INSTRUCTOR SOLUTIONS MANUAL

THIRD EDITION

physics

FOR SCIENTISTS AND ENGINEERS

a strategic approach

randall d. knight

Larry Smith
Snow College

Brett Kraabel
PhD-Physics, University of Santa Barbara

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Publisher: James Smith
Senior Development Editor: Alice Houston, Ph.D.
Senior Project Editor: Martha Steele
Assistant Editor: Peter Alston
Media Producer: Kelly Reed
Senior Administrative Assistant: Cathy Glenn
Director of Marketing: Christy Lesko
Executive Marketing Manager: Kerry McGinnis
Managing Editor: Corinne Benson
Production Project Manager: Beth Collins
Production Management, Illustration, and Composition: PreMediaGlobal, Inc.

ISBN 13: 978-0-321-76940-4
ISBN 10: 0-321-76940-6

PEARSON

www.pearsonhighered.com

Contents

Preface

This *Instructor Solutions Manual* has a twofold purpose. First, and most obvious, is to provide worked solutions for the use of instructors. Second, but equally important, is to provide examples of good problem-solving techniques and strategies that will benefit your students if you post these solutions.

Far too many solutions manuals simply plug numbers into equations, thereby reinforcing one of the worst student habits. The solutions provided here, by contrast, attempt to:

- Follow, in detail, the problem-solving strategies presented in the text.
- Articulate the reasoning that must be done before computation.
- Illustrate how to use drawings effectively.
- Demonstrate how to utilize graphs, ratios, units, and the many other "tactics" that must be successfully mastered and marshaled if a problem-solving strategy is to be effective.
- Show examples of assessing the reasonableness of a solution.
- Comment on the significance of a solution or on its relationship to other problems.

Most education researchers believe that it is more beneficial for students to study a smaller number of carefully chosen problems in detail, including variations, than to race through a larger number of poorly understood calculations. The solutions presented here are intended to provide a basis for this practice.

So that you may readily edit and/or post these solutions, they are available for download as editable Word documents and as pdf files via the "Resources" tab in the textbook's Instructor Resource Center (www.pearsonhighered.com/educator/catalog/index.page) or from the textbook's Instructor Resource Area in MasteringPhysics® (www.masteringphysics.com).

We have made every effort to be accurate and correct in these solutions. However, if you do find errors or ambiguities, we would be very grateful to hear from you. Please contact your Pearson Education sales representative.

Acknowledgments for the First Edition

We are grateful for many helpful comments from Susan Cable, Randall Knight, and Steve Stonebraker. We express appreciation to Susan Emerson, who typed the word-processing manuscript, for her diligence in interpreting our handwritten copy. Finally, we would like to acknowledge the support from the Addison Wesley staff in getting the work into a publishable state. Our special thanks to Liana Allday, Alice Houston, and Sue Kimber for their willingness and preparedness in providing needed help at all times.

Pawan Kahol
Missouri State University

Donald Foster
Wichita State University

Acknowledgments for the Second Edition

I would like to acknowledge the patient support of my wife, Holly, who knows what is important.

Larry Smith
Snow College

I would like to acknowledge the assistance and support of my wife, Alice Nutter, who helped type many problems and was patient while I worked weekends.

Scott Nutter
Northern Kentucky University

Acknowledgments for the Third Edition

To Holly, Ryan, Timothy, Nathan, Tessa, and Tyler, who make it all worthwhile.

Larry Smith
Snow College

I gratefully acknowledge the assistance of the staff at Physical Sciences Communication.

Brett Kraabel
PhD-University of Santa Barbara

1

CONCEPTS OF MOTION

Conceptual Questions

1.1. **(a)** 3 significant figures.
(b) 2 significant figures. This is more clearly revealed by using scientific notation:

$$0.53 = \overbrace{5.3}^{\text{2 sig. figs.}} \times 10^{-1}$$

(c) 4 significant figures. The trailing zero is significant because it indicates increased precision.
(d) 3 significant figures. The leading zeros are not significant but just locate the decimal point.

1.2. **(a)** 2 significant figures. Trailing zeros in front of the decimal point merely locate the decimal point and are not significant.
(b) 3 significant figures. Trailing zeros after the decimal point are significant because they indicate increased precision.
(c) 4 significant figures.
(d) 3 significant figures. Trailing zeros after the decimal point are significant because they indicate increased precision.

1.3. Without numbers on the dots we cannot tell if the particle in the figure is moving left or right, so we can't tell if it is speeding up or slowing down. If the particle is moving to the right it is slowing down. If it is moving to the left it is speeding up.

1.4. Because the velocity vectors get longer for each time step, the object must be speeding up as it travels to the left. The acceleration vector must therefore point in the same direction as the velocity, so the acceleration vector also points to the left. Thus, a_x is negative as per our convention (see Tactics Box 1.4).

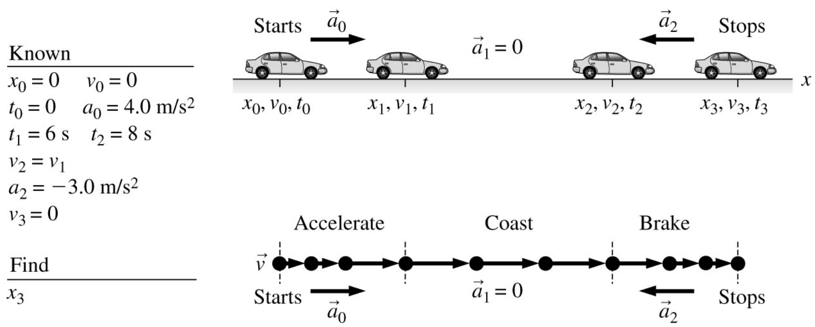
1.5. Because the velocity vectors get shorter for each time step, the object must be slowing down as it travels in the $-y$ direction (down). The acceleration vector must therefore point in the direction opposite to the velocity; namely, in the $+y$ direction (up). Thus, a_y is positive as per our convention (see Tactics Box 1.4).

1.6. The particle position is to the left of zero on the x-axis, so its position is negative. The particle is moving to the right, so its velocity is positive. The particle's speed is increasing as it moves to the right, so its acceleration vector points in the same direction as its velocity vector (i.e., to the right). Thus, the acceleration is also positive.

1.7. The particle position is below zero on the y-axis, so its position is negative. The particle is moving down, so its velocity is negative. The particle's speed is increasing as it moves in the negative direction, so its acceleration vector points in the same direction as its velocity vector (i.e., down). Thus, the acceleration is also negative.

2.53. Model: The car is a particle moving under constant-acceleration kinematic equations.
Visualize:

Pictorial representation



Solve: This is a three-part problem. First the car accelerates, then it moves with a constant speed, and then it decelerates.
First, the car accelerates:

$$v_1 = v_0 + a_0(t_1 - t_0) = 0 \text{ m/s} + (4.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s}) = 24 \text{ m/s}$$

$$x_1 = x_0 + v_0(t_1 - t_0) + \frac{1}{2}a_0(t_1 - t_0)^2 = 0 \text{ m} + \frac{1}{2}(4.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s})^2 = 72 \text{ m}$$

Second, the car moves at v_1:

$$x_2 - x_1 = v_1(t_2 - t_1) + \frac{1}{2}a_1(t_2 - t_1)^2 = (24 \text{ m/s})(8 \text{ s} - 6 \text{ s}) + 0 \text{ m} = 48 \text{ m}$$

Third, the car decelerates:

$$v_3 = v_2 + a_2(t_3 - t_2) \Rightarrow 0 \text{ m/s} = 24 \text{ m/s} + (-3.0 \text{ m/s}^2)(t_3 - t_2) \Rightarrow (t_3 - t_2) = 8 \text{ s}$$

$$x_3 = x_2 + v_2(t_3 - t_2) + \frac{1}{2}a_2(t_3 - t_2)^2 \Rightarrow x_3 - x_2 = (24 \text{ m/s})(8 \text{ s}) + \frac{1}{2}(-3.0 \text{ m/s}^2)(8 \text{ s})^2 = 96 \text{ m}$$

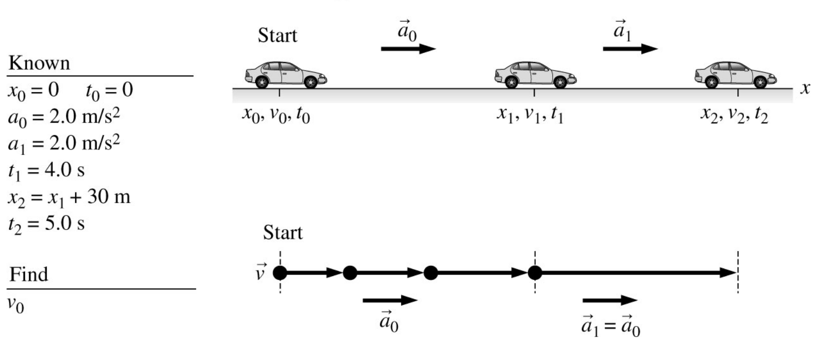
Thus, the total distance between stop signs is:

$$x_3 - x_0 = (x_3 - x_2) + (x_2 - x_1) + (x_1 - x_0) = 96 \text{ m} + 48\text{m} + 72 \text{ m} = 216 \text{ m}$$

Assess: A distance of approximately 600 ft in a time of around 10 s with an acceleration/deceleration of the order of 7 mph/s is reasonable.

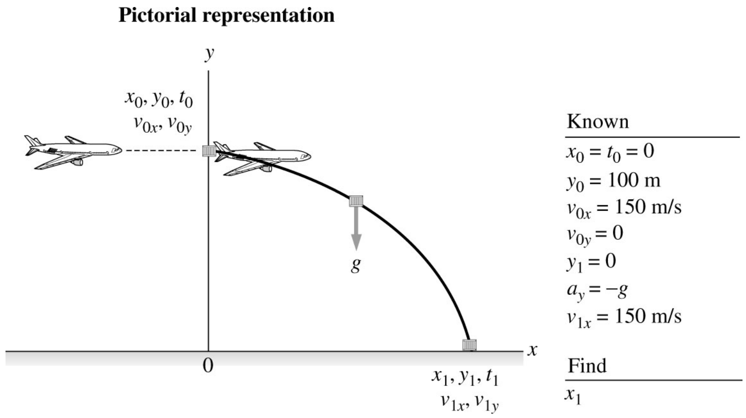
2.54. Model: The car is a particle moving under constant linear acceleration.
Visualize:

Pictorial representation



Solve: Using the kinematic equation for position:

4.14. Model: We will use the particle model for the food package and the constant-acceleration kinematic equations of motion.
Visualize:



Solve: For the horizontal motion,

$$x_1 = x_0 + v_{0x}(t_1 - t_0) + \tfrac{1}{2}a_x(t_1 - t_0)^2 = 0 \text{ m} + (150 \text{ m/s})(t_1 - 0 \text{ s}) + 0 \text{ m} = (150 \text{ m/s})t_1$$

We will determine t_1 from the vertical y-motion as follows:

$$y_1 = y_0 + v_{0y}(t_1 - t_0) + \tfrac{1}{2}a_y(t_1 - t_0)^2$$

$$\Rightarrow 0 \text{ m} = 100 \text{ m} + 0 \text{ m} + \tfrac{1}{2}(-9.8 \text{ m/s}^2)t_1^2 \Rightarrow t_1 = \sqrt{\frac{200 \text{ m}}{9.8 \text{ m/s}^2}} = 4.518 \text{ s} \approx 4.5 \text{ s}$$

From the above x-equation, the displacement is $x_1 = (150 \text{ m/s})(4.518 \text{ s}) = 678 \text{ m} \approx 680 \text{ m}$.

Assess: The horizontal distance of 678 m covered by a freely falling object from a height of 100 m and with an initial horizontal velocity of 150 m/s (≈ 335 mph) is reasonable.

Section 4.4 Relative Motion

4.15. Model: Assume motion along the x-direction (downstream to the right). Call the speed of the boat with respect to the water $(v_x)_{\text{BW}}$, the speed of the water with respect to the Earth $(v_x)_{\text{WE}}$, and the speed of the boat with respect to the Earth $(v_x)_{\text{BE}}$.
Solve: We seek $(v_x)_{\text{WE}}$.

Downstream: $$(v_x)_{\text{BE}} = (v_x)_{\text{BW}} + (v_x)_{\text{WE}} = \frac{30 \text{ km}}{3.0 \text{ h}} = 10 \text{ km/h}$$

Upstream: $$(v_x)_{\text{BE}} = -(v_x)_{\text{BW}} + (v_x)_{\text{WE}} = \frac{30 \text{ km}}{5.0 \text{ h}} = -6.0 \text{ km/h}$$

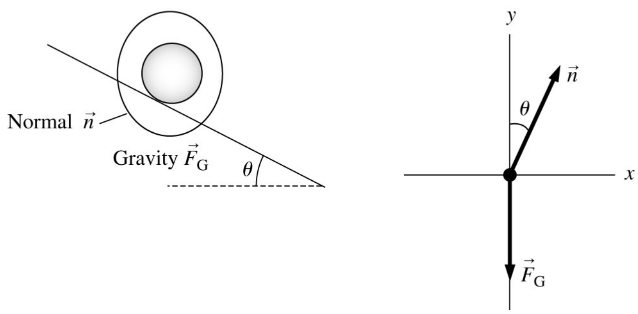
Add the two equations to get $2(v_x)_{\text{WE}} = 4.0$ km/h, so the river flows at 2.0 m/s.

Assess: This means that the boat goes at 8.0 m/s relative to the water. Both these numbers sound reasonable.

4.16. Model: Assume motion along the x-direction. Let $\Delta x = x_1 - x_0$ be the distance between the gate and the baggage claim. Call your walking speed $(v_x)_{\text{YS}}$, the speed of the moving sidewalk with respect to the floor $(v_x)_{\text{SF}}$, and the speed of you with respect to the floor $(v_x)_{\text{YF}}$ while walking and riding.
Solve: We seek Δt, the time it takes to go Δx while walking on the moving sidewalk.

Walking alone: $$(v_x)_{\text{YS}} = \frac{\Delta x}{50 \text{ s}}$$

Pictorial representation



Solve: Newton's second law is

$$\sum F_x = n\sin\theta = ma_x \qquad \sum F_y = n\cos\theta - F_G = ma_y = 0 \text{ N}$$

Combining the two equations, we get

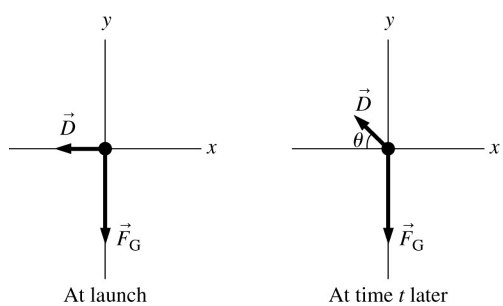
$$ma_x = \frac{F_G}{\cos\theta}\sin\theta = mg\tan\theta \Rightarrow a_x = g\tan\theta$$

The curve is described by $y = x^2$. Its slope a position x is $\tan\theta$, which is also the derivative of the curve. Hence,

$$\frac{dy}{dx} = \tan\theta = 2x \Rightarrow a_x = (2x)g$$

(b) The acceleration at $x = 0.20$ m is $a_x = (2)(0.20)(9.8 \text{ m/s}^2) = 3.9 \text{ m/s}^2$.

6.75. Visualize:



Solve: (a) The horizontal velocity as a function of time is determined by the horizontal net force. Newton's second law as the x-direction gives

$$(F_{\text{net}})_x = ma_x = -D\cos\theta = -bv\cos\theta = -bv_x$$

Note that $\vec{D}$ points opposite to $\vec{v}$, so the angle θ with the x-axis is the same for both vectors, and the x components of both vectors have the same $\cos\theta$ term. As the particle changes direction as it falls, the evolution of the horizontal motion depends only on the horizontal component of the velocity.
Thus

$$m\frac{dv_x}{dt} = -bv_x$$

14.31. Solve: The position and the velocity of a particle in simple harmonic motion are

$$x(t) = A\cos(\omega t + \phi_0) \text{ and } v_x(t) = -A\omega\sin(\omega t + \phi_0) = -v_{\text{max}}\sin(\omega t + \phi_0)$$

(a) At $t = 0$ s, the equation for x yields

$$(-5.0 \text{ cm}) = (10.0 \text{ cm})\cos(\phi_0) \Rightarrow \phi_0 = \cos^{-1}(-0.5) = \pm\tfrac{2}{3}\pi \text{ rad}$$

Because the particle is moving to the left at $t = 0$ s, it is in the upper half of the circular motion diagram, and the phase constant is between 0 and π radians. Thus, $\phi_0 = \frac{2}{3}\pi$ rad.

(b) The period is 4.0 s. At $t = 0$ s,

$$v_{0x} = -A\omega\sin\phi_0 = -(10.0 \text{ cm})\left(\frac{2\pi}{T}\right)\sin\left(\frac{2\pi}{3}\right) = -13.6 \text{ cm/s}$$

(c) The maximum speed is

$$v_{\text{max}} = \omega A = \left(\frac{2\pi}{4.0 \text{ s}}\right)(10.0 \text{ cm}) = 15.7 \text{ cm/s}$$

Assess: The negative velocity at $t = 0$ s is consistent with the position-vs-time graph and the positive sign of the phase constant.

14.32. Model: The vertical mass/spring systems are in simple harmonic motion.
Solve: Spring/mass A undergoes three oscillations in 12 s, giving it a period $T_A = 4.0$ s. Spring/mass B undergoes 2 oscillations in 12 s, giving it a period $T_B = 6.0$ s. We have

$$T_A = 2\pi\sqrt{\frac{m_A}{k_A}} \text{ and } T_B = 2\pi\sqrt{\frac{m_B}{k_B}} \Rightarrow \frac{T_A}{T_B} = \sqrt{\left(\frac{m_A}{m_B}\right)\left(\frac{k_B}{k_A}\right)} = \frac{4.0 \text{ s}}{6.0 \text{ s}} = \frac{2}{3}$$

If $m_A = m_B$, then

$$\frac{k_B}{k_A} = \frac{4}{9} \Rightarrow \frac{k_A}{k_B} = \frac{9}{4} = 2.25$$

14.33. Solve: The object's position as a function of time is $x(t) = A\cos(\omega t + \phi_0)$. Letting $x = 0$ m at $t = 0$ s, gives

$$0 = A\cos\phi_0 \Rightarrow \phi_0 = \pm\tfrac{1}{2}\pi$$

Since the object is traveling to the right, it is in the lower half of the circular motion diagram, giving a phase constant between $-\pi$ and 0 radians. Thus, $\phi_0 = -\frac{1}{2}\pi$ and

$$x(t) = A\cos(\omega t - \tfrac{1}{2}\pi) \Rightarrow x(t) = A\sin\omega t = (0.10 \text{ m})\sin(\tfrac{1}{2}\pi t)$$

where we have used $A = 0.10$ m and

$$\omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{4.0 \text{ s}} = \frac{\pi}{2} \text{ rad/s}$$

Let us now find t where $x = 0.060$ m:

$$0.060 \text{ m} = (0.10 \text{ m})\sin\left(\frac{\pi}{2}t\right) \Rightarrow t = \frac{2}{\pi}\sin^{-1}\left(\frac{0.060 \text{ m}}{0.10 \text{ m}}\right) = 0.41 \text{ s}$$

Assess: The answer is reasonable because it is approximately $\frac{1}{8}$ of the period.

14.34. Model: The block attached to the spring is in simple harmonic motion.
Visualize: The position and the velocity of the block are given by the equations

$$x(t) = A\cos(\omega t + \phi_0) \text{ and } v_x(t) = -A\omega\sin(\omega t + \phi_0)$$

Solve: (a) To graph $x(t)$ we need to determine ω, ϕ_0, and A. These quantities will be found by using the initial $(t = 0 \text{ s})$ conditions on $x(t)$ and $v_x(t)$. The period is

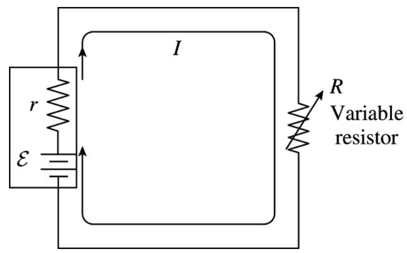
$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{1.0 \text{ kg}}{20 \text{ N/m}}} = 1.405 \text{ s} \approx 1.4 \text{ s} \quad \Rightarrow \quad \omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{1.405 \text{ s}} = 4.472 \text{ rad/s}$$

Note that the *IR* terms are all negative because we're applying the loop law in the direction of current flow, and the potential *decreases* as current flows through a resistor. We can solve to find the unknown resistance *R*:

$$6\text{ V} - I(18\ \Omega) - IR = 0 \quad \Rightarrow \quad R = \frac{6\text{ V} - (18\ \Omega)I}{I} = \frac{6\text{ V} - (18\ \Omega)(0.25\text{ A})}{0.25\text{ A}} = 6\ \Omega$$

The power is $P = I^2R = (0.25\text{ A})^2(6\ \Omega) = 0.4\text{ W}$.

31.43. Model: Assume that the connecting wires are ideal but the battery is not ideal.
Visualize:



Solve: The figure shows a variable resistor *R* connected across the terminals of a battery that has an emf ε and an internal resistance *r*. Using Kirchhoff's loop law and starting from the lower-left corner gives

$$+\varepsilon - Ir - IR = 0 \quad \Rightarrow \quad \varepsilon = I(r + R)$$

From the point in Figure P31.43 that corresponds to $R = 0\ \Omega$, we have

$$\varepsilon = (6\text{ A})(r + 0\ \Omega) = (6\text{ A})r$$

From the point that corresponds to $R = 10\ \Omega$, we have

$$\varepsilon = (3\text{ A})(r + 10\ \Omega)$$

Combining the two equations gives

$$(6\text{ A})r = (3\text{ A})(r + 10\ \Omega) \quad \Rightarrow \quad 2r = r + 10\ \Omega \quad \Rightarrow \quad r = 10\ \Omega$$

Also, $\varepsilon = (3\text{ A})(10\ \Omega + 10\ \Omega) = 60\text{ V}$.

Assess: With $\varepsilon = 60\text{ V}$ and $r = 10\ \Omega$, the equation $\varepsilon = I(r + R)$ is satisfied by all values of *R* and *I* on the graph in Figure P31.43.

31.44. Model: The connecting wires are ideal, but the battery is not.
Visualize: Please refer to Fig. P31.44. We will designate the current in the $5\ \Omega$ resistor I_5 and the voltage drop ΔV_5. Similar designations will be used for the other resistors.
Solve: Since the $10\ \Omega$ resistor is dissipating 40 W,

$$P_{10} = I_{10}^2 R_{10} = 40\text{ W} \quad \Rightarrow \quad I_{10} = \sqrt{\frac{P_{10}}{R_{10}}} = \sqrt{\frac{40\text{ W}}{10\ \Omega}} = 2.0\text{ A}$$

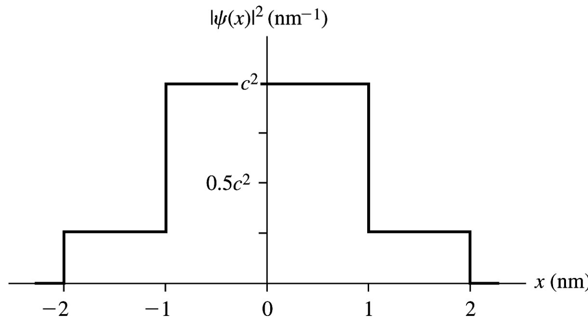
Because the $5\ \Omega$ resistor is in series with the $10\ \Omega$ resistor, the same current must run through the $5\ \Omega$ resistor. Therefore, the power dissipated by the $5\ \Omega$ resistor is

$$P_5 = I^2 R_5 = (2.0\text{ A})^2(5\ \Omega) = 20\text{ W}$$

The potential drop across the two left-hand resistors is the same as that across the right-hand resistor, so the power dissipated by the $20\ \Omega$ resistor is

$$P_{20} = \frac{V_{20}^2}{R_{20}} = \frac{(V_5 + V_{10})^2}{R_{20}} = \frac{(I_{10}R_5 + I_{10}R_{10})^2}{R_{20}} = \frac{(2.0\text{ A})^2(5\ \Omega + 10\ \Omega)^2}{20} = 45\text{ W}$$

31.45. Model: Assume that the connecting wires are ideal, but the battery is not. The battery has internal resistance. Also assume that the ammeter does not have any resistance.
Visualize: Please refer to Figure P31.45.



The area of the $|\psi(x)|^2$ versus x graph is

$$\int_{-2.0\text{nm}}^{-1.0\text{ nm}} |\psi(x)|^2\,dx + \int_{-1.0\text{ nm}}^{1.0\text{ nm}} |\psi(x)|^2\,dx + \int_{1.0\text{ nm}}^{2.0\text{ nm}} |\psi(x)|^2\,dx = (0.25c^2)(1.0\text{ nm}) + (c^2)(2.0\text{ nm}) + (0.25c^2)(1.0\text{ nm}) = 2.5c^2$$

$$2.5c^2\text{ nm} = 1.0$$

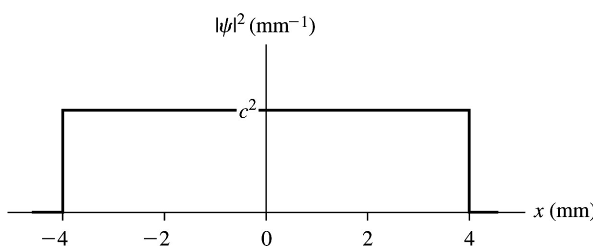
$$c = \frac{1.0}{\sqrt{2.5}}\text{ nm}^{-1/2} = 0.632\text{ nm}^{-1/2} \approx 0.63\text{ nm}^{-1/2}$$

(b) The graph is shown in part (a).
(c) The probability is

$$\text{Prob}(-1.0\text{ nm } \le x \le 1.0\text{ nm}) = \int_{-1.0\text{ nm}}^{1.0\text{ nm}} |\psi(x)|^2\,dx = (c^2)(2.0\text{ nm}) = \left(\frac{1.0}{2.5}\text{ nm}^{-1}\right)(2.0\text{ nm}) = 0.80$$

39.17. Model: The probability of finding the particle is determined by the probability density $P(x) = |\psi(x)|^2$.

Solve: (a) According to the normalization condition, $\int_{-\infty}^{\infty} |\psi(x)|^2\,dx = 1$. From the given $\psi(x)$-versus-x graph, we first generate a $|\psi(x)|^2$-versus-x graph and then find the area under the curve.



The area under the $|\psi(x)|^2$-versus-x graph is

$$\int_{-4.0\text{ mm}}^{4.0\text{ mm}} c^2 dx = (8.0\text{ mm})c^2 = 1.0 \quad\Rightarrow\quad c = \sqrt{\frac{1.0}{8.0\text{ mm}}} = 0.35\text{ mm}^{-1/2}$$

(b) The graph is shown above.
(c) The probability is

$$\text{Prob}(1.0\text{ mm } \le x \le 1.0\text{ mm}) = \int_{-1.0\text{ mm}}^{1.0\text{ mm}} c^2 dx = c^2(2.0\text{ mm}) = \left(\frac{1.0}{8.0}\text{mm}^{-1}\right)(2.0\text{ mm}) = 0.25$$