

Exercises 1.3

Thus, the differential equation is

$$x \frac{d^2x}{dt^2} + \left(\frac{dx}{dt} \right)^2 + 32x = 160.$$

20. The force is the weight of the chain, $2L$, so by Newton's second law, $\frac{d}{dt}[mv] = 2L$. Since the mass of the portion of chain off the ground is $m = 2(L - x)/g$, we have

$$\frac{d}{dt} \left[\frac{2(L - x)}{g} v \right] = 2L \quad \text{or} \quad (L - x) \frac{dv}{dt} + v \left(-\frac{dx}{dt} \right) = Lg.$$

Thus, the differential equation is

$$(L - x) \frac{d^2x}{dt^2} - \left(\frac{dx}{dt} \right)^2 = Lg.$$

21. From $g = k/R^2$ we find $k = gR^2$. Using $a = d^2r/dt^2$ and the fact that the positive direction is upward we get

$$\frac{d^2r}{dt^2} = -a = -\frac{k}{r^2} = -\frac{gR^2}{r^2} \quad \text{or} \quad \frac{d^2r}{dt^2} + \frac{gR^2}{r^2} = 0.$$

22. The gravitational force on m is $F = -kM_r m/r^2$. Since $M_r = 4\pi\delta r^3/3$ and $M = 4\pi\delta R^3/3$ we have $M_r = r^3 M/R^3$ and

$$F = -k \frac{M_r m}{r^2} = -k \frac{r^3 M m / R^3}{r^2} = -k \frac{m M}{R^3} r.$$

Now from $F = ma = d^2r/dt^2$ we have

$$m \frac{d^2r}{dt^2} = -k \frac{m M}{R^3} r \quad \text{or} \quad \frac{d^2r}{dt^2} = -\frac{k M}{R^3} r.$$

23. The differential equation is $\frac{dA}{dt} = k(M - A)$.

24. The differential equation is $\frac{dA}{dt} = k_1(M - A) - k_2 A$.

25. The differential equation is $x'(t) = r - kx(t)$ where $k > 0$.

26. By the Pythagorean Theorem the slope of the tangent line is $y' = \frac{-y}{\sqrt{x^2 - y^2}}$.

27. We see from the figure that $2\theta + \alpha = \pi$. Thus

$$\frac{y'}{-x} = \tan \alpha = \tan(\pi - 2\theta) = -\tan 2\theta = -\frac{2 \tan \theta}{1 - \tan^2 \theta}.$$

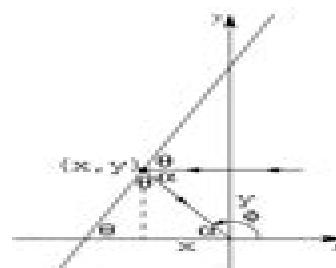
Since the slope of the tangent line is $y' = \tan \theta$ we have $y/x = 2y'/[1 - (y')^2]$ or $y - y(y')^2 = 2xy'$, which is the quadratic equation $y(y')^2 + 2xy' - y = 0$ in y' . Using the quadratic formula we get

$$y' = \frac{-2x \pm \sqrt{4x^2 + 4y^2}}{2y} = \frac{-x \pm \sqrt{x^2 + y^2}}{y}.$$

Since $dy/dx > 0$, the differential equation is

$$\frac{dy}{dx} = \frac{-x + \sqrt{x^2 + y^2}}{y} \quad \text{or} \quad y \frac{dy}{dx} - \sqrt{x^2 + y^2} + x = 0.$$

28. The differential equation is $dP/dt = kP$, so from Problem 29 in Exercises 1.1, $P = e^{kt}$, and a one-parameter family of solutions is $P = ce^{kt}$.



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JA Banks

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Table of Contents Advanced Engineering Mathematics W Student Solutions Manual

1. Understanding the eBook Advanced Engineering Mathematics W Student Solutions Manual
 - The Rise of Digital Reading Advanced Engineering Mathematics W Student Solutions Manual
 - Advantages of eBooks Over Traditional Books
2. Identifying Advanced Engineering Mathematics W Student Solutions Manual
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Advanced Engineering Mathematics W Student Solutions Manual
 - User-Friendly Interface
4. Exploring eBook Recommendations from Advanced Engineering Mathematics W Student Solutions Manual
 - Personalized Recommendations
 - Advanced Engineering Mathematics W Student Solutions Manual User Reviews and Ratings
 - Advanced Engineering Mathematics W Student Solutions Manual and Bestseller Lists
5. Accessing Advanced Engineering Mathematics W Student Solutions Manual Free and Paid eBooks
 - Advanced Engineering Mathematics W Student Solutions Manual Public Domain eBooks
 - Advanced Engineering Mathematics W Student Solutions Manual eBook Subscription Services
 - Advanced Engineering Mathematics W Student Solutions Manual Budget-Friendly Options

6. Navigating Advanced Engineering Mathematics W Student Solutions Manual eBook Formats
 - ePUB, PDF, MOBI, and More
 - Advanced Engineering Mathematics W Student Solutions Manual Compatibility with Devices
 - Advanced Engineering Mathematics W Student Solutions Manual Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Advanced Engineering Mathematics W Student Solutions Manual
 - Highlighting and Note-Taking Advanced Engineering Mathematics W Student Solutions Manual
 - Interactive Elements Advanced Engineering Mathematics W Student Solutions Manual
8. Staying Engaged with Advanced Engineering Mathematics W Student Solutions Manual
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Advanced Engineering Mathematics W Student Solutions Manual
9. Balancing eBooks and Physical Books Advanced Engineering Mathematics W Student Solutions Manual
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Advanced Engineering Mathematics W Student Solutions Manual
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Advanced Engineering Mathematics W Student Solutions Manual
 - Setting Reading Goals Advanced Engineering Mathematics W Student Solutions Manual
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Advanced Engineering Mathematics W Student Solutions Manual
 - Fact-Checking eBook Content of Advanced Engineering Mathematics W Student Solutions Manual
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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