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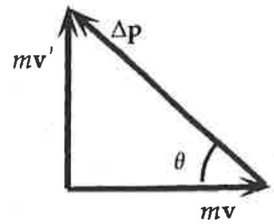
62. For the system of railroad car and snow, the horizontal momentum will be constant. For the horizontal motion, we take the direction of the car for the positive direction. The snow initially has no horizontal velocity. For this perfectly inelastic collision, we use momentum conservation:

$M_1v_1 + M_2v_2 = (M_1 + M_2)V;$

$(5800\ \text{kg})(8.60\ \text{m/s}) + 0 = [5800\ \text{kg} + (3.50\ \text{kg/min})(90.0\ \text{min})]V$, which gives $\boxed{V = 8.16\ \text{m/s}.}$

Note that there is a vertical impulse, so the vertical momentum is not constant.

63. We find the speed after being hit from the height h using energy conservation:



$\frac{1}{2}mv'^2 = mgh$, or $v' = (2gh)^{1/2} = [2(9.80\ \text{m/s}^2)(55.6\ \text{m})]1/2 = 33.0\ \text{m/s}.$

We see from the diagram that the magnitude of the change in momentum is

$\Delta p = m(v^2 + v'^2)^{1/2}$

$= (0.145\ \text{kg})[(35.0\ \text{m/s})^2 + (33.0\ \text{m/s})^2]^{1/2} = 6.98\ \text{kg}\cdot\text{m/s}.$

We find the force from

$F\,\Delta t = \Delta p;$

$F(0.50 \times 10^{-3}\ \text{s}) = 6.98\ \text{kg}\cdot\text{m/s}$, which gives $F = \boxed{1.4 \times 10^4\ \text{N}.}$

We find the direction of the force from

$\tan\theta = v'/v = (33.0\ \text{m/s})/(35.0\ \text{m/s}) = 0.943,\ \theta = \boxed{43.3°.}$

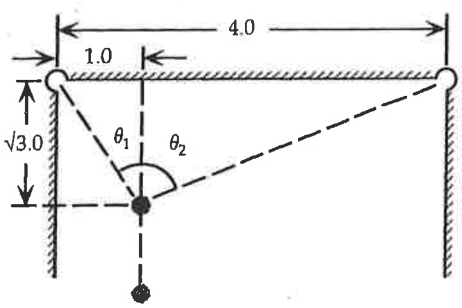
64. For momentum conservation we have

x: $mv_0 = \frac{2}{3}mv_x'$, which gives $\boxed{v_x' = \frac{3}{2}v_0;}$

y: $0 = \frac{1}{3}m(2v_0) - \frac{2}{3}mv_y'$, which gives $\boxed{v_y' = -v_0.}$

The rocket's forward speed increases because the fuel is shot backward relative to the rocket.

65. From the result of Problem 45, the angle between the two final directions will be 90° for an elastic collision. We take the initial direction of the cue ball to be parallel to the side of the table. The angles for the two balls after the collision are



$\tan\theta_1 = 1.0/\sqrt{3.0}$, which gives $\theta_1 = 30°$;

$\tan\theta_2 = (4.0 - 1.0)/\sqrt{3.0}$, which gives $\theta_2 = 60°$.

Because their sum is 90°, $\boxed{\text{this will be a "scratch shot".}}$

66. In the reference frame of the capsule before the push, we take the positive direction in the direction the capsule will move.

(*a*) Momentum conservation gives us

$mv_{\text{astronaut}} + Mv_{\text{satellite}} = mv_{\text{astronaut}}' + Mv_{\text{satellite}}'$,

$0 + 0 = (140\ \text{kg})(-2.50\ \text{m/s}) + (1800\ \text{kg})v_{\text{satellite}}'$, which gives $v_{\text{satellite}}' = \boxed{0.194\ \text{m/s}.}$

(*b*) We find the force on the satellite from

$F_{\text{satellite}} = \Delta p_{\text{satellite}}/\Delta t = m_{\text{satellite}}\,\Delta v_{\text{satellite}}/\Delta t$

$= (1800\ \text{kg})(0.194\ \text{m/s} - 0)/(0.500\ \text{s}) = \boxed{700\ \text{N}.}$

There will be an equal but opposite force on the astronaut.

67. For each of the elastic collisions with a step, conservation of kinetic energy means that the velocity reverses direction but has the same magnitude. Thus the golf ball always rebounds to the height from which it started. Thus, after five bounces, the bounce height will be $\boxed{4.00\ \text{m}.}$

68. For the elastic collision of the two balls, we use momentum conservation:

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2';$

$mv_1 + 0 = m(-v_1/4) + m_2v_2'$, or $m_2v_2' = 5mv_1/4.$

Because the collision is elastic, the relative speed does not change:

$v_1 - 0 = -(v_1' - v_2');\ v_1 = v_2' - (-v_1/4)$, or $v_2' = 3v_1/4.$

Combining these two equations, we get $\boxed{m_2 = 5m/3.}$

69. On the horizontal surface, the normal force on a car is $F_N = mg$. We find the speed of a car immediately after the collision by using the work-energy principle for the succeeding sliding motion:

$W_{fr} = \Delta KE;$

$-\mu_k mgd = 0 - \frac{1}{2}mv^2.$

We use this to find the speeds of the cars after the collision:

$0.60(9.80\ m/s^2)(15\ m) = \frac{1}{2}v_A'^2$, which gives $v_A' = 13.3\ m/s$;

$0.60(9.80\ m/s^2)(30\ m) = \frac{1}{2}v_B'^2$, which gives $v_B' = 18.8\ m/s$.

For the collision, we use momentum conservation:

$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$;

$(2000\ kg)v_A + 0 = (2000\ kg)(13.3\ m/s) + (1000\ kg)(18.8\ m/s)$, which gives $v_A = 22.7\ m/s$.

We find the speed of car A before the brakes were applied by using the work-energy principle for the preceding sliding motion:

$W_{fr} = \Delta KE;$

$-\mu_k m_A gd = \frac{1}{2}m_A v_A^2 - \frac{1}{2}m_A v_{A0}^2;$

$-0.60(9.80\ m/s^2)(15\ m) = \frac{1}{2}[(22.7\ m/s)^2 - v_{A0}^2],$

which gives $v_{A0} = 26.3\ m/s = 94.7\ km/h =$ **59 mi/h.**

71. (*a*) We take the direction of the meteor for the positive direction.

For this perfectly inelastic collision, we use momentum conservation:

$M_{meteor}v_{meteor} + M_{Earth}v_{Earth} = (M_{meteor} + M_{Earth})V;$

$(10^8\ kg)(15 \times 10^3\ m/s) + 0 = (10^8\ kg + 6.0 \times 10^{24}\ kg)V$, which gives **$V = 2.5 \times 10^{-13}$ m/s.**

(*b*) The fraction transformed was

$\text{fraction} = \Delta KE_{Earth}/KE_{meteor} = \frac{1}{2}m_{Earth}V^2/\frac{1}{2}m_{meteor}v_{meteor}^2$

$= (6.0 \times 10^{24}\ kg)(2.5 \times 10^{-13}\ m/s)^2/(10^8\ kg)(15 \times 10^3\ m/s)^2 =$ **1.7×10^{-17}.**

(*c*) The change in the Earth's kinetic energy was

$\Delta KE_{Earth} = \frac{1}{2}m_{Earth}V^2$

$= \frac{1}{2}(6.0 \times 10^{24}\ kg)(2.5 \times 10^{-13}\ m/s)^2 =$ **0.19 J.**

72. Momentum conservation gives

$0 = m_1 v_1' + m_2 v_2'$, or $v_2'/v_1' = -m_1/m_2$.

The ratio of kinetic energies is

$KE_2/KE_1 = \frac{1}{2}m_2 v_2'^2/\frac{1}{2}m_1 v_1'^2 = (m_2/m_1)(v_2'/v_1')^2 = 2.$

When we use the result from momentum, we get

$(m_2/m_1)(-m_1/m_2)^2 = 2$, which gives $m_1/m_2 =$ **2.**

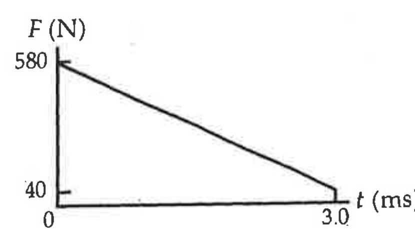
73. (*b*) The force would become zero at

$t = 580/(1.8 \times 10^5) = 3.22 \times 10^{-3}$ s.

At $t = 3.0 \times 10^{-3}$ s the force is

$580 - (1.8 \times 10^5)(3.0 \times 10^{-3}\ s) = +40$ N.

The impulse is the area under the F vs. t curve, and consists of a triangle and a rectangle:



$\text{Impulse} = \frac{1}{2}(580\ N - 40\ N)(3.0 \times 10^{-3}\ s) +$

$(40\ N)(3.0 \times 10^{-3}\ s) =$ **0.93 N·s.**

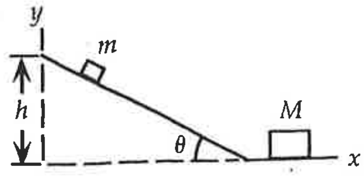
(*c*) We find the mass of the bullet from

$\text{Impulse} = \Delta p = m\,\Delta v;$

$0.93\ N \cdot s = m(220\ m/s - 0)$, which gives $m = 4.23 \times 10^{-3}\ kg =$ **4.2 g.**

74. We find the speed for falling or rising through a height h from energy conservation:

$\frac{1}{2}mv^2 = mgh$, or $v^2 = 2gh$.



(*a*) The speed of the first block after sliding down the incline and just before the collision is

$v_1 = [2(9.80\ \text{m/s}^2)(3.60\ \text{m})]^{1/2} = 8.40\ \text{m/s}.$

For the elastic collision of the two blocks, we use momentum conservation:

$mv_1 + Mv_2 = mv_1' + Mv_2'$;

$(2.20\ \text{kg})(8.40\ \text{m/s}) + (7.00\ \text{kg})(0) = (2.20\ \text{kg})v_1' + (7.00\ \text{kg})v_2'$.

Because the collision is elastic, the relative speed does not change:

$v_1 - v_2 = -(v_1' - v_2')$, or $8.40\ \text{m/s} - 0 = v_2' - v_1'$.

Combining these two equations, we get

$\boxed{v_1' = -4.38\ \text{m/s},\ v_2' = 4.02\ \text{m/s}.}$

(*b*) We find the height of the rebound from

$v_1'^2 = 2gh'$;

$(-4.38\ \text{m/s})^2 = 2(9.80\ \text{m/s}^2)h'$, which gives $h' = 0.979$ m.

The distance along the incline is

$d = h'/\sin\theta = (0.979\ \text{m})/\sin 30° = \boxed{1.96\ \text{m.}}$

75. Because energy is conserved for the motion up and down the incline, mass m will return to the level with the speed $-v_1'$. For a second collision to occur, mass m must be moving faster than mass M: $-v_1' \geq v_2'$.

In the first collision, the relative speed does not change:

$v_1 - 0 = -(v_1' - v_2')$, or $-v_1' = v_1 - v_2'$,

so the condition becomes $v_1 - v_2' \geq v_2'$, or $v_1 \geq 2v_2'$.

For the first collision, we use momentum conservation:

$mv_1 + 0 = mv_1' + Mv_2'$, or $v_1 - v_1' = (M/m)v_2'$.

When we use the two versions of the condition, we get $v_1 - v_1' \geq 3v_2'$, so we need

$(M/m) \geq 3$, or $\boxed{m \leq M/3.}$

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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

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

$\frac{1}{2}mv_i^2 + mgy_i = \frac{1}{2}mv_f^2 + mgy_f$;

$\frac{1}{2}mv_i^2 + m(9.80\ \text{m/s}^2)(0) = \frac{1}{2}m(6.5\ \text{m/s})^2 + m(9.80\ \text{m/s}^2)(1.1\ \text{m})$, which gives $v_i = \boxed{8.0\ \text{m/s.}}$

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

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

$\frac{1}{2}(v_f^2 - 0) = -(9.80\ \text{m/s}^2)(0 - 18\ \text{m})$, which gives $v_f = \boxed{19\ \text{m/s.}}$

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

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

$F_{air}(18\ \text{m}) = \frac{1}{2}(0.20\ \text{kg})[(10.0\ \text{m/s})^2 - 0] + (0.20\ \text{kg})(9.80\ \text{m/s}^2)(0 - 18\ \text{m})$,

which gives $F_{air} = \boxed{-1.4\ \text{N.}}$

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

$0 = \Delta KE + \Delta PE = (\frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2) + mg(h_1 - h_0)$, or

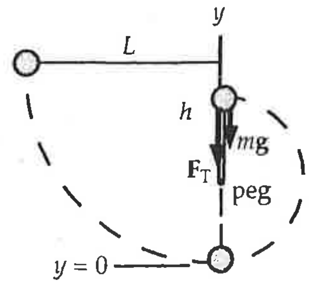
$\frac{1}{2}(v_1^2 - 0) = -g(0 - L)$, which gives $v_1 =$ $\boxed{(2gL)^{1/2}}$.

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

$0 = \Delta KE + \Delta PE = (\frac{1}{2}mv_2^2 - \frac{1}{2}mv_0^2) + mg(h_2 - h_0)$, or

$\frac{1}{2}(v_2^2 - 0) = -g[2(L - h) - L] = g(2h - L) = 0.60gL$,

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



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

$W = \Delta PE = mg(h_f - h_i) = (65\text{ kg})(9.80\text{ m/s}^2)(3900\text{ m} - 2200\text{ m}) =$ $\boxed{1.1 \times 10^6\text{ J}}$.

(b) We find the power from

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

(c) We find the power input from

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

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

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

$KE_i + PE_i = KE_f + PE_f$;

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

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

$KE_i + PE_i = KE_f + PE_f$;

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

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

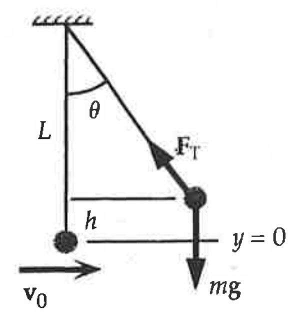
(a) Because the tension in the vine does no work, energy is conserved, so we have

$KE_i + PE_i = KE_f + PE_f$;

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

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

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



(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

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

(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

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

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

$P = W/t = \Delta PE/t = mg(h_f - h_i)/t$

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