Chapters 5-7 Practice Problems

Solutions appear at the end of each chapter.

Chapter 5

1. A ball is being swung in a horizontal circular path at the end of a string, making four revolutions per second. By what factor will the tension in the string be increased if the ball instead were to make six revolutions per second?

2. The breaking strength of a rope is 20,000 N. At the end of 2.0 meters of this rope a 4.0-kg object is swinging in a horizontal circular path. (a) What is the maximum speed the object can have without the rope breaking? (b) How many revolutions per minute (RPM) is this?

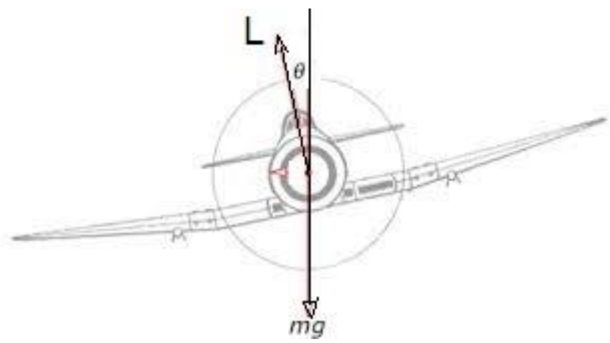
3. A 3.0-kg object is swung at the end of a 1.3-meter string in a vertical circle, making 0.30 revolutions per second. What is the tension in the string when the object is at the bottom of its swing?

4. Suppose in a hypothetical universe the gravitational force law were
$F = GMm/r$, instead of $F = GMm/r^2$. Which of the following statements about circular solar orbits would be true, if any?

(a) The force on all planets would be the same.
(b) The orbital period of all planets would be the same.
(c) The orbital speed of all planets would be the same.
(d) The orbital speed would depend on the planet's mass.
(e) None of these

5. The airplane in the figure below is traveling in a horizontal circular path of radius r. The center of the circle (not shown) is to the left of the airplane. The aerodynamic "lifting" force L makes an angle of θ degrees with respect to the vertical direction.

Calculate the radius (in meters) of the circular path, given that $v = 100$ m/s and $\theta = 12$ degrees. Hint: the vertical acceleration of the airplane is zero.

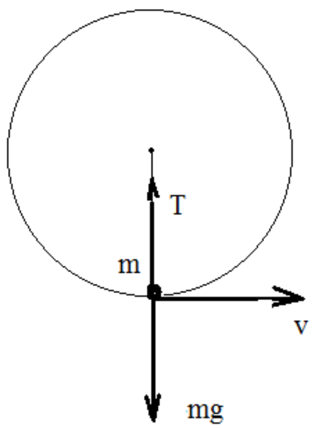


6. The orbital period of a planet around the sun is the time it takes it to complete one orbit. Derive an expression for the period in terms of G, M, and r.

7. If one planet's orbital radius is is 20 times another planet's, how many times longer is the second planet's orbital period?

Chapter 5 Problem Solutions

1. $F_r = ma_r$ $T_1 = mv_1{}^2/r$ $T_2 = mv_1{}^2/r$ $T_2/T_1 = (v_2{}^2/v_1)^2$ $= (v_2/v_1)^2$ If the number of revolutions made per second is made to be six instead of four, then the new speed will be 6/4 = 2.25 times as great: $T_2T_1 = (2.25)^2$ $= 5.06$ The new tension will be a factor of 5.06 times the old one.	2. m = 4.0 kg r = 2.0 m $F_r = ma_r$ $T = mv^2/r$ $20{,}000 = 4.0\ v^2/2.0$ (a) v = 100 m/s (b) In one minute the ball travels 100 (60) = 6000 meters. Circumference = 2π (2.0) = 12.57 m 6000 / 12.57 = 477 revolutions The number of revolutions (RPM) made per minute is sometimes called the "angular speed." "Angular speed "= 477 RPM

3. m = 3.0 kg r = 1.3 m Circumference = 2π (1.3) = 8.17 m 0.3 revolutions per second: v = 0.3 (8.17) = 2.45 m/s  $F_r = ma_r$ $T - mg = mv^2/r$ $T - (3)(9.8) = (3)\ (2.45)^2/1.3$ $T = 43.25$ N Note: In this problem, the positive radial direction is upward because "upward" is the direction toward the center of the circle.	

4.

$F_r = ma_r$

$GMm/r = mv^2/r$

$v = (GM)^{1/2}$

G and M are constants, so v = constant.

Answer: (c)

5.

Sum of the y-forces is zero:

$L\cos\theta - mg = 0$

$L = mg/\cos\theta$ (Equation 1)

$F_r = ma_r$

$L\sin\theta = mv^2/r$

Substitute $mg/\cos\theta$ for L:

$(mg/\cos\theta)\sin\theta = mv^2/r$

$\tan\theta = v^2/gr$

$r = v^2/g\tan\theta$

$= 100^2/9.8/\tan 12$

$= 4801$ m

6.

$GMm/r^2 = mv^2/r$

$v = (GM/r)^{1/2}$

Time = Distance/Speed

= Circumference/Speed

$T = 2\pi r/v$

$= 2\pi r / (GM/r)^{1/2}$

$= [2\pi / (GM)^{1/2}]\, r\, r^{/1/2}$

$=$ Constant x $r^{3/2}$

The orbital period is proportional to the three-halves power of the orbital radius.

7.
From Problem 7:

$T_o = [2\pi (GM)^{1/2}]\ r_o^{3/2}$ Equation 1
$T = [2\pi (GM)^{1/2}]\ (20\ r_o)^{3/2}$ Equation 2

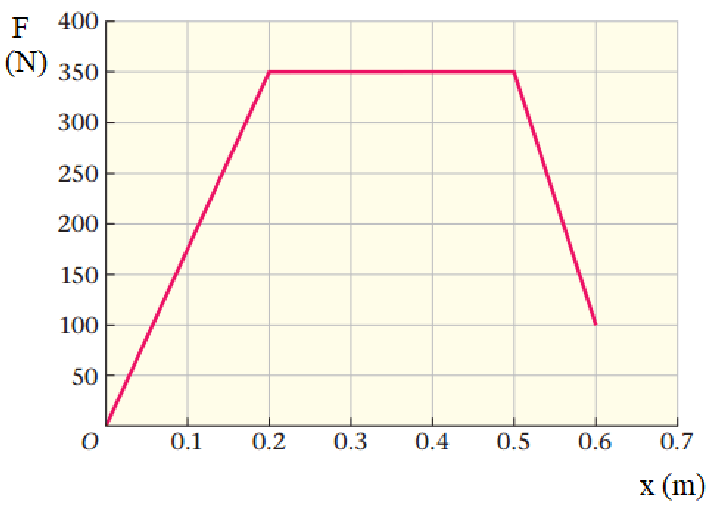
Divide Equation 2 by Equation 1:

$T/T_o = (20\ r_o)^{3/2} / r_o^{3/2}$
$= 20^{3/2}$
$= 89.44$

$T = 89.44\ T_o$

Chapter 6

1. An object of mass m = 5.0 kg at x = 0 is moving at 20.0 m/s to the right along the x-axis. The force on the object varies with position according to the graph below. What is the object's speed (in m/s) when it is at x = 0.6 m? Recall: the work done by a force equals the area under the force vs. distance curve.



2. A 3.0 kg block sliding horizontally on frictionless surface at 12 m/s encounters a rough surface. The coefficient of kinetic friction for the block on the rough surface is 0.23. About how far (in meters) over the rough surface will the block travel by the time its speed has been reduced to 6.0 m/s? (Use the work-kinetic energy theorem.)

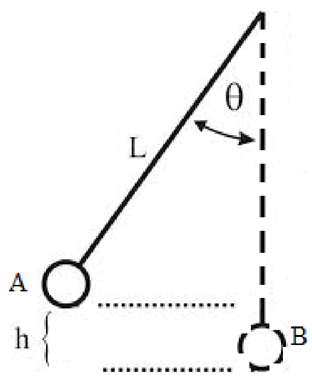
3. What horsepower is required of a machine that can accelerate upward a 30-kg object resting on the ground and give it a speed of 3.0 m/s by the time it reaches the top of a 20-meter building?

4. A 4.0-kg object's speed changes from 3.0 m/s to 7.0 m/s in 8.0 seconds. What was the power (in watts) delivered to the object?

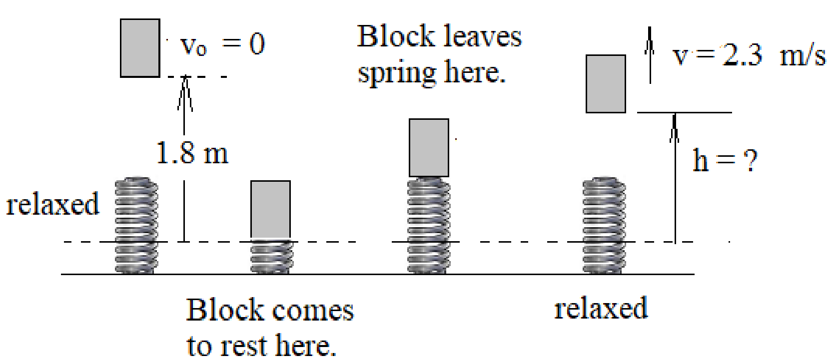
5. A force F = 900 N is pushing on an object that is moving at a certain moment at 3.0 m/s. What is the instantaneous power output of the force, in watts?

6. A ball attached to a string of length L = 1.6 m tied to the ceiling is pulled to the side and released. When the ball is at Point A in the figure below the string makes an angle $\theta = 20^{o}$ with respect to the vertical direction; the ball's speed at Point A is 0.24 m/s.

Use conservation of energy to find the ball's speed (in m/s) when it reaches the bottom of the swing, at Point B. Hint: Let the elevation at Point B be the zero elevation, then find an expression for the height h (in terms of L and θ) of the ball when it is at Point A.

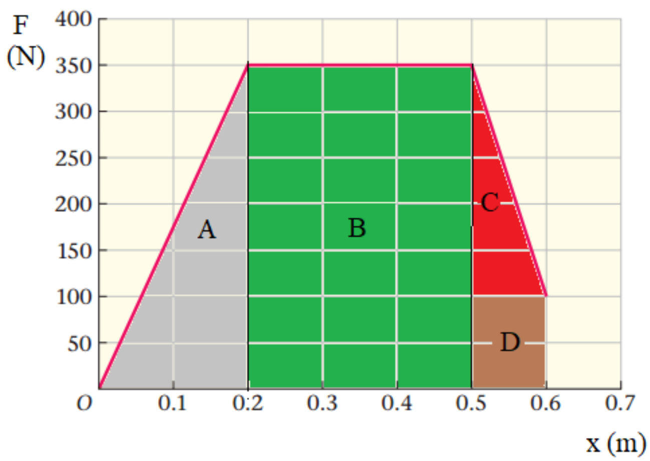


7. A spring whose spring constant is 600 N/m is attached to a tabletop and is positioned vertically. A 4.0 kg object is dropped toward the spring. The object slows down as it compresses the spring, comes to a momentary rest at its lowest point 1.8 m below the point from which it was dropped, and then is pushed upward by the spring. How high above that lowest point will the object be when its upward speed is 2.3 m/s?



Chapter 6 Problem Solutions

1.



A: 0.5 (0.2)(350) = 35.0 J
B: 0.3 (350) = 105.0 J
C: 0.5 (0.1)(250) = 12.5 J
D: 0.1 (100) = 10.0 J
Total = **162.5 J**

$\frac{1}{2}(5.0)v^2 - \frac{1}{2}(5.0)(20)^2 = 162.5$
$v = 21.56$ m/s

2.
$C = mg$
$= 3.0 (9.8)$
$= 29.4$ N

$f = \mu C$
$= 0.23 (29.4)$
$= 6.76$ N

$W = 6.76 x \cos 180$
$= - 6.76 x$

$W = \Delta K$
$-6.76 x = \frac{1}{2}(3.0)(6)^2 - \frac{1}{2}(3.0)(12)^2$
$x = 24$ m

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Let W = Work by Machine
Work by Earth = 30 (9.8) (20) cos 180
= -5880 J

W_{tot} = W -5880

W - 5880 = ΔK
= ½ (30)$(3.0)^2$ - 0
= 135 J

W - 5880 = 135
W = 6015 J

Average speed = ½ (0 + 3.0)
= 1.5 m/s
Time Up = 20.0/1.5
= 13.33 s

P = 6015 /13.33
= 451 watts
= 451/746
= 0.60 hp</td>
<td>4. W = K - K_o
= ½ (4.0)7.0^2 - ½ (4.0)3.0^2
= 80 J

P = W/t
= (80 J)/(8 s)
= 10 J/s
= 10 watts</td>
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<td>5.

P = Fv
= 900 (3)
= 2700 watts</td>
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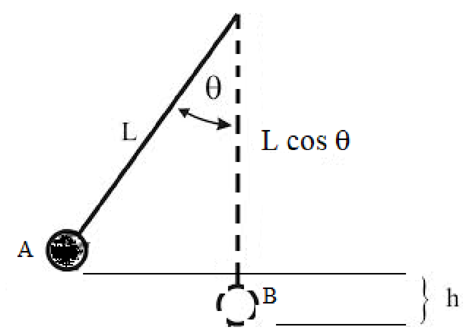
6.



$h = L - L \cos \theta$
$\quad = L (1 - \cos \theta)$

Bottom of Ball at Point B is reference elevation.

$E = ½ mv^2 + mg (0)$
$\quad = ½ mv^2$

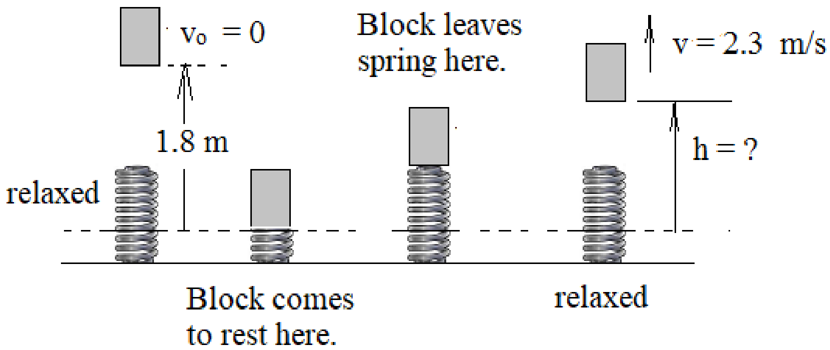
$E_o = ½ m (0.24)^2 + mgh$
$\quad = ½ m (0.24)^2 + mg L(1 - \cos \theta)$

$E = E_o$
$½ mv = ½ m (0.24)^2 + mg L(1 - \cos \theta)$

Divide by m:

$½ v^2 = ½ (0.24)^2 + 9.8 (1.6)(1 - \cos 20)$
$v = 1.4$ m/s

7.



The reference elevation is at the top of the compressed spring.

$$E = E_o$$

$$K + U^{grav} + U^{spring} = K_o + U_o^{grav} + U_o^{spring}$$

$$\tfrac{1}{2} m(2.3)^2 + mgh = 0 + mg(1.8) + 0$$

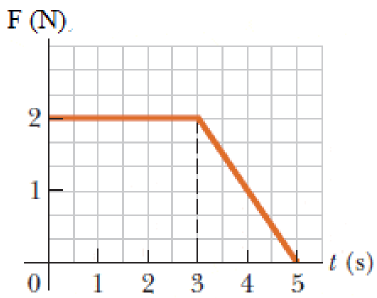
Divide by m:

$$\tfrac{1}{2} (2.3)^2 + 9.8\,h = 9.8\,(1.8)$$

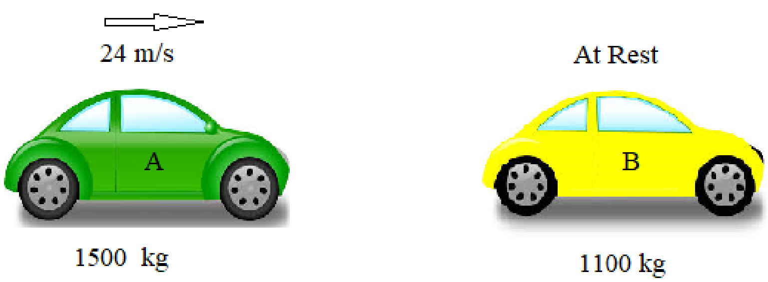
$$h = 1.53 \text{ m}$$

Chapter 7 Problems

1. The graph below shows the net force versus time acting on an object of mass m = 6 kg. At the time t = 2 s, the speed of the object is 3 m/s. What is the velocity of the object at time t = 4s?



2. Car A in the figure below is moving to the right at 24 m/s, toward Car B at rest. After collision, Car B is moving to the right at 7.0 m/s. What is the velocity of Car A? The collision is not elastic.



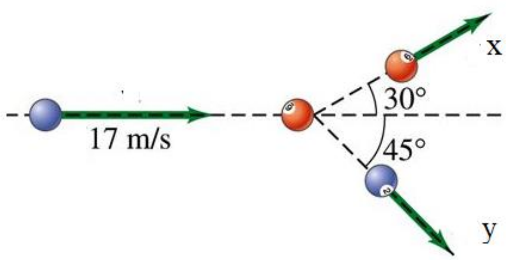
3. A 3.0 kg object moving to the left with momentum -70 kg-m/s is struck a blow directed to the left that imparts an impulse of -110 N-s. What is the velocity (in m/s) of the object at the end of the impulse?

4. The 4.0-kg block on the left in the figure below is about to collide elastically with the 6-kg block. What will be the velocities of the two blocks after collision?

5. A rifle having a mass of 4.0 kg is at rest on the frictionless shoulder of a person who fires horizontally a 0.020 kg bullet at 200 m/s. What will be the recoil velocity of the rifle?

6. A 0.20 kg block is at rest on a frictionless tabletop. A 0.020 kg bullet moving at 200 m/s is fired into one side of the block and exits out the opposite side with speed 170 m/s. What speed does the block acquire?

7. An object moving at 17 m/s collides with an object of equal mass at rest as shown in the figure. The collision is not elastic. Solve for the velocities x and y after collision.



Chapter 7 Problem Solutions

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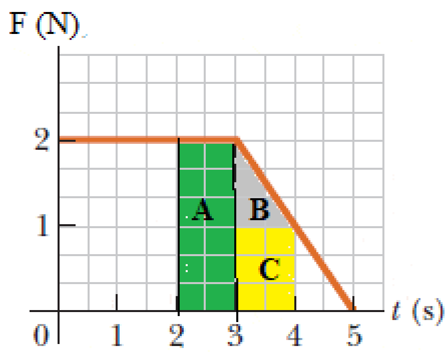

A: (1)(2)   = 2.0 N-s
B: (0.5)(1)(1)   = 0.5 N-s
C: (1)(1)   = 1.0 N-s
Total: = 3.5 N-s

(6)v - (6)(3) = 3.50
v = 3.58 m/s
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2.

$P = P_o$
1500 v + 1100 (7) = 1500 (24) + 1100 (0)
v = 18.87 m/s
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3.

$p - p_o = I$
3v - (-70) = -110
v = -60 m/s
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4.

x = velocity of 4 kg
y = velocity of 6 kg

Conserve Momentum:
$4x + 6y = 4(2)$
$y = (8 - 4x)/6$ (Equation 1)

Conserve Kinetic Energy:
$\frac{1}{2} (4) x^2 + \frac{1}{2} (6) y^2 = \frac{1}{2} (4)2^2$

Replace y by the expression in Equation 1:

$2x^2 + 3 [(8 - 4x)/6]^2 = 8$

x = -0.40 m/s
y = 1.60 m/s

The other solution pair:

x = 2.00 m/s
y = 6.00 m/s

The second set of solutions must be rejected as meaningless because both objects have the same velocities after collision.

5.	6.
Rifle and bullet are initially at rest: $P_o = 0$ After bullet is fired: $P = 4v + 0.02\ (200)$ $P = P_o$ $4v + 0.02\ (200) = 0$ $v = -1.0$ m/s	P_o = Bullet's Momentum $= 0.02\ (200)$ $= 4.0$ kg-m/s P = Block's Momentum + Bullet's Momentum $= 0.20\ v + 0.02\ (170)$ $P = P_o$ $0.20\ v + 0.02\ (170) = 4.0$ $v = 3.00$ m/s

7.
Conserve x-momentum: x cos 30 + y cos 45 = 17 (Equation 1) Conserve y-momentum: x sin 30 - y sin 45 = 0 (Equation 2) y = x sin 30 / sin 45 = 0.707 x Replace y in Equation 1 with 0.707 x: x cos 30 + (0.707 x) cos 45 = 17 **x = 12.44 m/s** y = 0.707 x = 0.707 (12.44) **y = 8.80 m/s**