Answers to selected problems from Essential Physics, Chapter 7

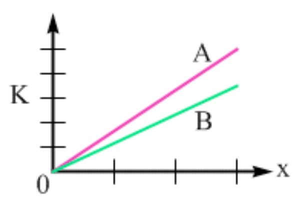
1. It is more tiring to walk uphill for an hour than it is to walk over level ground, because when you walk uphill you are doing work against gravity.

3. The kinetic energy comes from the gravitational potential energy of the snow or mud, stored in the position of the snow or mud high up at the top of the slope.

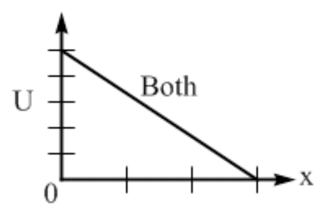
5. The speeds are equal in cases B and C, and smaller in case A. The final kinetic energy is equal to the initial kinetic energy (which is zero in case A and equal to the same non-zero value in cases B and C) plus the difference in gravitational potential energy between the initial and final positions.

7. (a) Mechanical energy is not conserved. The rock does work on the can, crushing it. The rock's mechanical energy gets transformed into other forms of energy, such as thermal energy and sound energy. (b) Energy is conserved in this process. This is consistent with the law of conservation of energy. If you account for all the different forms of energy before and after the crushing of the can, there is the same total amount of energy beforehand and afterwards.

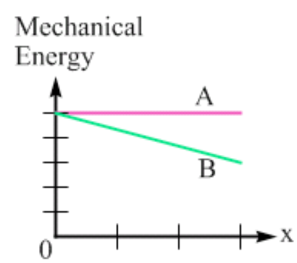
9. (a)



(b)



(c)

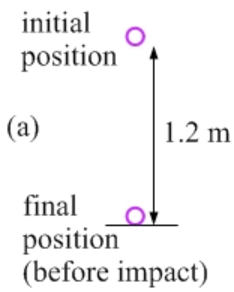


11. The energy is stored temporarily in the spring. The more the spring is compressed, the more energy is stored in it. So, as the block compresses the spring, the spring slows down, and the block's kinetic energy is transformed into potential energy in the spring. After the block comes momentarily to rest, the spring pushes on the block, transforming the potential energy back into the block's kinetic energy.

13. (a) 4.95 m/s (b) The ball reaches its maximum speed when it passes through its lowest point, immediately below the hook. (c) Because of energy conservation, the ball goes to 1.25 m higher than the equilibrium position. (d) The only numerical value we need is the vertical distance that the ball starts above equilibrium. The mass cancels out of the energy equation, and the string length is not needed.

15. (a) This is a reasonable assumption. A typical observation is that, in one swing, the ball reaches almost the same vertical position on one side that it started from on the other, meaning that only a small fraction of the ball's mechanical energy is removed in one swing. (b) After many swings, the ball comes to rest. All of the initial gravitational potential energy is converted to thermal energy because of the negative work done on the ball by the resistive forces. This work is negative because the resistive forces always oppose the ball's motion. (c) –2.45 J

17.



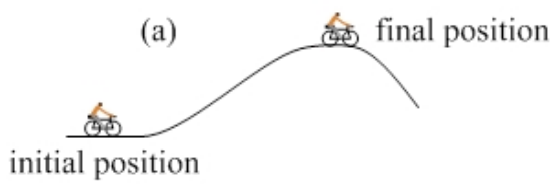
(b) $U_i + K_i + W_{nc} = U_f + K_f$, and define the zero level for gravitational energy to be at the level of the floor.

(c) $K_i = 0$, because the keys start at rest; $W_{nc} = 0$, because we assume that air resistance is negligible; $U_f = 0$, because the keys end up on the floor, which is where we defined the zero for gravitational potential energy to be.

Our equation thus becomes $U_i = K_f \quad \Rightarrow \quad mgh = \frac{1}{2}mv_f^2$

(d) $v_f = \sqrt{2gh} = 4.8$ m/s

19.



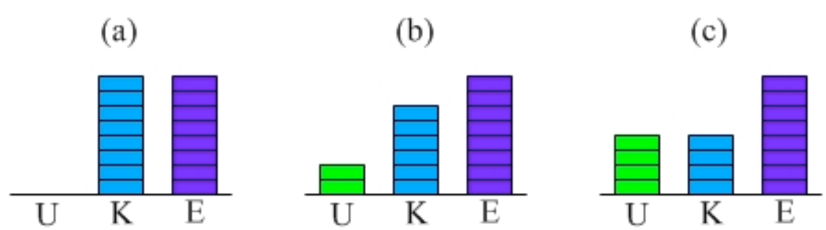
(b) $U_i + K_i + W_{nc} = U_f + K_f$, and define the zero level for gravitational energy to be at the starting point.

(c) $K_i = 0$, because you start from rest; $U_i = 0$, because you start from the zero level for gravitational potential energy. Let's also assume that the number given in the problem for the work represents the net work done by non-conservative forces.

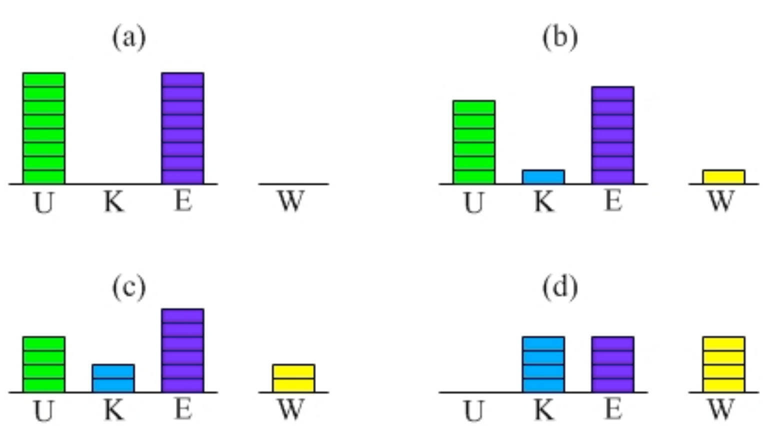
Our equation thus becomes $W_{nc} = U_f + K_f \quad \Rightarrow \quad 1.5\times10^4 \text{ J} = mgh + \frac{1}{2}mv_f^2$

(d) $h = \dfrac{1.5\times10^4 \text{ J} - \frac{1}{2}mv_f^2}{mg} = 22$ m

21.



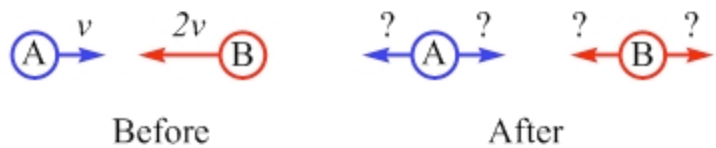
23.



25. (a)


(b) $m(50\text{ km/h}) + M(0) = (m+M)(10\text{ km/h})$, with the positive direction being the direction of the car's velocity before the collision (which is the same direction as the velocity of the car and the truck after the collision).

(c) $M = \dfrac{m(50\text{ km/h}) - m(10\text{ km/h})}{10\text{ km/h}} = 4m = 8000\text{ kg}$

27. (a)


(b) Let's define left as the positive direction, because the net momentum of the system is in that direction:

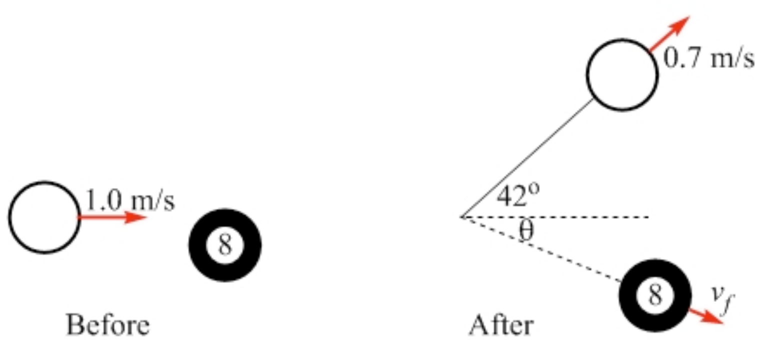
$-mv + 2mv = mv_{Af} + mv_{Bf}$

$v = v_{Af} + v_{Bf}$

(c) $v_{Bf} - v_{Af} = v_{Ai} - v_{Bi} = -3v$

(d) $2v_{Bf} = -2v \quad \Rightarrow \quad v_{Bf} = -v \qquad\qquad v_{Af} = +2v$

Puck B is moving to the right after the collision, and puck A is moving left after the collision.

29. (a)


(b)

	Cue ball (initial)	8-ball (initial)	Cue ball (final)	8-ball (final)
x-direction	$m \times 1.0$ m/s	0	$m \times (0.70\text{ m/s})\cos(42°)$ $= m \times 0.520$ m/s	$mv_f \cos\theta$
y-direction	0	0	$m \times (0.70\text{ m/s})\sin(42°)$ $= m \times 0.468$	$-mv_f \sin\theta$

(c) From the y-direction, $mv_f \sin\theta = m\times 0.468$ m/s $\Rightarrow$ $v_f \sin\theta = 0.468$ m/s

From the x-direction, $mv_f \cos\theta = m\times 0.480$ m/s $\Rightarrow$ $v_f \cos\theta = 0.480$ m/s

Dividing one equation by the other gives $\tan\theta = \dfrac{0.468}{0.480}$ $\Rightarrow$ $\theta = 44.3°$

Solving for v_f gives $v_f \cos\theta = 0.67$ m/s.

The velocity of the 8-ball after the collision is 0.67 m/s at an angle of 44° from the direction of the cue ball's velocity before the collision.

31. (a) $v_{2f} = \sqrt{2\mu_K g d} = 1.0$ m/s (b) h = 0.293 m; $v_{1i} = \sqrt{2gh} = 2.42$ m/s; $v_{1f} = v_{1i} - 2v_{2f} = 0.42$ m/s, in the same direction as the ball's velocity just before the collision.

33. (a) 4×10^{10} J (b) For such a large object going that fast, neglecting air resistance is probably not a good idea. If air resistance could be neglected, the plane's engines could be switched off after reaching cruising altitude and the plane would continue at constant velocity after that. So, the energy is a good deal larger than the value we calculated in (a).

35. (a) Because mechanical energy (the sum of the potential and kinetic energies) is conserved in this situation, the mechanical energy at the beginning, at the lowest point, and in the final situation are all the same, so we can relate the energy at the beginning to the energy at the end. (b) $v_f = \sqrt{2gh} = \sqrt{2\times(9.8\text{ m/s}^2)\times(1.0\text{ m})} = 4.4$ m/s

37. (a) There must be a kinetic force of friction acting on the box. If there was no friction force, the box's speed would increase as it went down the incline. The kinetic force of friction must exactly balance the component of the force of gravity that acts down the slope. (b) $\mu_K mg\cos\theta = mg\sin\theta$ $\Rightarrow$ $\mu_K = \tan\theta = 0.75$ (c) We don't need to know either the mass or the speed. The mass cancels out of the equation, and all we need to know about the velocity is that it is constant – the exact value does not matter.

39. (a) $v = \sqrt{2gh} = \sqrt{16\text{ m}^2/\text{s}^2} = 4.0$ m/s

(b) $$W_{nc} = \frac{1}{2}mv_f^2 - mgh = m\left(\frac{v_f^2}{2} - gh\right) = (0.050\text{ kg})\left(\frac{(3.0\text{ m/s})^2}{2} - (10\text{ m/s}^2)(0.8\text{ m})\right)$$

$W_{nc} = -0.175$ J

(c) The work done by air resistance is negative, which makes sense because the force of air resistance is opposite in direction to the ball's displacement.

41. The motion would be similar, it would just happen more slowly than it would on the Earth. On the Moon, the block would reach the same positions on either side that it did on the Earth, and it would stop in the same place that it did on the Earth, but the speed during the motion would be smaller on the Moon than it is on the Earth.

43. For the first block, $mgh = K_1$. For the second block, $mgh + W_{nc} = 0.8K_1$. Combining these gives $W_{nc} = -0.2mgh$. However, the work done by non-conservative forces is the work done by the kinetic friction force, which is $W_{nc} = -\mu_K F_N d$, where $F_N = mg\cos\theta$, and *d*, the distance moved along the slope, is related to *h* by $d = h/\sin\theta$. Bringing everything together gives:

$-\frac{\mu_K mgh\cos\theta}{\sin\theta} = -0.2mgh$ which gives $\tan\theta = 1.25$, which gives an angle of 51°.

45. $m_B = \frac{0.5m_A v_f^2 + m_A g(2.0\text{ m})\sin\theta + \mu_K m_A g\cos\theta(2.0\text{ m})}{g(2.0\text{ m}) - 0.5v_f^2} = \frac{36+24+20}{20-18} = 40\text{ kg}$

47. (a) Energy conservation: $mgh = \frac{1}{2}mv_b^2 + 2mgR$

Forces and circular motion: $2mg = \frac{mv_b^2}{R}$

Combining these gives $h = 3R$.

(b) Energy conservation: $mgh = 3mgR = \frac{1}{2}mv_a^2$

Forces and circular motion: $F_N - mg = \frac{mv_a^2}{R}$

Combining these gives $F_N = 7mg$

49. Energy conservation: $mgh = \frac{1}{2}mv_b^2 + 2mgR$

Forces and circular motion: $F_N = 0 \quad \Rightarrow \quad mg = \frac{mv_b^2}{R}$

Combining these gives $h = 2.5R$.

51. (a) 6 m/s to the right

(b) The collision is inelastic. One way to justify this is to work out the elasticity, which is 0.5 in this case. That is less than 1, implying an inelastic collision. A second way to justify this is to work out the kinetic energy before and after the collision. There is a lot less kinetic energy in the system after the collision ($m\times 80\text{ m}^2/\text{s}^2$) than before ($m\times 200\text{ m}^2/\text{s}^2$), so the collision is inelastic. It is not completely inelastic, because the two pucks do not stick together after the collision.

53. $0.5v$, directed left

55. (a) After the collision, the object of mass $3m$ is at rest, while the object of mass m is $-2v$ (b) $4h$

57. (a) Before the collision, the Jetta was traveling at 4/3 the speed of the Acura. The Jetta was traveling faster, in other words.

(b) Carrying out an energy analysis after the collision allows us to get a range of speeds for the cars immediately after the collision: $v = \sqrt{2\mu_K gd}$, so this speed is somewhere between 6.96 m/s and 7.41 m/s. Doing a momentum analysis, we can then find a range of speeds for the two cars after the collision. The range for the Acura is 8.61 m/s to 9.17 m/s, while the range for the Jetta is 11.5 m/s to 12.2 m/s. Converting these values to mph gives a range for the Acura of 19.3 mph to 20.5 mph and a range for the Jetta of 25.7 mph to 27.4 mph. Thus, the Jetta was clearly speeding, so that driver should get a speeding ticket. The Acura may or may not have been slightly speeding, so we can't really say that driver was entirely blameless. From these results, we can't say definitively that the driver of the Jetta was entirely to blame.

59. Yes, the result does match the result we got using the component method.

61. (a) (i) $v_i/5$ (ii) $4v_i/5$ (b) $4T$ and $16D$