differential equation.

(b) $\boxed{\text{4 pts.}}$ Next give the general solution to the differential equation.

(c) $\boxed{\text{4 pts.}}$ Finally, solve the initial-value problem.

4. $\boxed{\text{15 pts.}}$ Use the Method of Variation of Parameters to find a particular solution to

$$y'' + 2y' + y = e^{-x}/x,$$

and then find the general solution.

Method of Undetermined Coefficients. Let $P_m(x)$ be a nonzero polynomial of degree m, and let $y_p(x)$ denote a particular solution to $a_n y^{(n)} + \cdots + a_1 y' + a_0 y = f(x)$.

1. If $f(x) = P_m(x)e^{\alpha x}$, then
$$y_p(x) = x^s e^{\alpha x} \sum_{k=0}^{m} A_k x^k,$$
where $s = 0$ if α is not a root of the auxiliary equation, otherwise s equals the multiplicity of α as a root of the auxiliary equation.
2. If $f(x) = P_m(x)e^{\alpha x}\cos\beta x$ or $f(x) = P_m(x)e^{\alpha x}\sin\beta x$ for $\beta \neq 0$, then
$$y_p(x) = x^s e^{\alpha x}\left(\cos\beta x \sum_{k=0}^{m} A_k x^k + \sin\beta x \sum_{k=0}^{m} B_k x^k\right),$$
where $s = 0$ if $\alpha + i\beta$ is not a root of the auxiliary equation, otherwise s equals the multiplicity of $\alpha + i\beta$ as a root of the auxiliary equation.

Method of Variation of Parameters (2nd-Order Case).

$$u_1(x) = \frac{1}{a_2}\int \frac{-y_2(x)f(x)}{y_1(x)y_2'(x) - y_1'(x)y_2(x)}dx \quad \text{and} \quad u_2(x) = \frac{1}{a_2}\int \frac{y_1(x)f(x)}{y_1(x)y_2'(x) - y_1'(x)y_2(x)}dx$$

Some Most Excellent Formulae.

1. $\displaystyle\int \frac{1}{\sqrt{a^2 - x^2}}\,dx = \sin^{-1}\left(\frac{x}{a}\right) + c$, for $a \in (0, \infty)$
2. $\displaystyle\int \frac{1}{a^2 + x^2}\,dx = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right) + c$, for $a \neq 0$
3. $\displaystyle\int \frac{1}{x\sqrt{x^2 - a^2}}\,dx = \frac{1}{a}\sec^{-1}\left|\frac{x}{a}\right| + c$, for $a \in (0, \infty)$
4. $\displaystyle\int \tan x\,dx = -\ln|\cos x| + c = \ln|\sec x| + c$
5. $\displaystyle\int \cot x\,dx = \ln|\sin x| + c$
6. $\displaystyle\int \sec x\,dx = \ln|\sec x + \tan x| + c$
7. $\displaystyle\int \csc x\,dx = -\ln|\csc x + \cot x| + c$