CHAPTER 6

1. Because there is no acceleration, the contact force must have the same magnitude as the weight. The displacement in the direction of this force is the vertical displacement. Thus,

   $W = F\,\text{Æ}y = (mg)\,\text{Æ}y = (75.0\text{ kg})(9.80\text{ m/s}^2)(10.0\text{ m}) =$ $7.35 \times 10^3\text{ J}$.

2. (*a*) Because there is no acceleration, the horizontal applied force must have the same magnitude as the friction force. Thus,

   $W = F\,\text{Æ}x = (180\text{ N})(6.0\text{ m}) =$ $1.1 \times 10^3\text{ J}$.

   (*b*) Because there is no acceleration, the vertical applied force must have the same magnitude as the weight. Thus,

   $W = F\,\Delta y = mg\,\Delta y = (900\text{ N})(6.0\text{ m}) =$ $5.4 \times 10^3\text{ J}$.

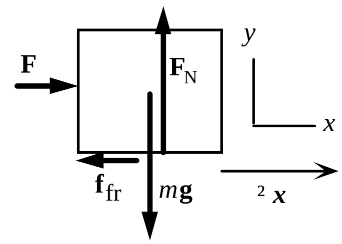
3. Because there is no acceleration, from the force diagram we see that

   $F_N = mg$, and $F = F_{fr} = \mu_k mg$.

   Thus,

   $W = F\,x \cos 0° = \mu_k mg\,x \cos 0°$

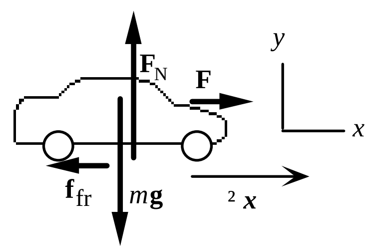
   $= (0.70)(150\text{ kg})(9.80\text{ m/s}^2)(12.3\text{ m})(1) =$ $1.3 \times 10^4\text{ J}$.



4. Because there is no acceleration, the net work is zero, that is, the (positive) work of the car and the (negative) work done by the average retarding force must add to zero. Thus,

   $W_{net} = W_{car} + F_{fr}\,\text{Æ}x \cos 180° = 0$, or

   $F_{fr} = -\,W_{car}/\text{Æ}x \cos 180° = -\,(7.0 \times 10^4\text{ J})/(2.8 \times 10^3\text{ m})(-1) =$ 25 N.



5. Because the speed is zero before the throw and when the rock reaches the highest point, the positive work of the throw and the (negative) work done by the (downward) weight must add to zero. Thus,

   $W_{net} = W_{throw} + mgh \cos 180° = 0$, or

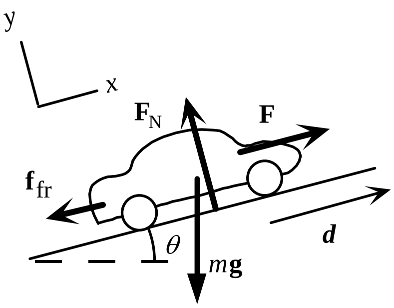
   $h = -\,W_{throw}/mg \cos 180° = -\,(115\text{ J})/(0.325\text{ kg})(9.80\text{ m/s}^2)(-1) =$ 36.1 m.

6. The maximum amount of work that the hammer can do is the work that was done by the weight as the hammer fell:

   $W_{max} = mgh \cos 0° = (2.0\text{ kg})(9.80\text{ m/s}^2)(0.40\text{ m})(1) =$ 7.8 J.

   People add their own force to the hammer as it falls in order that additional work is done before the hammer hits the nail, and thus more work can be done on the nail.

7. The minimum work is needed when there is no acceleration.



(*a*) From the force diagram, we write $\Sigma\mathbf{F} = m\mathbf{a}$:

y-component: $F_N - mg \cos\theta = 0$;

x-component: $F_{min} - mg \sin\theta = 0$.

For a distance d along the incline, we have

$W_{min} = F_{min} d \cos 0° = mgd \sin\theta(1)$

$= (1000\ \text{kg})(9.80\ \text{m/s}^2)(300\ \text{m}) \sin 17.5°$

$= \quad 8.8 \times 10^5$ J.

(*b*) When there is friction, we have

x-component: $F_{min} - mg \sin\theta - \mu_k F_N = 0$, or

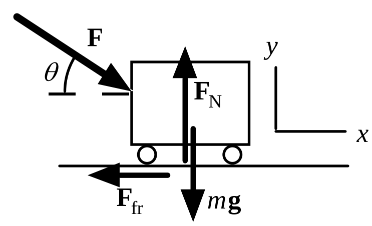
$F_{min} = mg \sin\theta + \mu_k mg \cos\theta = 0$,

For a distance d along the incline, we have

$W_{min} = F_{min} d \cos 0° = mgd (\sin\theta + \mu_k \cos\theta)(1)$

$= (1000\ \text{kg})(9.80\ \text{m/s}^2)(300\ \text{m})(\sin 17.5° + 0.25 \cos 17.5°) = \quad 1.6 \times 10^6$ J.

8. Because the motion is in the x-direction, we see that the weight and normal forces do no work:



$W_{FN} = W_{mg} = 0$.

From the force diagram, we write $\Sigma\mathbf{F} = m\mathbf{a}$:

x-component: $F \cos\theta - F_{fr} = 0$, or $F_{fr} = F \cos\theta$.

For the work by these two forces, we have

$W_F = F$ Æx $\cos\theta = (12\ \text{N})(15\ \text{m}) \cos 20° = 1.7 \times 10^2$ J.

$W_{fr} = F \cos\theta$ Æx $\cos 180° = (12\ \text{N}) \cos 20°\ (15\ \text{m})(-1) = -1.7 \times 10^2$ J.

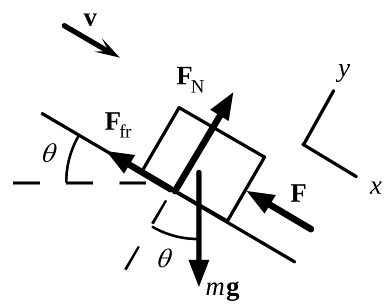
As expected, the total work is zero: $W_F = -W_{fr} = 1.7 \times 10^2$ J.

9. Because the net work must be zero, the work to stack the books will have the same magnitude as the work done by gravity. For each book the work is mg times the distance the center is raised (zero for the first book, one book-height for the second book, etc.).

$W_1 = 0, W_2 = mgh, W_3 = mg2h; \ldots$.

Thus for eight books, we have

$W = W_1 + W_2 + W_3 + \ldots + W_8 = mgh(0 + 1 + 2 + \ldots + 7) = (1.8\ \text{kg})(9.80\ \text{m/s}^2)(0.046\ \text{m})(28) = \quad 23$ J.



10. (*a*) From the force diagram, we write $\Sigma\mathbf{F} = m\mathbf{a}$:

y-component: $F_N - mg \cos \theta = 0$;

x-component: $- F - \mu_k F_N + mg \sin \theta = 0$.

Thus we have

$F = - \mu_k F_N + mg \sin \theta = - \mu_k mg \cos \theta + mg \sin \theta$

$= mg (\sin \theta - \mu_k \cos \theta)$

$= (280 \text{ kg})(9.80 \text{ m/s}^2)(\sin 30° - 0.40 \cos 30°) =$ 4.2×10^2 N.

(*b*) Because the piano is sliding down the incline, we have

$W_F = F\, d \cos 180° = (4.2 \times 10^2 \text{ J})(4.3 \text{ m})(- 1) =$ $- 1.8 \times 10^3$ J.

(*c*) For the friction force, we have

$W_{fr} = \mu_k mg \cos \theta\, d \cos 180°$

$= (0.40)(280 \text{ kg})(9.80 \text{ m/s}^2)(\cos 30°)(4.3 \text{ m})(- 1) =$ $- 4.1 \times 10^3$ J.

(*d*) For the force of gravity, we have

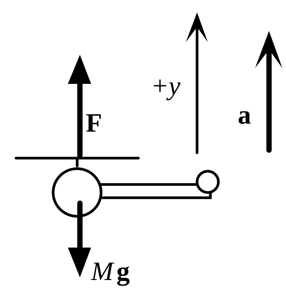
$W_{grav} = mg\, d \cos 60°$

$= (280 \text{ kg})(9.80 \text{ m/s}^2)(4.3 \text{ m})(\cos 60°) =$ 5.9×10^3 J.

(*e*) Because the normal force does no work, we have

$W_{net} = W_{grav} + W_F + W_{fr} + W_N$

$= 5.9 \times 10^3 \text{ J} - 1.8 \times 10^3 \text{ J} - 4.1 \times 10^3 \text{ J} + 0 =$ 0.



11. (*a*) To find the required force, we use the force diagram to write $\Sigma F_y = ma_y$:

$F - Mg = Ma$, so we have

$F = M(a + g) = M(0.10g + g) =$ $1.10Mg$.

(*b*) For the work, we have

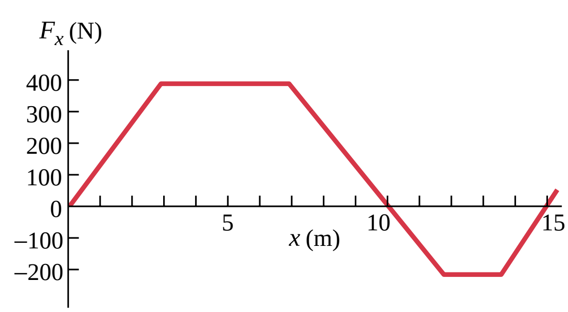
$W_F = Fh \cos 0° =$ $1.10Mgh$.

12. From the graph we obtain the forces at the two ends:

at $d_A = 10.0$ m, $(F \cos \theta)_A = 150$ N; at $d_B = 35.0$ m, $(F \cos \theta)_B = 250$ N.

The work done in moving the object is the area under the $F \cos \theta$ vs. x graph. If we assume the graph is a straight line, we have

$W \approx$![(F cos θ)$_A$ + (F cos θ)$_B$]($d_B - d_A$) = !(150 N + 250 N)(35.0 m – 10.0 m) = 5.0×10^3 J.



13. The work done in moving the object is the area under the $F \cos \theta$ vs. x graph.

(*a*) For the motion from 0.0 m to 10.0 m, we find the area of two triangles and one rectangle:

W = !(400 N)(3.0 m – 0.0 m) +

(400 N)(7.0 m – 3.0 m) +

!(400 N)(10.0 m – 7.0 m)

= 2.8×10^3 J.

(*b*) For the motion from 0.0 m to 15.0 m, we add the negative area of two triangles and one rectangle:

$W = 2.8 \times 10^3$ J – !(200 N)12.0 m – 10.0 m) – (200 N)(13.5 m – 12.0 m) –

!(200 N)(15.0 m – 13.5 m) = 2.1×10^3 J.

14. We obtain the forces at the beginning and end of the motion:

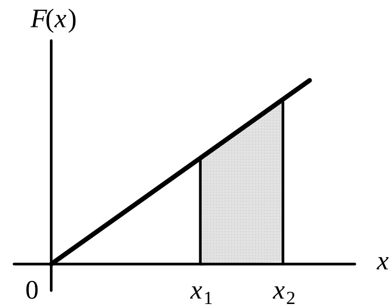
at x_1 = 0.038 m, $F_1 = kx_1$ = (88 N/m)(0.038 m) = 3.34 N;

at x_2 = 0.058 m, $F_2 = kx_2$ = (88 N/m)(0.058 m) = 5.10 N.

From the graph the work done in stretching the object is the area under the F vs. x graph:

W = ![$F_1 + F_2$]($x_2 - x_1$)

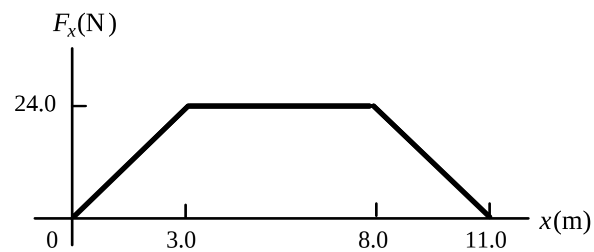
= !(3.34 N + 5.10 N)(0.058 m – 0.038 m) = 0.084 J.



15. The work done in moving the object is the area under the F_x vs. x graph. For the motion from 0.0 m to 11.0 m, we find the area of two triangles and one rectangle:

W = !(24.0 N)(3.0 m – 0.0 m) + (24.0 N)(8.0 m – 3.0 m) + !(24.0 N)(11.0 m – 8.0 m)

= 1.9×10^2 J.



16. We obtain the forces at the beginning and end of the motion:

at $r_E + h = 6.38 \times 10^6$ m + 2.5×10^6 m = 8.88×10^6 m,

$F_2 = GM_Em/r^2$

= (6.67×10^{-11} N·m²/kg²)(5.98×10^{24} kg)(1300 kg)/[(8.88×10^6 m)]^2 = 6.58×10^3 N.

at $r_E = 6.38 \times 10^6$ m,

$F_1 = GM_Em/r_E^2$

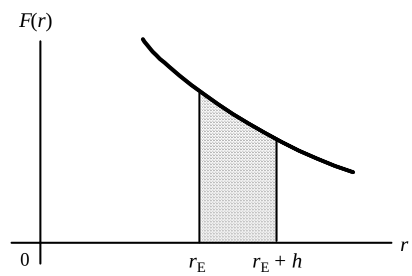
= (6.67×10^{-11} N·m²/kg²)(5.98×10^{24} kg)(1300 kg)/[(6.38×10^6 m)]^2 = 1.27×10^4 N.

From the graph the work done in stretching the object is the area under the F vs. r graph, which we approximate as a straight line:

W = ![$F_1 + F_2$]h

= !(6.58×10^3 N + 1.27×10^4 N)(2.5×10^6 m) = 2.4×10^{10} J.

This will be a slight overestimate.



17. We find the speed from

KE = !mv^2;

6.21×10^{-21} J = !(5.31×10^{-26} kg)v^2, which gives v = 484 m/s.

18. (*a*) KE_2 = !mv_2^2 = 2 KE_1 = 2(!mv_1^2), which gives $v_2 = v_1$Ã2, so the speed increases by a factor of Ã2.

(*b*) KE_2 = !mv_2^2 = !$m(2v_1)^2$ = 4(!mv_1^2) = 4 KE_1, so the kinetic energy increases by a factor of 4.

19. The work done on the electron decreases its kinetic energy:

W = ÆKE = !mv^2 – !mv_0^2 = 0 – !(9.11×10^{-31} kg)(1.90×10^6 m/s)^2 = -1.64×10^{-18} J.

20. The work done on the car decreases its kinetic energy:

W = ÆKE = !mv^2 – !mv_0^2 = 0 – !(1000 kg)[(110 km/h)/(3.6 ks/h)]^2 = – 4.67 × 10^5 J.

21. The percent increase in the kinetic energy is

% increase $= [(!mv_2^2 - !mv_1^2)/!mv_1^2](100\%) = (v_2^2 - v_1^2)(100\%)/v_1^2$

$= [(100\text{ km/h})^2 - (90\text{ km/h})^2](100\%)/(90\text{ km/h})^2 =$ 23%.

22. The work done on the arrow increases its kinetic energy:

$W = Fd = Æ\text{KE} = !mv^2 - !mv_0^2;$

$(95\text{ N})(0.80\text{ m}) = !(0.080\text{ kg})v^2 - 0$, which gives $v =$ 44 m/s.

23. The work done by the force of the glove decreases the kinetic energy of the ball:

$W = Fd = Æ\text{KE} = !mv^2 - !mv_0^2;$

$F(0.25\text{ m}) = 0 - !(0.140\text{ kg})(35\text{ m/s})^2$, which gives $F = -3.4 \times 10^2$ N.

The force by the ball on the glove is the reaction to this force:

3.4×10^2 N in the direction of the motion of the ball.

24. The work done by the braking force decreases the kinetic energy of the car:

$W = Æ\text{KE};$

$-Fd = !mv^2 - !mv_0^2 = 0 - !mv_0^2.$

Assuming the same braking force, we form the ratio:

$d_2/d_1 = (v_{02}/v_{01})^2 = (1.5)^2 =$ 2.25.

25. On a level road, the normal force is mg, so the kinetic friction force is $\mu_k mg$. Because it is the (negative) work of the friction force that stops the car, we have

$W = Æ\text{KE};$

$-\mu_k mg\, d = !mv^2 - !mv_0^2;$

$-(0.42)m(9.80\text{ m/s}^2)(88\text{ m}) = -!mv_0^2$, which gives $v_0 =$ 27 m/s (97 km/h or 60 mi/h).

Because every term contains the mass, it cancels.

26. The work done by the air resistance decreases the kinetic energy of the ball:

$W = F_{\text{air}}d = Æ\text{KE} = !mv^2 - !mv_0^2 = !m(0.90v_0)^2 - !mv_0^2 = !mv_0^2[(0.90)^2 - 1];$

$F_{\text{air}}(15\text{ m}) = !(0.25\text{ kg})[(95\text{ km/h})/(3.6\text{ ks/h})]^2[(0.90)^2 - 1]$, which gives $F_{\text{air}} =$ – 1.1 N.

27. With $m_1 = 2m_2$, for the initial condition we have

$\text{KE}_1 = !\text{KE}_2$;

$!m_1v_1^2 = !(!m_2v_2^2)$, or $2m_2 v_1^2 = !m_2v_2^2$, which gives $v_1 = !v_2$.

After a speed increase of $Æv$, we have

$\text{KE}_1' = \text{KE}_2';$

$!m_1(v_1 + Æv)^2 = !m_2(v_2 + Æv)^2;$

$2m_2(!v_2 + 5.0\text{ m/s})^2 = m_2(v_2 + 5.0\text{ m/s})^2.$

When we take the square root of both sides, we get

$Ã2(!v_2 + 5.0\text{ m/s}) = \pm (v_2 + 5.0\text{ m/s})$, which gives a positive result of $v_2 =$ 7.1 m/s.

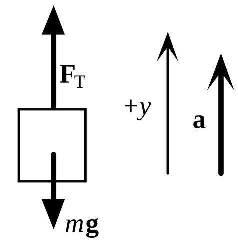
For the other speed we have $v_1 = !v_2 =$ 3.5 m/s.

28. (*a*) From the force diagram we write $\Sigma F_y = ma_y$:

$F_T - mg = ma$;

$F_T - (220\text{ kg})(9.80\text{ m/s}^2) = (220\text{ kg})(0.150)(9.80\text{ m/s}^2)$,

which gives $F_T = 2.48 \times 10^3$ N.



(*b*) The net work is done by the net force:

$W_{net} = F_{net}h = (F_T - mg)h$

$= [2.48 \times 10^3\text{ N} - (220\text{ kg})(9.80\text{ m/s}^2)](21.0\text{ m}) = 6.79 \times 10^3$ J.

(*c*) The work is done by the cable is

$W_{cable} = F_T h$

$= (2.48 \times 10^3\text{ N})(21.0\text{ m}) = 5.21 \times 10^4$ J.

(*d*) The work is done by gravity is

$W_{grav} = -mgh$

$= -(220\text{ kg})(9.80\text{ m/s}^2)(21.0\text{ m}) = -4.53 \times 10^4$ J.

Note that $W_{net} = W_{cable} + W_{grav}$.

(*e*) The net work done on the load increases its kinetic energy:

W_{net} = ÆKE = $!mv^2 - !mv_0^2$;

$6.79 \times 10^3\text{ J} = !(220\text{ kg})v^2 - 0$, which gives $v = 7.86$ m/s.

29. The potential energy of the spring is zero when the spring is not stretched ($x = 0$). For the stored potential energy, we have

PE = $!kx_f^2 - 0$;

$25\text{ J} = !(440\text{ N/m})x_f^2 - 0$, which gives $x_f = 0.34$ m.

30. For the potential energy change we have

ÆPE = mg Æy = (6.0 kg)(9.80 m/s²)(1.2 m) = 71 J.

31. For the potential energy change we have

ÆPE = mg Æy = (64 kg)(9.80 m/s²)(4.0 m) = 2.5×10^3 J.

32. (*a*) With the reference level at the ground, for the potential energy we have

$PE_a = mgy_a = (2.10\text{ kg})(9.80\text{ m/s}^2)(2.20\text{ m}) = 45.3$ J.

(*b*) With the reference level at the top of the head, for the potential energy we have

$PE_b = mg(y_b - h) = (2.10\text{ kg})(9.80\text{ m/s}^2)(2.20\text{ m} - 1.60\text{ m}) = 12.3$ J.

(*c*) Because the person lifted the book from the reference level in part (*a*), the potential energy is equal to the work done: 45.3 J. In part (*b*) the initial potential energy was negative, so the final potential energy is not the work done.

33. (*a*) With the reference level at the ground, for the potential energy change we have

ÆPE = mg Æy = (55 kg)(9.80 m/s²)(3100 m – 1600 m) = 8.1×10^5 J.

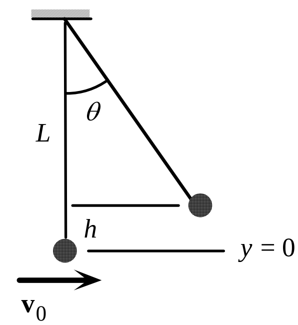
(*b*) The minimum work would be equal to the change in potential energy:

W_{min} = ÆPE = 8.1×10^5 J.

(*c*) Yes, the actual work will be more than this. There will be additional work required for any kinetic energy change, and to overcome retarding forces, such as air resistance and ground deformation.

34. The potential energy of the spring is zero when the spring is not stretched or compressed (x= 0).
 (a) For the change in potential energy, we have
 ÆPE = !kx^2 – !kx_0^2 = !$k(x^2 - x_0^2)$.
 (b) If we call compressing positive, we have
 ÆPE$_{compression}$ = !$k(+ x_0)^2$ – 0 = !kx_0^2;
 ÆPE$_{stretching}$ = !$k(- x_0)^2$ – 0 = !kx_0^2.
 The change in potential energy is the same.

35. We choose the potential energy to be zero at the ground (y = 0).
Because the tension in the vine does no work, energy is conserved, so we have
 E = KE$_i$ + PE$_i$ = KE$_f$ + PE$_f$;
 !mv_i^2 + mgy_i = !mv_f^2 + mgy_f ;
 !m(5.6 m/s)^2 + m(9.80 m/s^2)(0) = !m(0)^2 + m(9.80 m/s^2)h,
which gives h = 1.6 m.
No, the length of the vine does not affect the height; it affects the angle.



36. We choose the potential energy to be zero at the bottom (y = 0). Because there is no friction and the normal force does no work, energy is conserved, so we have
 E = KE$_i$ + PE$_i$ = KE$_f$ + PE$_f$;
 !mv_i^2 + mgy_i = !mv_f^2 + mgy_f ;
 !m(0)^2 + m(9.80 m/s^2)(125 m) = !mv_f^2 + m(9.80 m/s^2)(0), which gives v_f = 49.5 m/s.
This is 180 km/h! It is a good thing there is friction on the ski slopes.

37. We choose the potential energy to be zero at the bottom (y = 0). Because there is no friction and the normal force does no work, energy is conserved, so we have
 E = KE$_i$ + PE$_i$ = KE$_f$ + PE$_f$;
 !mv_i^2 + mgy_i = !mv_f^2 + mgy_f ;
 !mv_i^2 + m(9.80 m/s^2)(0) = !m(0)^2 + m(9.80 m/s^2)(1.35 m), which gives v_i = 5.14 m/s.

38. We choose the potential energy to be zero at the ground (y = 0). We find the minimum speed by ignoring any frictional forces. Energy is conserved, so we have
 E = KE$_i$ + PE$_i$ = KE$_f$ + PE$_f$;
 !mv_i^2 + mgy_i = !mv_f^2 + mgy_f ;
 !mv_i^2 + m(9.80 m/s^2)(0) = !m(0.70 m/s)^2 + m(9.80 m/s^2)(2.10 m), which gives v_i = 6.5 m/s.
Note that the initial velocity will not be horizontal, but will have a horizontal component of 0.70 m/s.

39. We choose $y = 0$ at the level of the trampoline.

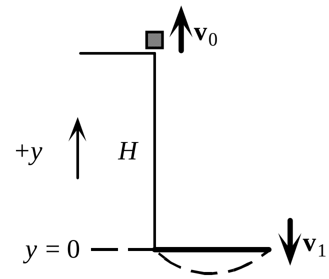
(*a*) We apply conservation of energy for the jump from the top of the platform to the trampoline:

$E = KE_i + PE_i = KE_f + PE_f$;

$!mv_0^2 + mgH = !mv_1^2 + 0$;

$!m(5.0 \text{ m/s})^2 + m(9.80 \text{ m/s}^2)(3.0 \text{ m}) = !mv_1^2$,

which gives $v_1 =$ 9.2 m/s.



(*b*) We apply conservation of energy from the landing on the trampoline to the maximum depression of the trampoline. If we ignore the small change in gravitational potential energy, we have

$E = KE_i + PE_i = KE_f + PE_f$;

$!mv_1^2 + 0 = 0 + !kx^2$;

$!(75 \text{ kg})(9.2 \text{ m/s})^2 = !(5.2 \times 10^4 \text{ N/m})x^2$,

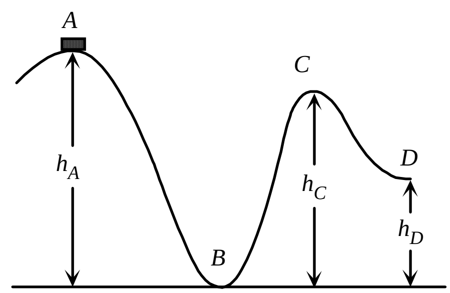
which gives $x =$ 0.35 m.

This will increase slightly if the gravitational potential energy is taken into account.

40. We choose $y = 0$ at point *B*. With no friction, energy is conserved. The initial (and constant) energy is

$E = E_A = mgy_A + !mv_A^2$

$= m(9.8 \text{ m/s}^2)(30 \text{ m}) + 0 = (294 \text{ J/kg})m$.



At point *B* we have

$E = mgy_B + !mv_B^2$;

$(294 \text{ J/kg})m = m(9.8 \text{ m/s}^2)(0) + !mv_B^2$,

which gives $v_B = 24$ m/s.

At point *C* we have

$E = mgy_C + !mv_C^2$;

$(294 \text{ J/kg})m = m(9.8 \text{ m/s}^2)(25 \text{ m}) + !mv_C^2$,

which gives $v_C = 9.9$ m/s.

At point *D* we have

$E = mgy_D + !mv_D^2$;

$(294 \text{ J/kg})m = m(9.8 \text{ m/s}^2)(12 \text{ m}) + !mv_D^2$,

which gives $v_D = 19$ m/s.

41. We choose the potential energy to be zero at the ground ($y = 0$). Energy is conserved, so we have

$E = KE_i + PE_i = KE_f + PE_f$;

$!mv_i^2 + mgy_i = !mv_f^2 + mgy_f$;

$!m(185 \text{ m/s})^2 + m(9.80 \text{ m/s}^2)(265 \text{ m}) = !mv_f^2 + m(9.80 \text{ m/s}^2)(0)$, which gives $v_f =$ 199 m/s.

Note that we have not found the direction of the velocity.

42. (*a*) For the motion from the bridge to the lowest point, we use energy conservation:

$KE_i + PE_{gravi} + PE_{cordi} = KE_f + PE_{gravf} + PE_{cordf}$;

$0 + 0 + 0 = 0 + mg(-h) + !k(h - L_0)^2$;

$0 = -(60\text{ kg})(9.80\text{ m/s}^2)(31\text{ m}) + !k(31\text{ m} - 12\text{ m})^2$,

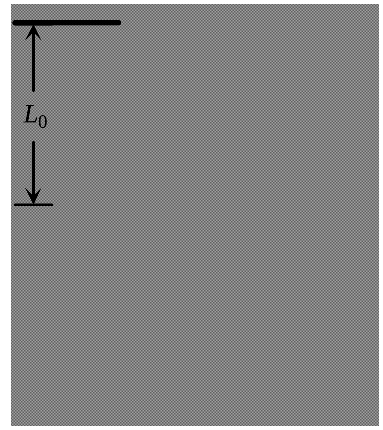
which gives $k =$ 1.0×10^2 N/m.

(*b*) The maximum acceleration will occur at the lowest point, where the upward restoring force in the cord is maximum:

$kx_{max} - mg = ma_{max}$;

$(1.0 \times 10^2\text{ N/m})(31\text{ m} - 12\text{ m}) - (60\text{ kg})(9.80\text{ m/s}^2) = (60\text{ kg})a_{max}$,

which gives $a_{max} =$ 22 m/s^2.



43. We choose the potential energy to be zero at the compressed position ($y = 0$).

(*a*) For the motion from the release point to where the ball leaves the spring, we use energy conservation:

$KE_i + PE_{gravi} + PE_{springi} = KE_f + PE_{gravf} + PE_{springf}$;

$0 + 0 + !kx^2 = !mv^2 + mgx + 0$;

$!(900\text{ N/m})(0.150\text{ m})^2 = !(0.300\text{ kg})v^2 + (0.300\text{ kg})(9.80\text{ m/s}^2)(0.150\text{ m})$,

which gives $v =$ 8.03 m/s.

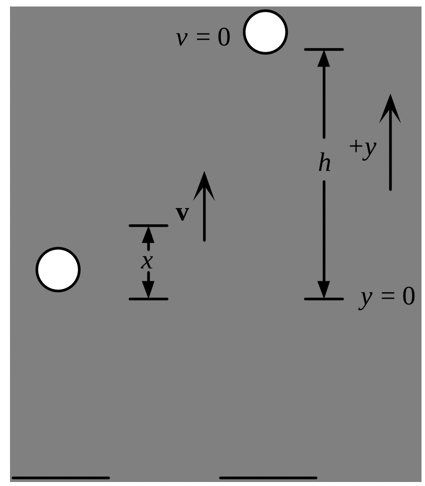
(*b*) For the motion from the release point to the highest point, we use energy conservation:

$KE_i + PE_{gravi} + PE_{springi} = KE_f + PE_{gravf} + PE_{springf}$;

$0 + 0 + !kx^2 = 0 + mgh + 0$;

$0 + 0 + !(900\text{ N/m})(0.150\text{ m})^2 = (0.300\text{ kg})(9.80\text{ m/s}^2)h$,

which gives $h =$ 3.44 m.



44. With $y = 0$ at the bottom of the circle, we call the start point *A*, the bottom of the circle *B*, and the top of the circle *C*. At the top of the circle we have the forces mg and F_N, both downward, that provide the centripetal acceleration:

$mg + F_N = mv_C^2/r$.

The minimum value of F_N is zero, so the minimum speed at *C* is found from

$v_{Cmin}^2 = gr$.

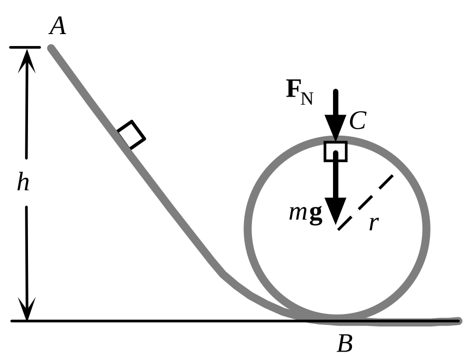
From energy conservation for the motion from *A* to *C* we have

$KE_A + PE_A = KE_C + PE_C$;

$0 + mgh = !mv_C^2 + mg(2r)$,

thus the minimum height is found from

$gh = !v_{Cmin}^2 + 2gr = !gr + 2gr$, which gives $h = 2.5r$.



45. The potential energy is zero at $x = 0$. For the motion from the release point, we use energy conservation:

$E = KE_i + PE_i = KE_f + PE_f$;

$E = 0 + !kx_0^2 = !mv^2 + !kx^2$, which gives $E = !kx_0^2 = !mv^2 + !kx^2$

46. The maximum acceleration will occur at the lowest point, where the upward restoring force in the spring is maximum:

$kx_{max} - Mg = Ma_{max} = M(5.0g)$, which gives $x_{max} = 6.0Mg/k$.

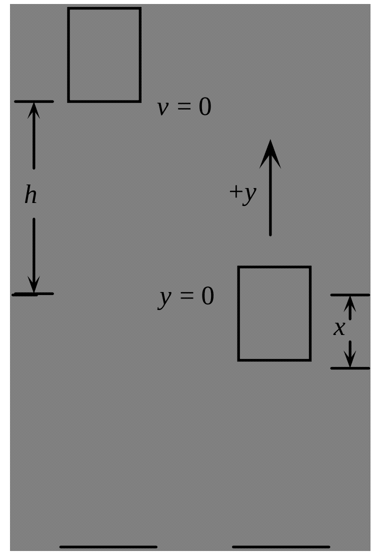
With $y = 0$ at the initial position of the top of the spring, for the motion from the break point to the maximum compression of the spring, we use energy conservation:

$KE_i + PE_{gravi} + PE_{springi} = KE_f + PE_{gravf} + PE_{springf}$;

$0 + Mgh + 0 = 0 + Mg(-x_{max}) + !kx_{max}^2$.

When we use the previous result, we get

$Mgh = -[6.0(Mg)^2/k] + !k(6.0Mg/k)^2$, which gives $k = 12Mg/h$.



47. The maximum acceleration will occur at the maximum compression of the spring:

$kx_{max} = Ma_{max} = M(5.0g)$, which gives $x_{max} = 5.0Mg/k$.

For the motion from reaching the spring to the maximum compression of the spring, we use energy conservation:

$KE_i + PE_{springi} = KE_f + PE_{springf}$;

$!Mv^2 + 0 = 0 + !kx_{max}^2$.

When we use the previous result, we get

$!Mv^2 = !k(5.0Mg/k)^2$, which gives

$k = 25Mg^2/v^2 = 25(1200\text{ kg})(9.80\text{ m/s}^2)^2/[(100\text{ km/h})/(3.6\text{ ks/h})]^2 =$ 3.7×10^3 N/m.

48. (*a*) The work done against gravity is the increase in the potential energy:

$W = mgh = (75.0\text{ kg})(9.80\text{ m/s}^2)(120\text{ m}) =$ 8.82×10^4 J.

(*b*) If this work is done by the force on the pedals, we need to find the distance that the force acts over one revolution of the pedals and the number of revolutions to climb the hill. We find the number of revolutions from the distance along the incline:

$N = (h/\sin\theta)/(5.10\text{ m/revolution})$

$= [(120\text{ m})/\sin 7.50°]/(5.10\text{ m/revolution}) = 180$ revolutions.

Because the force is always tangent to the circular path, in each revolution the force acts over a distance equal to the circumference of the path: ^1D. Thus we have

$W = NF^1D$;

$8.82 \times 10^4\text{ J} = (180\text{ revolutions})F^1(0.360\text{ m})$, which gives $F =$ 433 N.

49. The thermal energy is equal to the loss in kinetic energy:

$E_{thermal} = -ÆKE = !mv_i^2 - !mv_f^2 = !(2)(6500\text{ kg})[(95\text{ km/h})/(3.6\text{ ks/h})]^2 - 0 =$ 4.5×10^6 J.

50. We choose the bottom of the slide for the gravitational potential energy reference level. The thermal energy is the negative of the change in kinetic and potential energy:

$E_{thermal} = -(ÆKE + ÆPE) = !mv_i^2 - !mv_f^2 + mg(h_i - h_f)$

$= 0 - !(17\text{ kg})(2.5\text{ m/s})^2 + (17\text{ kg})(9.80\text{ m/s}^2)(3.5\text{ m} - 0) =$ 5.3×10^2 J.

51. (*a*) We find the normal force from the force diagram for the ski:

y-component: $F_{N1} = mg \cos \theta$;

which gives the friction force: $F_{fr1} = \mu_k mg \cos \theta$.

For the work-energy principle, we have

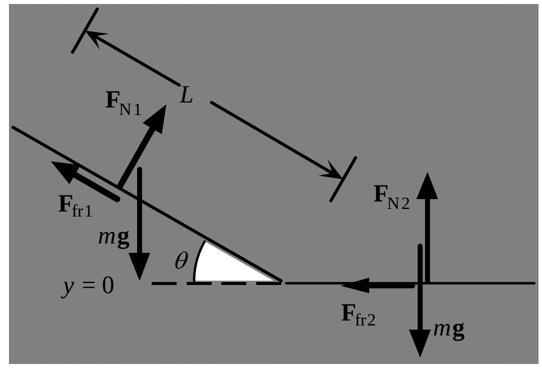
W_{NC} = ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

– $\mu_k mg \cos \theta L$ = (!mv_f^2 – 0) + $mg(0 - L \sin \theta)$;

– (0.090)(9.80 m/s²) cos 20° (100 m) =

!v_f^2 – (9.80 m/s²)(100 m) sin 20°,

which gives v_f = 22 m/s.



(*b*) On the level the normal force is $F_{N2} = mg$, so the friction force is $F_{fr2} = \mu_k mg$.

For the work-energy principle, we have

W_{NC} = ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

– $\mu_k mg D$ = (0 – !mv_i^2) + $mg(0 - 0)$;

– (0.090)(9.80 m/s²)D = – !(22 m/s)² ,

which gives D = 2.9×10^2 m.

52. On the level the normal force is $F_N = mg$, so the friction force is $F_{fr} = \mu_k mg$.

For the work-energy principle, we have

W_{NC} = ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

$F(L_1 + L_2)$ – $\mu_k mg L_2$ = (!mv_f^2 – 0) + $mg(0 - 0)$;

(350 N)(15 m + 15 m) – (0.30)(90 kg)(9.80 m/s²)(15 m) = !(90 kg)v_f^2,

which gives v_f = 12 m/s.

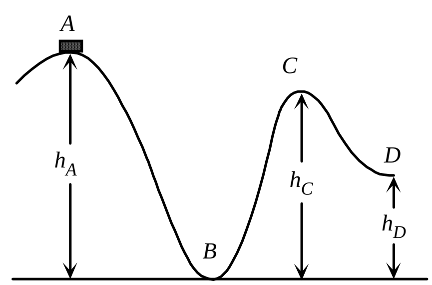
53. We choose $y = 0$ at point B. For the work-energy principle applied to the motion from A to B, we have

W_{NC} = ÆKE + ÆPE = (!mv_B^2 – !mv_A^2) + $mg(h_B - h_A)$;

– 0.2mgL = (!mv_B^2 – !mv^2) + $mg(0 - h_A)$;

– 0.2(9.80 m/s²)(45.0 m) = !v_B^2 ! – (1.70 m/s)²– (9.80 m/s²)(30 m),

which gives v_B = 20 m/s.



54. We find the normal force from the force diagram for the skier:

y-component: $F_N = mg \cos \theta$;

which gives the friction force: $F_{fr} = \mu_k mg \cos \theta$.

For the work-energy principle for the motion up the incline, we have

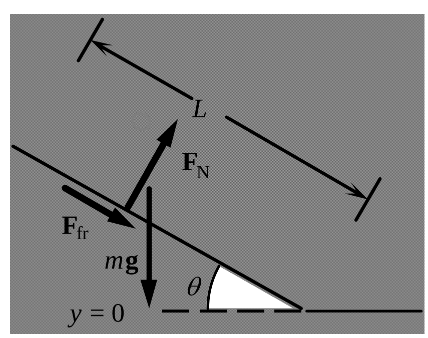
W_{NC} = ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

– $\mu_k mg \cos \theta L$ = (0 – !mv_i^2) + $mg(L \sin \theta - 0)$;

– μ_k(9.80 m/s²) cos 18° (12.2 m) =

– !(12.0 m/s)² + (9.80 m/s²)(12.2 m) sin 18°,

which gives μ_k = 0.31.



55. On the level the normal force is $F_N = mg$, so the friction force is $F_{fr} = \mu_k mg$.
The block is at rest at the release point and where it momentarily stops before turning back.
For the work-energy principle, we have

$W_{NC} = \Delta KE + \Delta PE = (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2) + (\frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2);$

$-\mu_k mg L = (0 - 0) + \frac{1}{2}k(x_f^2 - x_i^2);$

$-\mu_k(0.520 \text{ kg})(9.80 \text{ m/s}^2)(0.050 \text{ m} + 0.023 \text{ m}) = \frac{1}{2}(180 \text{ N/m})[(0.023 \text{ m})^2 - (-0.050 \text{ m})^2],$

which gives $\mu_k =$ 0.48.

56. We find the spring constant from the force required to compress the spring:

$k = F/x_i = (-20 \text{ N})/(-0.18 \text{ m}) = 111 \text{ N/m}.$

On the level the normal force is $F_N = mg$, so the friction force is $F_{fr} = \mu_k mg$.
The block is at rest at the release point and where it momentarily stops before turning back.
For the work-energy principle, we have

$W_{NC} = \Delta KE + \Delta PE = (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2) + (\frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2);$

$-\mu_k mg L = (0 - 0) + \frac{1}{2}k(x_f^2 - x_i^2);$

$-(0.30)(0.180 \text{ kg})(9.80 \text{ m/s}^2)(0.18 \text{ m} + x_f) = \frac{1}{2}(111 \text{ N/m})[x_f^2 - (-0.18 \text{ m})^2].$

This reduces to the quadratic equation

$55.5x_f^2 + 0.529x_f - 1.70 = 0$, which has the solutions $x_f = 0.17$ m, -0.18 m.

The negative solution corresponds to no motion, so the physical result is $x_f =$ 0.17 m.

57. We choose the potential energy to be zero at the ground ($y = 0$).
We convert the speeds: (500 km/h)/(3.6 ks/h) = 139 m/s; (200 km/h)/(3.6 ks/h) = 55.6 m/s.

(*a*) If there were no air resistance, energy would be conserved:

$0 = \Delta KE + \Delta PE = (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2) + mg(h_f - h_i);$

$0 = \frac{1}{2}(1000 \text{ kg})[(v_f^2 - (139 \text{ m/s})^2] + (1000 \text{ kg})(9.80 \text{ m/s}^2)(0 - 3500 \text{ m}),$

which gives $v_f = 297$ m/s = 1.07×10^3 km/h.

(*b*) With air resistance we have

$W_{NC} = \Delta KE + \Delta PE = (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2) + mg(h_f - h_i);$

$-F(h_i / \sin \theta) = \frac{1}{2}m(v_f^2 - v_i^2) + mg(0 - h_i);$

$-F(3500 \text{ m})/\sin 10° = \frac{1}{2}(1000 \text{ kg})[(55.6 \text{ m/s})^2 - (139 \text{ m/s})^2] + (1000 \text{ kg})(9.80 \text{ m/s}^2)(-3500 \text{ m})$

which gives $F =$ 2.1×10^3 N.

58. The amount of work required is the increase in potential energy: $W = mg\,\Delta y$.
We find the time from

$P = W/t = mg\,\Delta y/t;$

1750 W = (285 kg)(9.80 m/s^2)(16.0 m)/t, which gives $t =$ 25.5 s.

59. We find the equivalent force exerted by the engine from

$P = Fv;$

(18 hp)(746 W/hp) = F(90 km/h)/(3.6 ks/h), which gives $F = 5.4 \times 10^2$ N.

At constant speed, this force is balanced by the average retarding force, which must be 5.4×10^2 N.

60. (*a*) 1 hp = (550 ft·lb/s)(4.45 N/lb)/(3.281 ft/m) = 746 W.

(*b*) P = (100 W)/(746 W/hp) = 0.134 hp.

61. (*a*) 1 kWh = (1000 Wh)(3600 s/h) = 3.6×10^6 J.
(*b*) $W = Pt$ = (500 W)(1 kW/1000W)(1 mo)(30 day/mo)(24 h/day) = 360 kWh.
(*c*) W = (360 kWh)(3.6×10^6 J/kWh) = 1.3×10^9 J.
(*d*) Cost = $W \times$ rate = (360 kWh)($0.12/kWh) = $43.20.
The charge is for the amount of energy used, and thus is independent of rate.

62. We find the average resistance force from the acceleration:
$R = ma = m$ Æv/Æt = (1000 kg)(70 km/h – 90 km/h)/(3.6 ks/h)(6.0 s) = – 933 N.
If we assume that this is the resistance force at 80 km/h, the engine must provide an equal and opposite force to maintain a constant speed. We find the power required from
$P = Fv$ = (933 N)(80 km/h)/(3.6 ks/h) = 2.1×10^4 W = (2.1×10^4 W)/(746 W/hp) = 28 hp.

63. We find the work from
$W = Pt$ = (3.0 hp)(746 W/hp)(1 h)(3600 s/h) = 8.1×10^6 J.

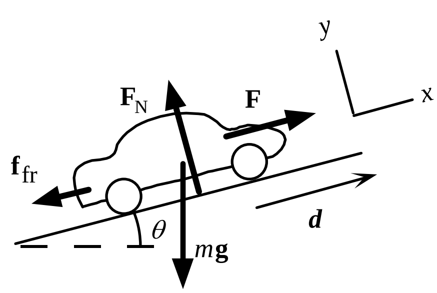
64. The work done by the shot-putter increases the kinetic energy of the shot. We find the power from
$P = W/t$ = ÆKE/t = (!mv_f^2 – !mv_i^2)/t
= !(7.3 kg)[(14 m/s)^2 – 0]/(2.0 s) = 3.6×10^2 W (about 0.5 hp).

65. The work done by the pump increases the potential energy of the water. We find the power from
$P = W/t$ = ÆPE/t = $mg(h_f - h_i)/t = (m/t)g(h_f - h_i)$
= [(8.00 kg/min)/(60 s/min)](9.80 m/s^2)(3.50 m – 0) = 4.57 W.

66. The work done increases the potential energy of the player. We find the power from
$P = W/t$ = ÆPE/t = $mg(h_f - h_i)/t$
= (105 kg)(9.80 m/s^2)[(140 m) sin 30° – 0]/(61 s) = 1.2×10^3 W (about 1.6 hp).

67. The work done increases the potential energy of the player. We find the speed from
$P = W/t$ = ÆPE/t = $mg(h_f - h_i)/t = mg(L \sin\theta - 0)/t = mgv \sin\theta$
(0.25 hp)(746 W/hp) = (70 kg)(9.80 m/s^2)v sin 6.0°, which gives v = 2.6 m/s.

68. From the force diagram for the car, we have:
x-component: $F - F_{fr} = mg \sin\theta$.
Because the power output is $P = Fv$, we have
$(P/v) - F_{fr} = mg \sin\theta$.
The maximum power determines the maximum angle:
$(P_{max}/v) - F_{fr} = mg \sin\theta_{max}$;
(120 hp)(746 W/hp)/[(70 km/h)/(3/6 ks/h)] – 600 N =
(1000 kg)(9.80 m/s^2) sin θ_{max},
which gives sin θ_{max} = 0.409, or θ_{max} = 24°.



69. The work done by the lifts increases the potential energy of the people. We assume an average mass of 70 kg and find the power from

$P = W/t =$ ÆPE$/t = mg(h_f - h_i)/t = (m/t)g(h_f - h_i)$

$= [(47{,}000 \text{ people/h})(70 \text{ kg/person})/(3600 \text{ s/h})](9.80 \text{ m/s}^2)(200 \text{ m} - 0)$

$=$ 1.8×10^6 W (about 2.4×10^3 hp).

70. For the work-energy principle applied to coasting down the hill a distance L, we have

$W_{NC} =$ ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

$- F_{fr}L$ = (!mv^2 – !mv^2) + $mg(0 - L \sin \theta)$, which gives $F_{fr} = mg \sin \theta$.

Because the climb is at the same speed, we assume the resisting force is the same.

For the work-energy principle applied to climbing the hill a distance L, we have

$W_{NC} =$ ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$;

$FL - F_{fr}L$ = (!mv^2 – !mv^2) + $mg(0 - L \sin \theta)$;

$(P/v) - mg \sin \theta = mg \sin \theta$, which gives

$P = 2mgv \sin \theta = 2(75 \text{ kg})(9.80 \text{ m/s}^2)(5.0 \text{ m/s}) \sin 7.0° =$ 9.0×10^2 W (about 1.2 hp).

71. (*a*) If we ignore the small change in potential energy when the snow brings the paratrooper to rest, the work done decreases the kinetic energy:

$W =$ ÆKE = !mv_f^2 – !mv_i^2

= !(80 kg)[0 – (30 m/s)^2] = -3.6×10^4 J.

(*b*) We find the average force from

$F = W/d = (-3.6 \times 10^4 \text{ J})/(1.1 \text{ m}) =$ -3.3×10^3 N.

(*c*) With air resistance during the fall we have

W_{NC} = ÆKE + ÆPE = (!mv_f^2 – !mv_i^2) + $mg(h_f - h_i)$

= !(80 kg)[(30 m/s)^2 – 0] + (80 kg)(9.80 m/s^2)(0 – 370 m) = -2.5×10^5 J.

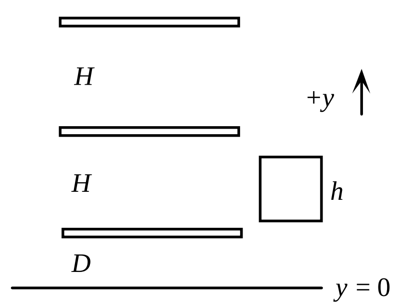
72. For the motion during the impact until the car comes momentarily to rest, we use energy conservation:

$KE_i + PE_{springi} = KE_f + PE_{springf}$;

!mv_i^2 + 0 = 0 + !kx^2;

(1400 kg kg)[(8 km/h)/(3/6 ks/h)]^2 = k(0.015 m)^2, which gives $k =$ 3×10^7 N/m.

73. We let N represent the number of books of mass m that can be placed on a shelf. For each book the work increases the potential energy and thus is mg times the distance the center is raised. From the diagram we see that the work required to fill the nth shelf is



$W_n = Nmg[D$ + !$h + (n - 1)H]$.

Thus for the five shelves, we have

$W = W_1 + W_2 + W_3 + W_4 + W_5$

$= Nmg[5(D$ + !$h) + H + 2H + 3H + 4H]$

$= Nmg[5(D$ + !$h) + 10H]$

$= (25)(1.5 \text{ kg})(9.80 \text{ m/s}^2)\{5[0.100 \text{ m}$ + !$(0.20 \text{ m})] + 10(0.300 \text{ m})\}$

$=$ 1.5×10^3 J.

74. We choose the potential energy to be zero at the ground (y = 0). We find the minimum speed by ignoring any frictional forces. Energy is conserved, so we have

$E = KE_i + PE_i = KE_f + PE_f$;

$!mv_i^2 + mgy_i = !mv_f^2 + mgy_f$;

$!mv_i^2 + m(9.80\ m/s^2)(0) = !m(6.5\ m/s)^2 + m(9.80\ m/s^2)(1.1\ m)$, which gives v_i = 8.0 m/s.

Note that the initial velocity will not be horizontal, but will have a horizontal component of 6.5 m/s.

75. We choose the reference level for the gravitational potential energy at the ground.

(*a*) With no air resistance during the fall we have

$0 = ÆKE + ÆPE = (!mv_f^2 - !mv_i^2) + mg(h_f - h_i)$, or

$!(v_f^2 - 0) = -(9.80\ m/s^2)(0 - 18\ m)$, which gives v_f = 19 m/s.

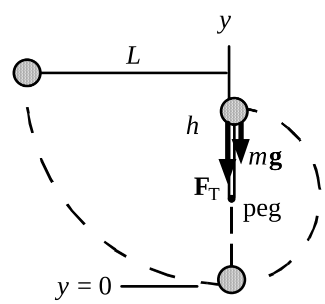
(*b*) With air resistance during the fall we have

$W_{NC} = ÆKE + ÆPE = (!mv_f^2 - !mv_i^2) + mg(h_f - h_i)$;

$F_{air}(18\ m) = !(0.20\ kg)[(10.0\ m/s)^2 - 0] + (0.20\ kg)(9.80\ m/s^2)(0 - 18\ m)$,

which gives F_{air} = – 1.4 N.

76. We choose the reference level for the gravitational potential energy at the lowest point. The tension in the cord is always perpendicular to the displacement and thus does no work.



(*a*) With no air resistance during the fall, we have

$0 = ÆKE + ÆPE = (!mv_1^2 - !mv_0^2) + mg(h_1 - h_0)$, or

$!(v_1^2 - 0) = -g(0 - L)$, which gives v_1 = $(2gL)^{1/2}$.

(*b*) For the motion from release to the rise around the peg, we have

$0 = ÆKE + ÆPE = (!mv_2^2 - !mv_0^2) + mg(h_2 - h_0)$, or

$!(v_2^2 - 0) = -g[2(L - h) - L] = g(2h - L) = 0.60gL$,

which gives v_2 = $(1.2gL)^{1/2}$.

77. (*a*) The work done against gravity is the increase in the potential energy:

$W = ÆPE = mg(h_f - h_i) = (65\ kg)(9.80\ m/s^2)(3900\ m - 2200\ m)$ = 1.1×10^6 J.

(*b*) We find the power from

$P = W/t = (1.1 \times 10^6\ J)/(5.0\ h)(3600\ s/h)$ = 60 W = 0.081 hp.

(*c*) We find the power input from

$P_{input} = P/\text{efficiency} = (60\ W)/(0.15)$ = 4.0×10^2 W = 0.54 hp.

78. The potential energy is zero at x = 0.

(*a*) Because energy is conserved, the maximum speed occurs at the minimum potential energy:

$KE_i + PE_i = KE_f + PE_f$;

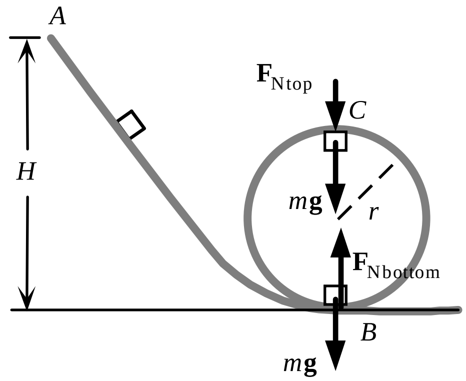
$!mv_0^2 + !kx_0^2 = !mv_{max}^2 + 0$, which gives $v_{max} = [v_0^2 + (kx_0^2/m)]^{1/2}$.

(*b*) The maximum stretch occurs at the minimum kinetic energy:

$KE_i + PE_i = KE_f + PE_f$;

$!mv_0^2 + !kx_0^2 = 0 + !kx_{max}^2$, which gives $x_{max} = [x_0^2 + (mv_0^2/k)]^{1/2}$.

79. (*a*) With $y = 0$ at the bottom of the circle, we call the start point A, the bottom of the circle B, and the top of the circle C. At the top of the circle we have the forces mg and F_{Ntop}, both downward, that provide the centripetal acceleration:



$$mg + F_{\text{Ntop}} = mv_C^2/r.$$

The minimum value of F_{Ntop} is zero, so the minimum speed at C is found from

$$v_{C\text{min}}^2 = gr.$$

From energy conservation for the motion from A to C we have

$$\text{KE}_A + \text{PE}_A = \text{KE}_C + \text{PE}_C;$$

$$0 + mgh = !mv_C^2 + mg(2r),$$

thus the minimum height is found from

$$gh = !v_{C\text{min}}^2 + 2gr = !gr + 2gr, \text{ which gives } \quad h = 2.5r.$$

(*b*) From energy conservation for the motion from A to B we have

$$\text{KE}_A + \text{PE}_A = \text{KE}_B + \text{PE}_B;$$

$$0 + mg2h = 5mgr = !mv_B^2 + 0, \text{ which gives } v_B^2 = 10gr.$$

At the bottom of the circle we have the forces mg down and F_{Nbottom} up that provide the centripetal acceleration:

$$-mg + F_{\text{Nbottom}} = mv_B^2/r.$$

If we use the previous result, we get

$$F_{\text{Nbottom}} = mv_B^2/r + mg = \quad 11mg.$$

(*c*) From energy conservation for the motion from A to C we have

$$\text{KE}_A + \text{PE}_A = \text{KE}_C + \text{PE}_C;$$

$$0 + mg2h = 5mgr = !mv_C^2 + mg(2r), \text{ which gives } v_C^2 = 6gr.$$

At the top of the circle we have the forces mg and F_{Ntop}, both down, that provide the centripetal acceleration:

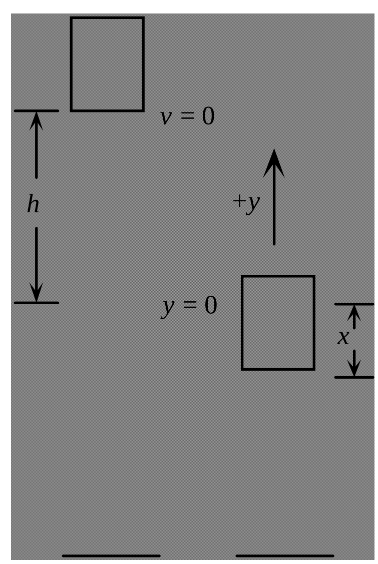
$$mg + F_{\text{Ntop}} = mv_C^2/r.$$

If we use the previous result, we get

$$F_{\text{Ntop}} = mv_C^2/r - mg = \quad 5mg.$$

(*d*) On the horizontal section we have $F_N = \quad mg.$

80. (*a*) The work done by gravity is the decrease in the potential energy:



$$W_{\text{grav}} = -\text{ÆPE} = -mg(h_f - h_i) = (900\text{ kg})(9.80\text{ m/s}^2)(0 - 30\text{ m})$$
$$= \quad 2.6 \times 10^5\text{ J}.$$

(*b*) The work done by gravity increases the kinetic energy:

$$W_{\text{grav}} = \text{ÆKE};$$

$$2.6 \times 10^5\text{ J} = !(900\text{ kg})v^2 - 0, \text{ which gives } \quad v = 24\text{ m/s}.$$

(*c*) For the motion from the break point to the maximum compression of the spring, we use energy conservation:

$$\text{KE}_i + \text{PE}_{\text{gravi}} + \text{PE}_{\text{springi}} = \text{KE}_f + \text{PE}_{\text{gravf}} + \text{PE}_{\text{springf}};$$

$$0 + mgh + 0 = 0 + mg(-x_{\text{max}}) + !kx_{\text{max}}^2;$$

$$(900\text{ kg})(9.80\text{ m/s}^2)(30\text{ m}) =$$
$$-(900\text{ kg})(9.80\text{ m/s}^2)x_{\text{max}} + !(4.0 \times 10^5\text{ N/m})x_{\text{max}}^2.$$

This is a quadratic equation for x_{max}, which has the solutions

$$x_{\text{max}} = -1.13\text{ m}, 1.17\text{ m}.$$

Because x_{max} must be positive, the spring compresses $\quad 1.2\text{ m}.$

81. We choose the reference level for the gravitational potential energy at the lowest point.

(*a*) With no air resistance during the fall, we have

$0 = \text{ÆKE} + \text{ÆPE} = (!mv^2 - !mv_0^2) + mg(h - h_0)$, or

$!(v^2 - 0) = - g(0 - H)$, which gives

$v_1 = (2gH)^{1/2} = [2(9.80\ \text{m/s}^2)(80\ \text{m})] =$ 40 m/s.

(*b*) If 60% of the kinetic energy of the water is transferred, we have

$P = (0.60)!mv^2/t = (0.60)!(m/t)v^2$

$= (0.60)!(550\ \text{kg/s})(40\ \text{m/s})^2) =$ 2.6×10^5 W (about 3.5×10^2 hp).

82. We convert the speeds: (10 km/h)/(3.6 ks/h) = 2.78 m/s; (30 km/h)/(3.6 ks/h) = 8.33 m/s.
We use the work-energy principle applied to coasting down the hill a distance L to find b:

$W_{NC} = \text{ÆKE} + \text{ÆPE} = (!mv_f^2 - !mv_i^2) + mg(h_f - h_i)$;

$- bv_1^2L = (!mv_1^2 - !mv_1^2) + mg(0 - L \sin \theta)$,

which gives $b = (mg/v^2) \sin \theta = [(75\ \text{kg})(9.80\ \text{m/s}^2)/(2.78\ \text{m/s})^2] \sin 4.0° = 6.63$ kg/m.
For the work-energy principle applied to speeding down the hill a distance L, the cyclist must provide a force so we have

$W_{NC} = \text{ÆKE} + \text{ÆPE} = (!mv_f^2 - !mv_i^2) + mg(h_f - h_i)$;

$F_2L - bv_2^2L = (!mv_2^2 - !mv_2^2) + mg(0 - L \sin \theta)$, which gives $F_2 = bv_2^2 - mg \sin \theta$.

The power supplied by the cyclist is

$P = F_2v_2 = [(6.63\ \text{kg/m})(8.33\ \text{m/s})^2 - (75\ \text{kg})(9.80\ \text{m/s}^2) \sin 4.0°](8.33\ \text{m/s}) = 3.41 \times 10^3$ W.

For the work-energy principle applied to climbing the hill a distance L, the cyclist will provide a force $F_3 = P/v_3$, so we have

$W_{NC} = \text{ÆKE} + \text{ÆPE} = (!mv_f^2 - !mv_i^2) + mg(h_f - h_i)$;

$(P/v_3)L - bv_3^2L = (!mv_3^2 - !mv_3^2) + mg(L \sin \theta - 0)$,

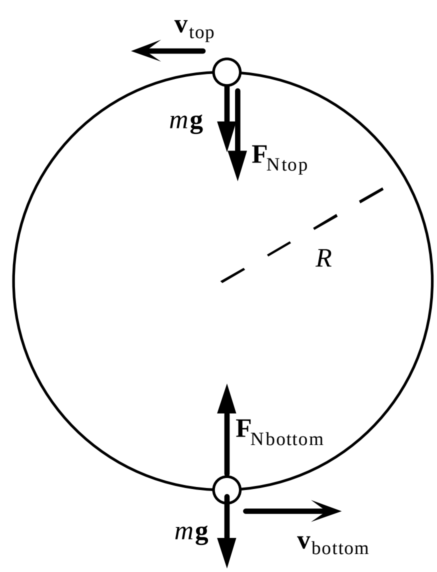
which gives $[(3.41 \times 10^3\ \text{W})/v_3] - (6.63\ \text{kg/m})v_3^2 = (75\ \text{kg})(9.80\ \text{m/s}^2) \sin 4.0°$.
This is a cubic equation for v_3, which has one real solution: $v_3 =$ 5.54 m/s.
The speed is (5.54 m/s)(3.6 ks/h) = 20 km/h.

83. We choose the reference level for the gravitational potential energy at the bottom. From energy conservation for the motion from top to bottom, we have

$KE_{top} + PE_{top} = KE_{bottom} + PE_{bottom}$;

$!mv_{top}^2 + mg2r = !mv_{bottom}^2 + 0$, which gives

$v_{bottom}^2 = v_{top}^2 + 4gr$.



At the bottom of the circle we have the forces mg down and $F_{Nbottom}$ up that provide the centripetal acceleration:

$- mg + F_{Nbottom} = mv_{bottom}^2/r$, which gives

$F_{Nbottom} = (mv_{bottom}^2/r) + mg$.

At the top of the circle we have the forces mg and F_{Ntop}, both down, that provide the centripetal acceleration:

$mg + F_{Ntop} = mv_{top}^2/r$, which gives

$F_{Ntop} = (mv_{top}^2/r) - mg$.

If we subtract the two equations, we get

$F_{Nbottom} - F_{Ntop} = (mv_{bottom}^2/r) + mg - [(mv_{top}^2/r) - mg]$

$= (m/r)(v_{bottom}^2 - v_{top}^2) + 2mg = 4mg + 2mg = 6mg$.

The speed must be above the minimum at the top so the roller coaster does not leave the track. From Problem 44, we know that we must have $h > 2.5r$.

The result we found does not depend on the radius or speed.

84. We choose $y = 0$ at the scale. We find the spring constant from the force (your weight) required to compress the spring:

$k = F_1/x_1 = (-700\ \text{N})/(-0.50 \times 10^{-3}\ \text{m}) = 1.4 \times 10^6\ \text{N/m}$.

We apply conservation of energy for the jump to the scale. If we ignore the small change in gravitational potential energy when the scale compresses, we have

$\text{KE}_i + \text{PE}_i = \text{KE}_f + \text{PE}_f;$

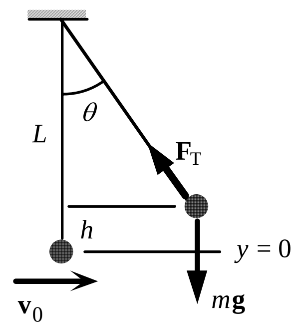
$0 + mgH = 0 + !kx_2^2;$

$(700\ \text{N})(1.0\ \text{m}) = !(1.4 \times 10^6\ \text{N/m})x_2^2$, which gives $x_2 = 0.032$ m.

The reading of the scale is

$F_2 = kx_2 = (1.40 \times 10^6\ \text{N/m})(0.032\ \text{m}) =$ 4.4×10^4 N.

85. We choose the potential energy to be zero at the lowest point ($y = 0$).



(*a*) Because the tension in the vine does no work, energy is conserved, so we have

$\text{KE}_i + \text{PE}_i = \text{KE}_f + \text{PE}_f;$

$!mv_0^2 + 0 = 0 + mgh = mg(L - L\cos\theta) = mgL(1 - \cos\theta);$

$!m(5.0\ \text{m/s})^2 = m(9.80\ \text{m/s}^2)(10.0\ \text{m})(1 - \cos\theta)$

which gives $\cos\theta = 0.872$, or $\theta =$ 29°.

(*b*) The velocity is zero just before he releases, so there is no centripetal acceleration. There is a tangential acceleration which has been decreasing his tangential velocity. For the radial direction we have

$F_T - mg\cos\theta = 0;$ or

$F_T = mg\cos\theta = (75\ \text{kg})(9.80\ \text{m/s}^2)(0.872) =$ 6.4×10^2 N.

(*c*) The velocity and thus the centripetal acceleration is maximum at the bottom, so the tension will be maximum there. For the radial direction we have

$F_T - mg = mv_0^2/L,$ or

$F_T = mg + mv_0^2/L = (75\ \text{kg})[(9.80\ \text{m/s}^2) + (5.0\ \text{m/s})^2/(10.0\ \text{m})] =$ 9.2×10^2 N.

86. We choose the potential energy to be zero at the floor. The work done increases the potential energy of the athlete. We find the power from

$P = W/t = Æ\text{PE}/t = mg(h_f - h_i)/t$

$= (70\ \text{kg})(9.80\ \text{m/s}^2)(5.0\ \text{m} - 0)/(9.0\ \text{s}) =$ 3.8×10^2 W (about 0.5 hp).