CHAPTER 4

1. If we select the sled and child as the object, we apply Newton's second law to find the force:
   ·$F = ma$;
   $F = (60.0\text{ kg})(1.15\text{ m/s}^2) =$ 69.0 N.

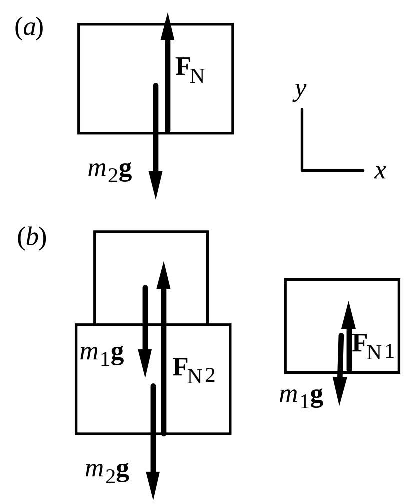
2. If we select the bike and rider as the object, we apply Newton's second law to find the mass:
   ·$F = ma$;
   $255\text{ N} = m(2.20\text{ m/s}^2)$, which gives $m = 116$ kg.

3. We apply Newton's second law to the object:
   ·$F = ma$;
   $F = (9.0 \times 10^{-3}\text{ kg})(10{,}000)(9.80\text{ m/s}^2) =$ 8.8×10^2 N.

4. Without friction, the only horizontal force is the tension. We apply Newton's second law to the car:
   ·$F = ma$;
   $F_T = (1050\text{ kg})(1.20\text{ m/s}^2) =$ 1.26×10^3 N.

5. We find the weight from the value of g.
   (*a*) Earth: $F_G = mg = (66\text{ kg})(9.80\text{ m/s}^2) =$ 6.5×10^2 N.
   (*b*) Moon: $F_G = mg = (66\text{ kg})(1.7\text{ m/s}^2) =$ 1.1×10^2 N.
   (*c*) Mars: $F_G = mg = (66\text{ kg})(3.7\text{ m/s}^2) =$ 2.4×10^2 N.
   (*d*) Space: $F_G = mg = (66\text{ kg})(0\text{ m/s}^2) =$ 0.

6. (*a*) The weight of the box depends on the value of g:
   $F_G = m_2g = (20.0\text{ kg})(9.80\text{ m/s}^2) =$ 196 N.
   We find the normal force from
   ·$F_y = ma_y$;
   $F_N - m_2g = 0$, which gives $F_N = m_2g =$ 196 N.
   (*b*) We select both blocks as the object and apply Newton's second law:
   ·$F_y = ma_y$;
   $F_{N2} - m_1g - m_2g = 0$, which gives
   $F_{N2} = (m_1 + m_2)g = (10.0\text{ kg} + 20.0\text{ kg})(9.80\text{ m/s}^2) =$ 294 N.
   If we select the top block as the object, we have
   ·$F_y = ma_y$;
   $F_{N1} - m_1g = 0$, which gives
   $F_{N1} = m_1g = (10.0\text{ kg})(9.80\text{ m/s}^2) =$ 98.0 N.



7. The acceleration can be found from the car's one-dimensional motion:

   $v = v_0 + at$;

   $0 = [(90 \text{ km/h})/(3.6 \text{ ks/h})] + a(8.0 \text{ s})$, which gives $a = -3.13 \text{ m/s}^2$.

   We apply Newton's second law to find the required average force

   $\cdot F = ma$;

   $F = (1100 \text{ kg})(-3.13 \text{ m/s}^2) =$ -3.4×10^3 N.

   The negative sign indicates that the force is opposite to the velocity.

8. The required average acceleration can be found from the one-dimensional motion:

   $v^2 = v_0^2 + 2a(x - x_0)$;

   $(175 \text{ m/s})^2 = 0 + 2a(0.700 \text{ m} - 0)$, which gives $a = 2.19 \times 10^4 \text{ m/s}^2$.

   We apply Newton's second law to find the required average force

   $\cdot F = ma$;

   $F = (7.00 \times 10^{-3} \text{ kg})(2.19 \times 10^4 \text{ m/s}^2) =$ 153 N.

9. Because the line snapped, the tension $F_T > 22$ N.

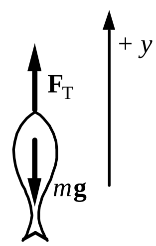
   We write $\cdot \mathbf{F} = m\mathbf{a}$ from the force diagram for the fish:

   y-component: $F_T - mg = ma$, or $F_T = m(a + g)$.

   We find the minimum mass from the minimum tension:

   $22 \text{ N} = m_{min}(4.5 \text{ m/s}^2 + 9.80 \text{ m/s}^2)$, which gives $m_{min} = 1.5$ kg.

   Thus we can say $m > 1.5$ kg.



10. The average acceleration of the ball can be found from the one-dimensional motion:

    $v^2 = v_0^2 + 2a(x - x_0)$;

    $0 = (45.0 \text{ m/s})^2 + 2a(0.110 \text{ m} - 0)$, which gives $a = -9.20 \times 10^3 \text{ m/s}^2$.

    We apply Newton's second law to find the required average force applied to the ball:

    $\cdot F = ma$;

    $F = (0.140 \text{ kg})(-9.20 \times 10^3 \text{ m/s}^2) = -1.29 \times 10^3$ N.

    The force on the glove has the same magnitude but the opposite direction:

    1.29×10^3 N in the direction of the ball's motion.

11. The average acceleration of the shot can be found from the one-dimensional motion:

    $v^2 = v_0^2 + 2a(x - x_0)$;

    $(13 \text{ m/s})^2 = 0 + 2a(2.8 \text{ m} - 0)$, which gives $a = 30.2 \text{ m/s}^2$.

    We apply Newton's second law to find the required average force applied to the shot:

    $\cdot F = ma$;

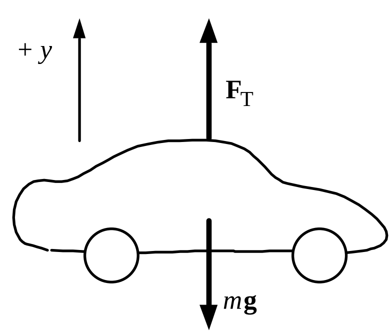
    $F = (7.0 \text{ kg})(30.2 \text{ m/s}^2) =$ 2.1×10^2 N.

12. We write $\cdot \mathbf{F} = m\mathbf{a}$ from the force diagram for the car:

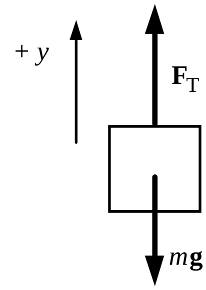
    y-component: $F_T - mg = ma$, or

    $F_T = m(a + g) = (1200 \text{ kg})(0.80 \text{ m/s}^2 + 9.80 \text{ m/s}^2)$

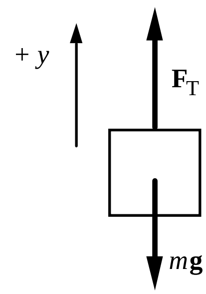
    $= 1.3 \times 10^4$ N.



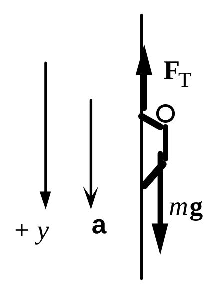
13. We write ·**F** = $m\mathbf{a}$ from the force diagram for the bucket:
    y-component: $F_T - mg = ma$;
    63 N – (10 kg)(9.80 m/s^2) = (10 kg)a,
    which gives a = – 3.5 m/s^2 (down).



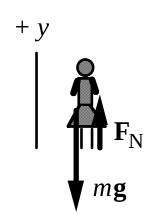
14. The maximum tension will be exerted by the motor when the elevator is accelerating upward.
    We write ·**F** = $m\mathbf{a}$ from the force diagram for the elevator:
    y-component: $F_{Tmax} - mg = ma$, or
    $F_{Tmax} = m(a + g)$ = (4850 kg)(0.0600 + 1)(9.80 m/s^2) = 5.04×10^4 N.
    The minimum tension will be exerted by the motor when the elevator is accelerating downward. We write ·**F** = $m\mathbf{a}$ from the force diagram for the car:
    y-component: $F_{Tmin} - mg = ma$, or
    $F_{Tmin} = m(a + g)$ = (4850 kg)(– 0.0600 + 1)(9.80 m/s^2) = 4.47×10^4 N.



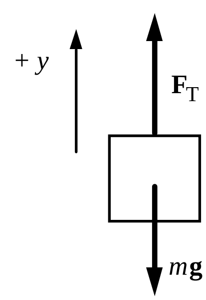
15. To have the tension less than the weight, the thief must have a downward acceleration so that the tension F_T ² $m_{effective}g$.
    We write ·**F** = $m\mathbf{a}$ from the force diagram for the thief:
    y-component: $mg - F_T = ma$.
    We find the minimum acceleration from the minimum tension:
    $mg - m_{effective}g = ma_{min}$;
    (75 kg – 58 kg)(9.80 m/s^2)= (75 kg)a_{min}, which gives a_{min} = 2.2 m/s^2.
    Thus we can say a (downward) ³ 2.2 m/s^2.



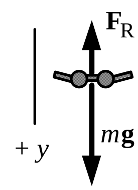
16. The scale reads the force the person exerts on the scale. From Newton's third law, this is also the magnitude of the normal force acting on the person.
    We write ·**F** = $m\mathbf{a}$ from the force diagram for the person:
    y-component: $F_N - mg = ma$, or
    $0.75mg - mg = ma$, which gives a = (0.75 – 1)(9.80 m/s^2) = – 2.5 m/s^2 (down).



17. The maximum tension will be exerted by the motor when the elevator has the maximum acceleration.
    We write ·**F** = $m\mathbf{a}$ from the force diagram for the elevator:
    y-component: $F_{Tmax} - mg = ma_{max}$;
    21,750 N – (2100 kg)(9.80 m/s^2) = (2100 kg)a_{max},
    which gives a_{max} = 0.557 m/s^2.



18. With down positive, we write $·\mathbf{F} = m\mathbf{a}$ from the force diagram for the skydivers:



$mg - F_R = ma;$

(*a*) Before the parachute opens, we have

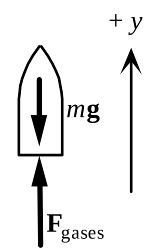
$mg - (mg = ma$, which gives $a = +g = 7.4\ \text{m/s}^2$ (down).

(*b*) Falling at constant speed means the acceleration is zero, so we have

$mg - F_R = ma = 0$, which gives

$F_R = mg = (120.0\ \text{kg})(9.80\ \text{m/s}^2) =$ 1176 N.

19. From Newton's third law, the gases will exert a force on the rocket that is equal and opposite to the force the rocket exerts on the gases.



(*a*) With up positive, we write $·\mathbf{F} = m\mathbf{a}$ from the force diagram for the rocket:

$F_{gases} - mg = ma;$

$33 \times 10^6\ \text{N} - (2.75 \times 10^6\ \text{kg})(9.80\ \text{m/s}^2) = (2.75 \times 10^6\ \text{kg})a,$

which gives $a = 2.2\ \text{m/s}^2$.

(*b*) If we ignore the mass of the gas expelled and any change in g, we can assume a constant acceleration. We find the velocity from

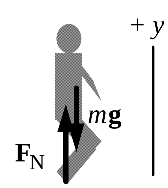
$v = v_0 + at = 0 + (2.2\ \text{m/s}^2)(8.0\ \text{s}) =$ 18 m/s.

(*c*) We find the time to achieve the height from

$y = y_0 + v_0 t + !at^2;$

$9500\ \text{m} = 0 + 0 + !(2.2\ \text{m/s}^2)t^2$, which gives $t = 93\ \text{s}$.

20. We find the velocity necessary for the jump from the motion when the person leaves the ground to the highest point, where the velocity is zero:



$v^2 = v_{jump}^2 + 2(-g)h;$

$0 = v_{jump}^2 + 2(-9.80\ \text{m/s}^2)(0.80\ \text{m})$, which gives $v_{jump} = 3.96\ \text{m/s}$.

We can find the acceleration required to achieve this velocity during the crouch from

$v_{jump}^2 = v_0^2 + 2a(y - y_0);$

$(3.96\ \text{m/s})^2 = 0 + 2a(0.20\ \text{m} - 0)$, which gives $a = 39.2\ \text{m/s}^2$.

Using the force diagram for the person during the crouch, we can write $·\mathbf{F} = m\mathbf{a}$:

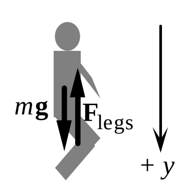
$F_N - mg = ma;$

$F_N - (66\ \text{kg})(9.80\ \text{m/s}^2) = (66\ \text{kg})(39.2\ \text{m/s}^2)$, which gives $F_N = 3.2 \times 10^3\ \text{N}$.

From Newton's third law, the person will exert an equal and opposite force on the ground:

3.2×10^3 N downward.

21. (*a*) We find the velocity just before striking the ground from



$v_1^2 = v_0^2 + 2(-g)h;$

$v_1^2 = 0 + 2(9.80\ \text{m/s}^2)(4.5\ \text{m})$, which gives $v_1 =$ 9.4 m/s.

(*b*) We can find the average acceleration required to bring the person to rest from

$v^2 = v_1^2 + 2a(y - y_0);$

$0 = (9.4\ \text{m/s})^2 + 2a(0.70\ \text{m} - 0)$, which gives $a = -63\ \text{m/s}^2$.

Using the force diagram for the person during the crouch, we can write $·\mathbf{F} = m\mathbf{a}$:

$mg - F_{legs} = ma;$

$(45\ \text{kg})(9.80\ \text{m/s}^2) - F_{legs} = (45\ \text{kg})(-63\ \text{m/s}^2)$, which gives $F_{legs} = 3.3 \times 10^3\ \text{N}$ up.

22. (*a*) If we assume that he accelerates for a time t_1 over the first 50 m and reaches a top speed of v, we have

$$x_1 = \tfrac{1}{2}(v_0 + v)t_1 = \tfrac{1}{2}vt_1, \quad \text{or} \quad t_1 = 2x_1/v = 2(50\text{ m})/v = (100\text{ m})/v.$$

Because he maintains this top speed for the last 50 m, we have

$$t_2 = (50\text{ m})/v.$$

Thus the total time is $T = t_1 + t_2 = (100\text{ m})/v + (50\text{ m})/v = 10.0\text{ s}$.

When we solve for v, we get $v = 15.0\text{ m/s}$; so the acceleration time is

$$t_1 = (100\text{ m})/(15.0\text{ m/s}) = 6.67\text{ s}.$$

We find the constant acceleration for the first 50 m from

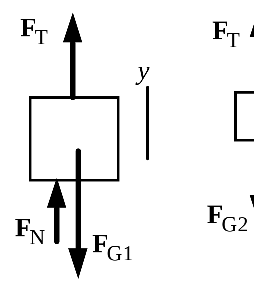
$$a = \Delta v/\Delta t = (15.0\text{ m/s} - 0)/(6.67\text{ s}) = 2.25\text{ m/s}^2.$$

We find the horizontal force component that will produce this acceleration from

$$F = ma = (65\text{ kg})(2.25\text{ m/s}^2) = 1.5 \times 10^2\text{ N}.$$

(*b*) As we found in part (*a*): $v = 15.0\text{ m/s}$.

23. If the boxes do not move, the acceleration is zero.
Using the force diagrams, we write $\Sigma\mathbf{F} = m\mathbf{a}$.



For the hanging box, we have

$$F_T - F_{G2} = 0, \quad \text{or} \quad F_T = F_{G2}.$$

For the box on the floor, we have

$$F_T - F_{G1} + F_N = 0, \quad \text{or} \quad F_N = F_{G1} - F_T = F_{G1} - F_{G2}.$$

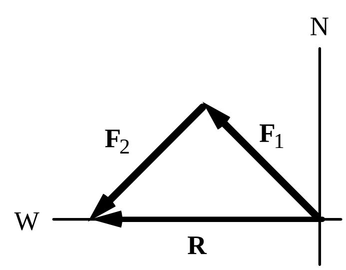
(*a*) $F_N = 70\text{ N} - 30\text{ N} = 40\text{ N}$.

(*b*) $F_N = 70\text{ N} - 60\text{ N} = 10\text{ N}$.

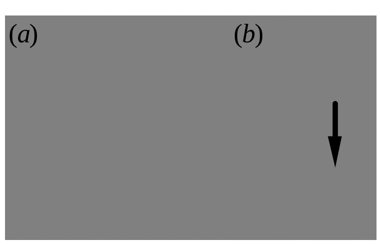
(*c*) $F_N = 70\text{ N} - 90\text{ N} = -20\text{ N}$.

Because the floor can only push up on the box, it is not possible to have a negative normal force. Thus the normal force is 0; the box will leave the floor and accelerate upward.

24. In order for the resultant to have no northerly component, the second force must have a northerly component equal in magnitude to that of the first force but pointing toward the south. Because the magnitudes of both the forces are equal and their northerly components are equal, the westerly components must also be equal. From the symmetry, the second force must be in the southwesterly direction.

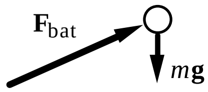


25.



26.

(*a*)



(*b*)

Note that we ignore air resistance.

27. (*a*) For the components of the net force we have

$F_{ax} = -F_1 = -10.2$ N;

$F_{ay} = -F_2 = -16.0$ N.

We find the magnitude from

$F_a{}^2 = F_{ax}{}^2 + F_{ay}{}^2 = (-10.2\text{ N})^2 + (-16.0\text{ N})^2$,

which gives $F_a = 19.0$ N.

We find the direction from

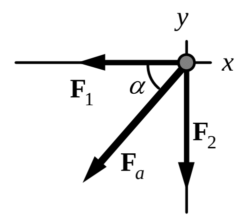
$\tan\alpha = |F_{ay}|/|F_{ax}| = (16.0\text{ N})/(10.2\text{ N}) = 1.57$,

which gives $\alpha = 57.5°$ below $-x$-axis.

The acceleration will be in the direction of the net force:

$a_a = F_a/m = (19.0\text{ N})/(27.0\text{ kg}) =$ 0.702 m/s², 57.5° below $-x$-axis.

(*a*)



(*b*) For the components of the net force we have

$F_{bx} = F_1\cos\theta = (10.2\text{ N})\cos 30° = 8.83$ N;

$F_{by} = F_2 - F_1\sin\theta = 16.0\text{ N} - (10.2\text{ N})\sin 30° = 10.9$ N.

We find the magnitude from

$F_b{}^2 = F_{bx}{}^2 + F_{by}{}^2 = (8.83\text{ N})^2 + (10.9\text{ N})^2$,

which gives $F_b = 14.0$ N.

We find the direction from

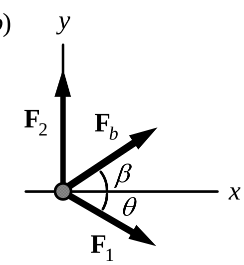
$\tan\beta = |F_{by}|/|F_{bx}| = (10.9\text{ N})/(8.83\text{ N}) = 1.23$,

which gives $\beta = 51.0°$ above $+x$-axis.

The acceleration will be in the direction of the net force:

$a_b = F_b/m = (14.0\text{ N})/(27.0\text{ kg}) =$ 0.519 m/s², 51.0° above $+x$-axis.

(*b*)



28.

(*b*) Because the velocity is constant, the acceleration is zero.

We write ·**F** = *m***a** from the force diagram for the mower:

x-component: $F\cos\theta - F_{fr} = ma = 0$, which gives

$F_{fr} = (88.0\text{ N})\cos 45° =$ 62.2 N.

(*c*) y-component: $F_N - mg - F\sin\theta = ma = 0$, which gives

$F_{fr} = (14.5\text{ kg})(9.80\text{ m/s}^2) + (88.0\text{ N})\sin 45° =$ 204 N.

(*d*) We can find the acceleration from the motion of the mower:

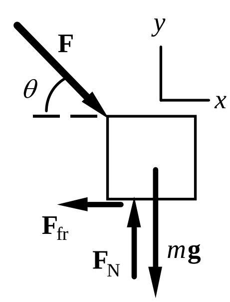
$a = Æv/Æt = (1.5\text{ m/s} - 0)/(2.5\text{ s}) = 0.60\text{ m/s}^2$.

For the x-component of ·**F** = *m***a** we now have

$F\cos\theta - F_{fr} = ma$;

$F\cos 45° - 62.2\text{ N} = (14.5\text{ kg})(0.60\text{ m/s}^2)$, which gives $F =$ 100 N.

(*a*)



29. (*a*) We find the horizontal acceleration from the horizontal component of the force exerted on the sprinter, which is the reaction to the force the sprinter exerts on the block:

$F \cos \theta = ma$;

(800 N) cos 22° = (65 kg)a, which gives a = 11 m/s^2.

(*b*) For the motion of the sprinter we can write

$v = v_0 + at = 0 + (11.4\ \text{m/s}^2)(0.38\ \text{s}) =$ 4.3 m/s.

30. (*a*) Because the buckets are at rest, the acceleration is zero.

We write ·**F** = m**a** from the force diagram for each bucket:

lower bucket: $F_{T2} - m_2 g = m_2 a = 0$, which gives

$F_{T2} = m_2 g = (3.0\ \text{kg})(9.80\ \text{m/s}^2) =$ 29 N.

upper bucket: $F_{T1} - F_{T2} - m_1 g = m_1 a = 0$, which gives

$F_{T1} = F_{T2} + m_1 g = 29\ \text{N} + (3.0\ \text{kg})(9.80\ \text{m/s}^2) =$ 58 N.

(*b*) The two buckets must have the same acceleration.

We write ·**F** = m**a** from the force diagram for each bucket:

lower bucket: $F_{T2} - m_2 g = m_2 a$, which gives

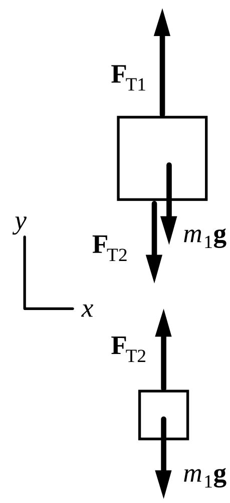
$F_{T2} = m_2(g + a)$

$= (3.0\ \text{kg})(9.80\ \text{m/s}^2 + 1.60\ \text{m/s}^2) =$ 34 N.

upper bucket: $F_{T1} - F_{T2} - m_1 g = m_1 a$, which gives

$F_{T1} = F_{T2} + m_1(g + a)$

$= 34\ \text{N} + (3.0\ \text{kg})(9.80\ \text{m/s}^2 + 1.60\ \text{m/s}^2) =$ 68 N.



31. (*a*) We select the helicopter and the car as the system.

We write ·**F** = m**a** from the force diagram:

$F_{air} - m_h g - m_c g = (m_h + m_c)a$, which gives

$F_{air} = (m_h + m_c)(a + g)$

$= (6500\ \text{kg} + 1200\ \text{kg})(0.60\ \text{m/s}^2 + 9.80\ \text{m/s}^2)$

$=$ 8.01×10^4 N.

(*b*) We select the car as the system.

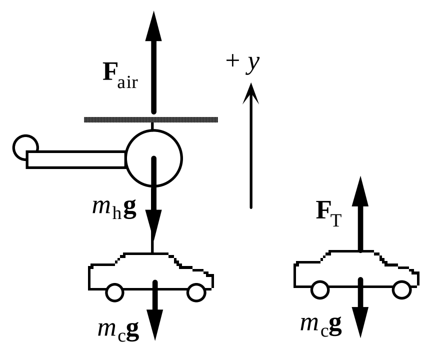
We write ·**F** = m**a** from the force diagram:

$F_T - m_c g = m_c a$, which gives

$F_T = m_c(a + g)$

$= (1200\ \text{kg})(0.60\ \text{m/s}^2 + 9.80\ \text{m/s}^2)$

$=$ 1.25×10^4 N.



32. (*a*) Because the speed is constant, the acceleration is zero.

We write ·**F** = m**a** from the force diagram:

$F_T + F_T - mg = ma = 0$, which gives

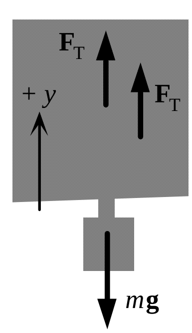
$F_T = !mg = !(65\ \text{kg})(9.80\ \text{m/s}^2) =$ 3.2×10^2 N.

(*b*) Now we have:

$F_T' + F_T' - mg = ma$;

$2(1.10)(!mg) - mg = ma$, which gives

$a = 0.10g = 0.10(9.80\ \text{m/s}^2) =$ 0.98 m/s^2.



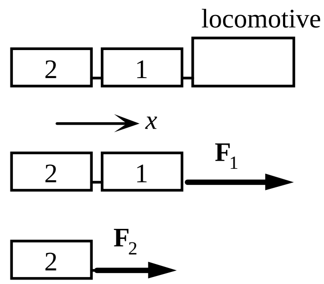
33. If we select the first and second cars as the system, the only horizontal force is the tension in the coupling between the locomotive and the first car. From the force diagram, we have

    $\cdot F_x = (m_1 + m_2)a_x$, or $F_1 = (m + m)a = 2ma$.

    If we select the second car as the system, the only horizontal force is the tension in the coupling between the first car and the second car. From the force diagram, we have

    $\cdot F_x = m_2 a_x$, or $F_2 = ma$.

    Thus we have $F_1/F_2 = 2ma/ma = 2$, for any nonzero acceleration.



34. From the motion of the car we can find its acceleration, which is the acceleration of the dice:

    $v = v_0 + at$;

    $(20\ \text{m/s}) = 0 + a(5.0\ \text{s})$, which gives $a = 4.0\ \text{m/s}^2$.

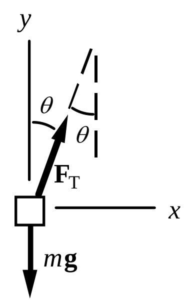
    We write $\cdot \mathbf{F} = m\mathbf{a}$ from the force diagram for the dice:

    x-component: $F_T \sin\theta = ma$;

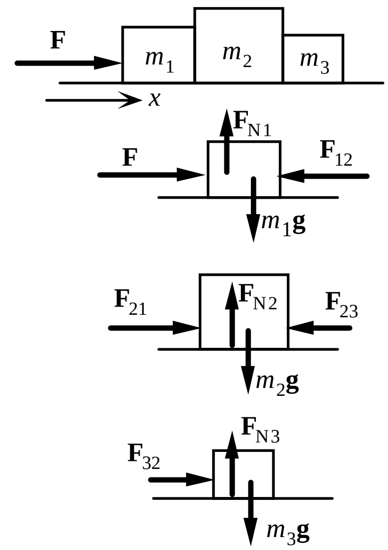
    y-component: $F_T \cos\theta - mg = 0$.

    If we divide the two equations, we get

    $\tan\theta = a/g = (4.0\ \text{m/s}^2)/(9.80\ \text{m/s}^2) = 0.408$, which gives $\theta = 22°$.



35. (*a*)



(*b*) If we select all three blocks as the system, we have

$\cdot F_x = ma_x$: $F = (m_1 + m_2 + m_3)a$,

which gives $a = F/(m_1 + m_2 + m_3)$.

(*c*) For the three blocks individually, for $\cdot F_x = ma_x$ we have

$F_{net1} = m_1 a = m_1 F/(m_1 + m_2 + m_3)$;

$F_{net2} = m_2 a = m_2 F/(m_1 + m_2 + m_3)$;

$F_{net3} = m_3 a = m_3 F/(m_1 + m_2 + m_3)$.

(*d*) From the force diagram for block 1 we have

$F_{net1} = F - F_{12} = m_1 a$, which gives

$F_{12} = F - m_1 a = F - m_1 F/(m_1 + m_2 + m_3)]$

$= F(m_2 + m_3)/(m_1 + m_2 + m_3)$.

This is also F_{21} (Newton's third law).

From the force diagram for block 2 we have

$F_{net2} = F_{21} - F_{23} = m_2 a$, which gives

$F_{23} = F_{21} - m_2 a = F - m_1 a - m_2 a$

$= F - (m_1 + m_2)F/(m_1 + m_2 + m_3)]$

$= Fm_3/(m_1 + m_2 + m_3)$.

This is also F_{32} (Newton's third law).

(*e*) When we use the given values, we get

$a = F/(m_1 + m_2 + m_3) = (96.0\ \text{N})/(12.0\ \text{kg} + 12.0\ \text{kg} + 12.0\ \text{kg}) =$ $2.67\ \text{m/s}^2$.

$F_{net1} = m_1 a = (12.0\ \text{kg})(2.67\ \text{m/s}^2) = 32\ \text{N}$.

$F_{net2} = m_2 a = (12.0\ \text{kg})(2.67\ \text{m/s}^2) = 32\ \text{N}$.

$F_{net3} = m_3 a = (12.0\ \text{kg})(2.67\ \text{m/s}^2) = 32\ \text{N}$.

Because the blocks have the same mass and the same acceleration, we expect

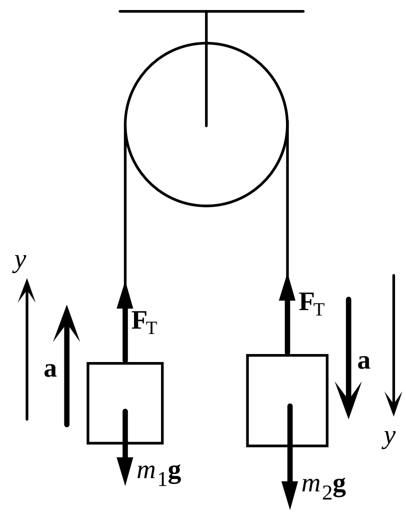
$F_{net1} = F_{net2} = F_{net3} = 32\ \text{N}$.

For the forces between the blocks we have

$F_{21} = F_{12} = F - m_1 a = 96.0\ \text{N} - (12.0\ \text{kg})(2.67\ \text{m/s}^2) =$ $64\ \text{N}$.

$F_{32} = F_{23} = F - m_1 a - m_2 a = 96.0\ \text{N} - (12.0\ \text{kg})(2.67\ \text{m/s}^2) - (12.0\ \text{kg})(2.67\ \text{m/s}^2) =$ $32\ \text{N}$.

36. Forces are drawn for each of the blocks. Because the string doesn't stretch, the tension is the same at each end of the string, and the accelerations of the blocks have the same magnitude. Note that we take the positive direction in the direction of the acceleration for each block.



We write ·**F** = $m\mathbf{a}$ from the force diagram for each block:

y-component (block 1): $F_T - m_1g = m_1a;$

y-component (block 2): $m_2g - F_T = m_2a.$

By adding the equations, we find the acceleration:

$a = (m_2 - m_1)g/(m_1 + m_2)$

$= (3.2 \text{ kg} - 2.2 \text{ kg})(9.80 \text{ m/s}^2)/(3.2 \text{ kg} + 2.2 \text{ kg})$

$= 1.81 \text{ m/s}^2$ for both blocks.

For the motion of block 1 we take the origin at the ground and up positive. Until block 2 hits the ground, we have

$v_1^2 = v_{01}^2 + 2a(y_1 - y_{01})$

$= 0 + 2(1.81 \text{ m/s}^2)(3.60 \text{ m} - 1.80 \text{ m})$, which gives

$v_1 = 2.56 \text{ m/s}.$

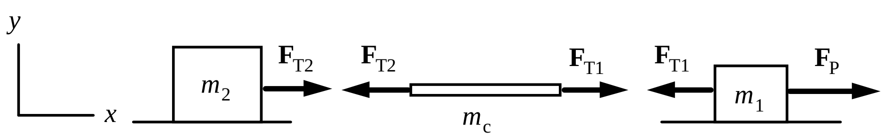
Once block 2 hits the floor, $F_T \to 0$ and block 1 will have the downward acceleration of g.

For this motion of block 1 up to the highest point reached, we have

$v^2 = v_1^2 + 2a(h - y_1)$

$0 = (2.56 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(h - 3.60 \text{ m})$, which gives $h = 3.93$ m.

37.



The blocks and the cord will have the same acceleration. If we select the two blocks and cord as the system, we have

·$F_x = ma_x$: $F_P = (m_1 + m_2 + m_c)a$, which gives

$a = F_P/(m_1 + m_2 + m_c) = (40.0 \text{ N})/(10.0 \text{ kg} + 1.0 \text{ kg} + 12.0 \text{ kg}) = 1.74 \text{ m/s}^2.$

For block 1 we have ·$F_x = ma_x$:

$F_P - F_{T1} = m_1a;$

$40.0 \text{ N} - F_{T1} = (10.0 \text{ kg})(1.74 \text{ m/s}^2)$, which gives $F_{T1} = 22.6$ N.

For block 2 we have ·$F_x = ma_x$:

$F_{T2} = m_2a;$

$F_{T2} = (12.0 \text{ kg})(1.74 \text{ m/s}^2) = 20.9$ N.

Note that we can see if these agree with the analysis of ·$F_x = ma_x$ for block 3:

$F_{T1} - F_{T2} = m_3a$:

$22.6 \text{ N} - 20.9 \text{ N} = (1.0 \text{ kg})a$, which gives $a = 1.7 \text{ m/s}^2$.

38. The friction is kinetic, so $F_{fr} = \mu_k F_N$. With constant velocity, the acceleration is zero.
Using the force diagram for the crate, we can write $\Sigma\mathbf{F} = m\mathbf{a}$:

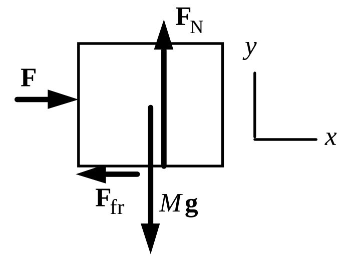
x-component: $F - \mu_k F_N = 0;$

y-component: $F_N - Mg = 0.$

Thus $F_N = Mg$, and

$F = \mu_k F_N = \mu_k Mg = (0.30)(35\text{ kg})(9.80\text{ m/s}^2) = 1.0 \times 10^2\text{ N}.$

If $\mu_k = 0$, there is no force required to maintain constant speed.



39. (*a*) In general, static friction is given by $F_{sfr} \le \mu_s F_N$. Immediately before the box starts to move, the static friction force reaches its maximum value: $F_{sfr,max} = \mu_s F_N$. For the instant before the box starts to move, the acceleration is zero.
Using the force diagram for the box, we can write $\Sigma\mathbf{F} = m\mathbf{a}$:

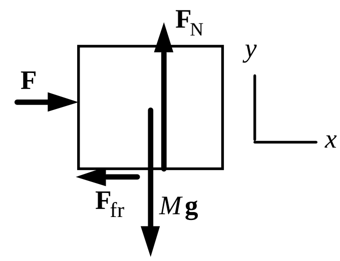
x-component: $F - \mu_s F_N = 0;$

y-component: $F_N - Mg = 0.$

Thus $F_N = Mg$, and

$F = \mu_s F_N = \mu_s Mg\,;$

$40.0\text{ N} = \mu_s(5.0\text{ kg})(9.80\text{ m/s}^2)$, which gives $\mu_s = 0.82.$

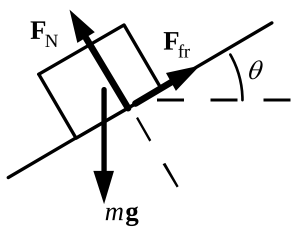


(*b*) When the box accelerates and the friction changes to kinetic, we have

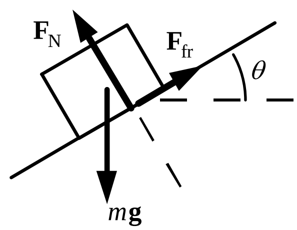
$F - \mu_k F_N = Ma;$

$40.0\text{ N} - \mu_k(5.0\text{ kg})(9.80\text{ m/s}^2) = (5.0\text{ kg})(0.70\text{ m/s}^2)$, which gives $\mu_k = 0.74.$

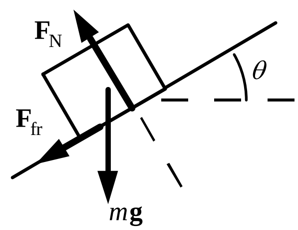
40. (*a*)



(*b*)



(*c*)



In (*a*) the friction is static and opposes the impending motion down the plane.
In (*b*) the friction is kinetic and opposes the motion down the plane.
In (*c*) the friction is kinetic and opposes the motion up the plane.

41. The drawer will suddenly open when the resisting static friction force reaches its maximum value: $F_{sfr,max} = \mu_s F_N$. Frequently drawers are stuck from pressure on the sides and top of the drawer. Here we assume that the friction force is produced only by the normal force on the bottom of the drawer.
For $\Sigma\mathbf{F} = m\mathbf{a}$ we have

x-component: $F - \mu_s F_N = 0;$

y-component: $F_N - Mg = 0.$

Thus $F_N = Mg$, and

$F = \mu_s F_N = \mu_s Mg;$

$8.0\text{ N} = \mu_s(2.0\text{ kg})(9.80\text{ m/s}^2)$, which gives $\mu_s = 0.41.$

42. We can find the required acceleration, assumed constant, from

$x = v_0t + \frac{1}{2}at^2$;

$(0.250\ \text{mi})(1610\ \text{m/mi}) = 0 + \frac{1}{2}a\,(6.0\ \text{s})^2$, which gives $a = 22.4\ \text{m/s}^2$.

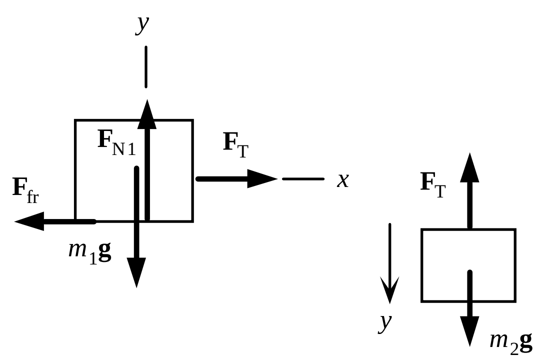
If we assume that the tires are just on the verge of slipping, $F_{\text{sfr,max}} = \mu_s F_N$, so we have

x-component: $\mu_s F_N = ma$;

y-component: $F_N - mg = 0$.

Thus we have $\mu_s = ma/mg = a/g = (22.4\ \text{m/s}^2)/(9.80\ \text{m/s}^2) =$ 2.3.

43. If motion is just about to begin, the static friction force will be maximum: $F_{\text{sfr,max}} = \mu_s F_N$, and the acceleration will be zero. We write $\Sigma\mathbf{F} = m\mathbf{a}$ from the force diagram for each block:



x-component (block 1): $F_T - \mu_s F_N = 0$;

y-component (block 1): $F_N - m_1g = 0$;

y-component (block 2): $m_2g - F_T = 0$.

Thus we see that

$F_T = \mu_s m_1 g = m_2 g$.

This allows us to find the minimum mass of body 1:

$(0.30)m_1 = 2.0$ kg, which gives $m_1 = 6.7$ kg.

44. The kinetic friction force provides the acceleration. For $\Sigma\mathbf{F} = m\mathbf{a}$ we have

x-component: $-\mu_k F_N = ma$;

y-component: $F_N - mg = 0$.

Thus we see that

$a = -\mu_k g = -(0.20)(9.80\ \text{m/s}^2) = -1.96\ \text{m/s}^2$.

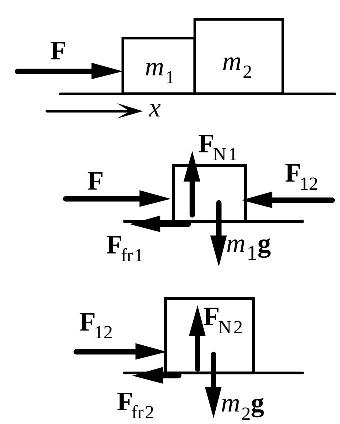
We can find the distance from the motion data:

$v^2 = v_0^2 + 2a(x - x_0)$;

$0 = (4.0\ \text{m/s})^2 + 2(-1.96\ \text{m/s}^2)(x - 0)$, which gives $x =$ 4.1 m.

45. (*a*) The two crates must have the same acceleration.

From the force diagram for crate 1 we have



x-component: $F - F_{12} - \mu_k F_{N1} = m_1 a$;

y-component: $F_{N1} - m_1 g = 0$, or $F_{N1} = m_1 g$.

From the force diagram for crate 2 we have

x-component: $F_{12} - \mu_k F_{N2} = m_2 a$;

y-component: $F_{N2} - m_2 g = 0$, or $F_{N2} = m_2 g$.

If we add the two x-equations, we get

$F - \mu_k m_1 g - \mu_k m_2 g = m_1 a + m_2 a$;

$730\ \text{N} - (0.15)(75\ \text{kg})(9.80\ \text{m/s}^2) - (0.15)(110\ \text{kg})(9.80\ \text{m/s}^2) =$

$(75\ \text{kg} + 110\ \text{kg})a$, which gives $a =$ $2.5\ \text{m/s}^2$.

(*b*) We can find the force between the crates from the x-equation for crate 2:

$F_{12} - \mu_k m_2 g = m_2 a$;

$F_{12} - (0.15)(110\ \text{kg})(9.80\ \text{m/s}^2) = (110\ \text{kg})(2.5\ \text{m/s}^2)$, which gives

$F_{12} =$ 4.4×10^2 N.

46. (*a*) If the automobile does not skid, the friction is static, with F_{sfr} ² $\mu_s F_N$. On a level road, the normal force is $F_N = mg$. The static friction force is the only force slowing the automobile and will be maximum in order to produce the minimum stopping distance. We find the acceleration from ·$F_x = ma_x$:

$- \mu_s mg = ma$, which gives $a = - \mu_s g$.

For the motion until the automobile stops, we have

$v_{final}^2 = v_0^2 + 2a(x - x_0)$;

$0 = v^2 + 2(- \mu_s g)(x_{min})$, which gives $x_{min} = v^2/2\mu_s g$.

(*b*) For the given data we have

x_{min} = [(95 km/h)/(3.6 ks/h)]^2/2(0.75)(9.80 m/s^2) = 47 m.

(*c*) The only change is in the value of g:

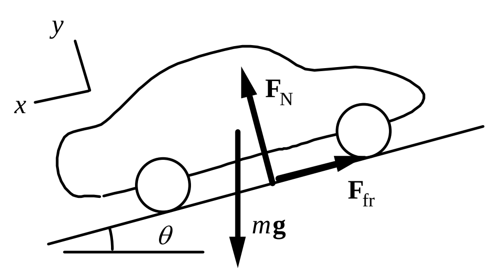
x_{min} = [(95 km/h)/(3.6 ks/h)]^2/2(0.75)(1.63 m/s^2) = 2.8×10^2 m.

47. If the crate does not slide, it must have the same acceleration as the truck. The friction is static, with F_{sfr} ² $\mu_s F_N$. On a level road, the normal force is $F_N = mg$. If we consider the crate as the system, the static friction force will be opposite to the direction of motion (to oppose the impending motion of the crate toward the front of the truck), is the only force providing the acceleration, and will be maximum in order to produce the maximum acceleration. We find the acceleration from the horizontal component of ·**F** = m**a**:

$\mu_s mg = ma$, which gives

$a = \mu_s g$ = – (0.75)(9.80 m/s^2) = – 7.4 m/s^2.

48. We simplify the forces to the three shown in the diagram. If the car does not skid, the friction is static, with F_{sfr} ² $\mu_s F_N$. The static friction force will be maximum just before the car slips. We write ·**F** = m**a** from the force diagram:



x-component: $mg \sin \theta_{max} - \mu_s F_N = 0$;

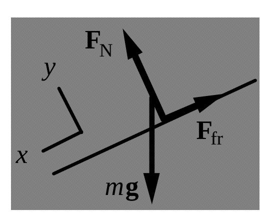
y-component: $F_N - mg \cos \theta_{max} = 0$.

When we combine these, we get

$\tan \theta_{max} = \mu_s = 0.15$, or $\theta_{max} = 8.5°$.

Thus a car will slip on any driveway with an incline greater than 8.5°. The only driveway safe to park in is Bonnie's.

49. The kinetic friction force will be up the slide to oppose the motion. We choose the positive direction in the direction of the acceleration. From the force diagram for the child, we have ·**F** = m**a**:



x-component: $mg \sin \theta - F_{fr} = ma$;

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

When we combine these, we get

$a = g \sin \theta - \mu_k g \cos \theta = g(\sin \theta - \mu_k \cos \theta)$.

For the motion of the child, we have

$v^2 = v_0^2 + 2a(x - x_0) = 0 + 2ad$, where d is the distance along the slide.

If we form the ratio for the two slides, we get

$(v_{friction}/v_{none})^2 = a_{friction}/a_{none} = (\sin \theta - \mu_k \cos \theta)/\sin \theta$;

$(!)^2 = (\sin 28° - \mu_k \cos 28°)/\sin 28°$, which gives $\mu_k = 0.40$.

50. We find the maximum permissible deceleration from the motion until the automobile stops:

$v = v_0 + at;$

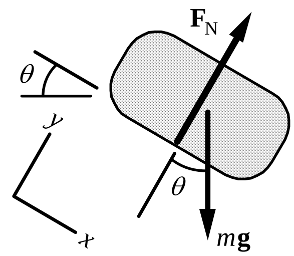
$0 = [(40\text{ km/h})/(3.6\text{ ks/h})] + a_{max}(3.5\text{ s})$, which gives $a_{max} = -3.17\text{ m/s}^2$.

The minimum time for deceleration without the cup sliding means that the static friction force, which is the force producing the deceleration of the cup, is maximum. On a level road, the normal force is $F_N = mg$. The maximum static friction force is $F_{sfr,max} = \mu_s F_N$. For the horizontal component of ·**F** = m**a**, we have

$-\mu_s mg = ma_{max}$, which gives

$\mu_s = -a_{max}/g = -(-3.17\text{ m/s}^2)/(9.80\text{ m/s}^2) =$ 0.32.

51. From the force diagram for the soap, we have ·**F** = m**a**:



x-component: $mg\sin\theta = ma;$

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

From the x-equation we find the acceleration:

$a = g\sin\theta = (9.80\text{ m/s}^2)\sin 7.3° = 1.25\text{ m/s}^2.$

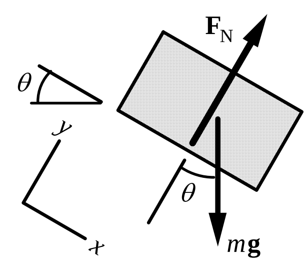
For the motion of the soap, we find the time from

$x = x_0 + v_0t + !at^2;$

$2.0\text{ m} = 0 + 0 + !(1.25\text{ m/s}^2)t^2$, which gives $t = 1.8\text{ s}$.

Because the acceleration does not depend on the mass, there will be no change.

52. (*a*) From the force diagram for the block, we have ·**F** = m**a**:



x-component: $mg\sin\theta = ma;$

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

From the x-equation we find the acceleration:

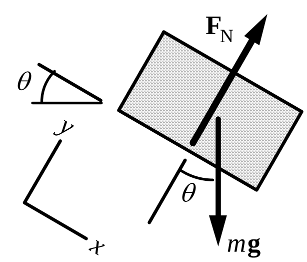
$a = g\sin\theta = (9.80\text{ m/s}^2)\sin 22.0° =$ 3.67 m/s^2.

(*b*) For the motion of the block, we find the speed from

$v^2 = v_0^2 + 2a(x - x_0);$

$v^2 = 0 + 2(3.67\text{ m/s}^2)(9.10\text{ m} - 0)$, which gives $v =$ 8.17 m/s.

53. We choose the origin for x at the bottom of the plane. Note that down the plane (the direction of the acceleration) is positive.



(*a*) From the force diagram for the block, we have ·**F** = m**a**:

x-component: $mg\sin\theta = ma;$

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

From the x-equation we find the acceleration:

$a = g\sin\theta = (9.80\text{ m/s}^2)\sin 22.0° = 3.67\text{ m/s}^2.$

For the motion of the block, we find the distance from

$v^2 = v_0^2 + 2a(x - x_0);$

$0 = (-3.0\text{ m/s})^2 + 2(3.67\text{ m/s}^2)(x - 0)$, which gives $x = -1.2\text{ m}$.

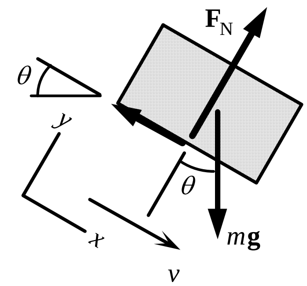
Thus the block travels 1.2 m up the plane.

(*b*) We find the time to return to the bottom from

$x = x_0 + v_0t + !at^2;$

$0 = 0 + (-3.0\text{ m/s})t + !(3.67\text{ m/s}^2)t^2$, which gives $t = 0$ (the start), and $t = 1.6\text{ s}$.

54. Note that down is the positive direction in both problems. While the block is sliding down, friction will be up the plane, opposing the motion. The x-component of the force equation becomes



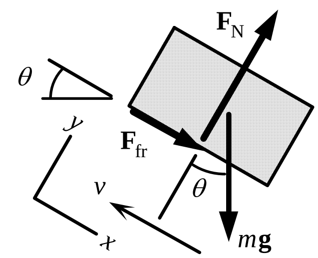
x-component: $mg \sin \theta - F_{fr} = ma_{down}$.

Thus the acceleration is now

$a_{down} = g \sin \theta - \mu_k g \cos \theta = g(\sin \theta - \mu_k \cos \theta)$

$= (9.80 \text{ m/s}^2)[\sin 22.0° - (0.20) \cos 22.0°] = 1.85 \text{ m/s}^2$.

While the block is sliding up, friction will be down the plane, opposing the motion. The x-component of the force equation becomes



x-component: $mg \sin \theta + F_{fr} = ma_{up}$.

Thus the acceleration is now

$a_{up} = g \sin \theta + \mu_k g \cos \theta = g(\sin \theta + \mu_k \cos \theta)$

$= (9.80 \text{ m/s}^2)[\sin 22.0° + (0.20) \cos 22.0°] = 5.49 \text{ m/s}^2$.

(*a*) For the motion of the block down the plane, the acceleration will be 1.85 m/s^2.

We find the speed from

$v^2 = v_0^2 + 2a_{down}(x - x_0)$;

$v^2 = 0 + 2(1.85 \text{ m/s}^2)(9.10 \text{ m} - 0)$, which gives $v =$ 5.81 m/s.

(*b*) For the motion of the block up the plane, we find the distance from

$v^2 = v_0^2 + 2a_{up}(x - x_0)$;

$0 = (-3.0 \text{ m/s})^2 + 2(5.49 \text{ m/s}^2)(x - 0)$, which gives $x = -0.82$ m.

Thus the block travels 0.82 m up the plane.

Because the acceleration changes, we must treat the motions up and down the plane separately.

We find the time to reach the highest point from

$v = v_0 + a_{up}t_{up}$;

$0 = (-3.0 \text{ m/s}) + (5.49 \text{ m/s}^2)t_{up}$, which gives $t_{up} = 0.55$ s.

We find the time to return to the bottom from

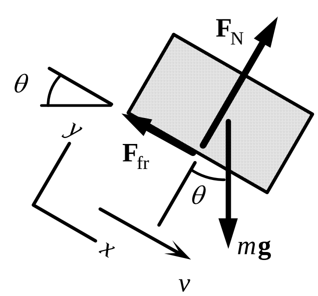
$x = x_0 + v_0 t_{down} + !a_{down}t_{down}^2$;

$0 = -0.82 \text{ m} + 0 + !(1.85 \text{ m/s}^2)t^2$, which gives $t_{down} = 0.94$ s.

Thus the total time is

$T = t_{up} + t_{down} = 0.55 \text{ s} + 0.94 \text{ s} =$ 1.49 s.

55. While the roller coaster is sliding down, friction will be up the plane, opposing the motion. From the force diagram for the roller coaster, we have ·$\mathbf{F} = m\mathbf{a}$:



x-component: $mg \sin \theta - F_{fr} = mg \sin \theta - \mu_k F_N = ma$.

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

We combine these equations to find the acceleration:

$a = g \sin \theta - \mu_k g \cos \theta = g(\sin \theta - \mu_k \cos \theta)$

$= (9.80 \text{ m/s}^2)[\sin 45° - (0.12) \cos 45°] = 6.10 \text{ m/s}^2$.

For the motion of the roller coaster, we find the speed from

$v^2 = v_0^2 + 2a(x - x_0)$;

$v^2 = [(6.0 \text{ km/h})/(3.6 \text{ ks/h})]^2 + 2(6.10 \text{ m/s}^2)(45.0 \text{ m} - 0)$, which gives $v =$ 23 m/s (85 km/h).

56. While the box is sliding down, friction will be up the plane, opposing the motion. From the force diagram for the box, we have ·$\mathbf{F} = m\mathbf{a}$:

x-component: $mg \sin \theta - F_{fr} = ma$.

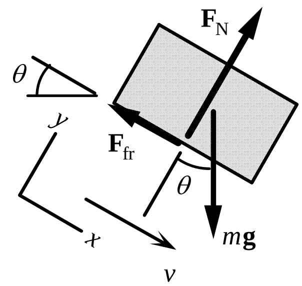
y-component: $F_N - mg \cos \theta = 0$.

From the x-equation, we have

$F_{fr} = mg \sin \theta - ma = m(g \sin \theta - a)$

$= (18.0 \text{ kg})[(9.80 \text{ m/s}^2) \sin 37.0° - (0.270 \text{ m/s}^2)]$

$=$ 101 N.



Because the friction is kinetic, we have

$F_{fr} = \mu_k F_N = \mu_k mg \cos \theta$;

$101.3 \text{ N} = \mu_k (18.0 \text{ kg})(9.80 \text{ m/s}^2) \cos 37.0°$, which gives $\mu_k = 0.719$.

57. When the cart is pushed up the ramp at constant speed, friction will be down, opposing the motion. From the force diagram for the cart, we have ·$\mathbf{F} = m\mathbf{a}$:

x-component: $F - mg \sin \theta - F_{fr} = ma = 0$;

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

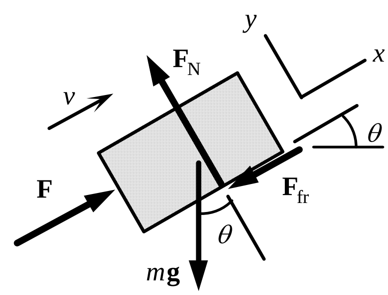
with $F_{fr} = \mu_k F_N$.

For a 5° slope we have

$F = mg(\sin \theta + \mu_k \sin \theta)$

$= (30 \text{ kg})[(9.80 \text{ m/s}^2)[\sin 5° + (0.10)\cos 5°]$

$= 55$ N.



Because this is greater than 50 N, a 5° slope is too steep.

58. For each object we take the direction of the acceleration as the positive direction. The kinetic friction from the table will oppose the motion of the bowl.

(*a*) From the force diagrams, we have ·$\mathbf{F} = m\mathbf{a}$:

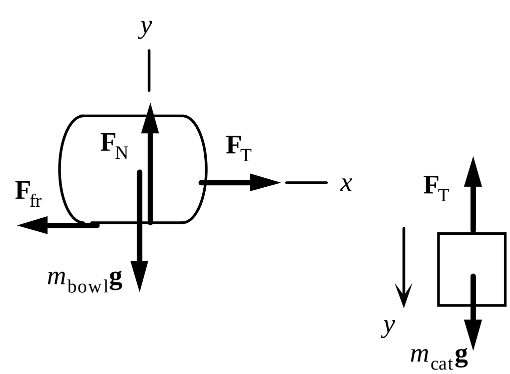
x-component(bowl): $F_T - F_{fr} = m_{bowl}a$;

y-component(bowl): $F_N - m_{bowl}g = 0$;

y-component(cat): $m_{cat}g - F_T = m_{cat}a$.

With $F_{fr} = \mu_k F_N$, we have

$F_T = F_{fr} = m_{bowl}a + \mu_k m_{bowl}g$.



When we eliminate F_T, we get

$(m_{cat} - \mu_k m_{bowl})g = (m_{cat} + m_{bowl})a$;

$[(5.0 \text{ kg}) - (0.44)(11 \text{ kg})](9.80 \text{ m/s}^2) = (5.0 \text{ kg} + 11 \text{ kg})a$, which gives $a = 0.098 \text{ m/s}^2$.

(*b*) We find the time for the bowl to reach the edge of the table from

$x = x_0 + v_0 t + !at^2$;

$0.9 \text{ m} = 0 + 0 + !(0.098 \text{ m/s}^2)t^2$, which gives $t = 4.3$ s.

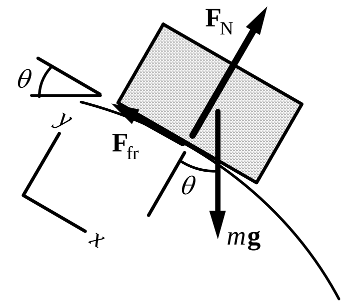
59. Before the mass slides, the friction is static, with $F_{sfr} \le \mu_s F_N$. The static friction force will be maximum just before the mass slides. We write $\Sigma \mathbf{F} = m\mathbf{a}$ from the force diagram:

    x-component: $mg \sin \theta_{max} - \mu_s F_N = 0$;

    y-component: $F_N - mg \cos \theta_{max} = 0$.

    When we combine these, we get

    $\tan \theta_{max} = \mu_s = 0.60$, or $\theta_{max} = 31°$.



60. We assume there is no tension in the rope and simplify the forces to those shown. From the force diagram, we have $\Sigma \mathbf{F} = m\mathbf{a}$:

    x-component: $F_{Nshoes} - F_{Nwall} = 0$,

    so the two normal forces are equal: $F_{Nshoes} = F_{Nwall} = F_N$;

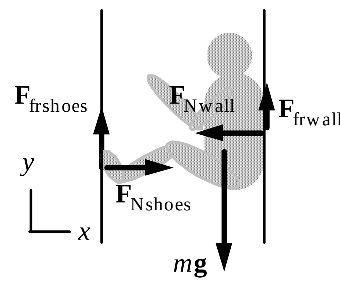
    y-component: $F_{frshoes} + F_{frwall} - mg = 0$.

    For a static friction force, we know that $F_{sfr} \le \mu_s F_N$.

    The minimum normal force will be exerted when the static friction forces are at the limit:

    $\mu_{sshoes} F_{Nshoes} + \mu_{swall} F_{Nwall} = mg$;

    $(0.80 + 0.60)F_N = (70 \text{ kg})(9.80 \text{ m/s}^2)$, which gives $F_N = 4.9 \times 10^2 \text{ N}$.



61. (*a*) The forces and coordinate systems are shown in the diagram. From the force diagram, with the block m_2 as the system, we can write $\Sigma \mathbf{F} = M\mathbf{a}$:

    y-component: $m_2 g - F_T = m_2 a$.

    From the force diagram, with the block m_1 as the system, we can write $\Sigma \mathbf{F} = m\mathbf{a}$:

    x-component: $F_T - m_1 g \sin \theta = m_1 a$.

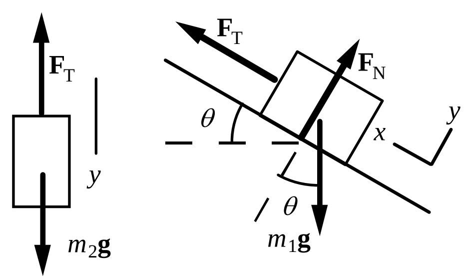
    When we eliminate F_T between these two equations, we get

    $a = (m_2 - m_1 \sin \theta)g/(m_1 + m_2)$.

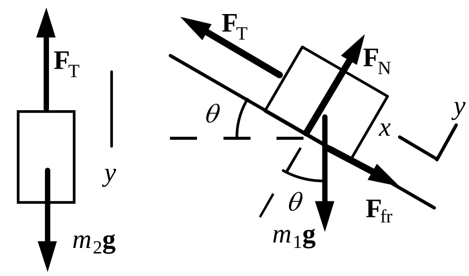
    (*b*) Because up the plane is our positive direction, we have

    a down (negative) requires $m_2 < m_1 \sin \theta$.

    a up (positive) requires $m_2 > m_1 \sin \theta$.



62. The direction of the kinetic friction force is determined by the direction of the velocity, not the direction of the acceleration. The block on the plane is moving up, so the friction force is down. The forces and coordinate systems are shown in the diagram. From the force diagram, with the block m_2 as the system, we can write ·$\mathbf{F} = M\mathbf{a}$:



   y-component: $m_2g - F_T = m_2a$.

   From the force diagram, with the block m_1 as the system, we can write ·$\mathbf{F} = m\mathbf{a}$:

   x-component: $F_T - F_{fr} - m_1g \sin\theta = m_1a$;

   y-component: $F_N - m_1g \cos\theta = 0$; with $F_{fr} = \mu_k F_N$.

   When we eliminate F_T between these two equations, we get

   $a = (m_2 - m_1 \sin\theta - \mu_k m_1 \cos\theta)g/(m_1 + m_2)$

   $= [2.7 \text{ kg} - (2.7 \text{ kg}) \sin 25° - (0.15)(2.7 \text{ kg}) \cos 25°](9.80 \text{ m/s}^2)/(2.7 \text{ kg} + 2.7 \text{ kg})$

   $=$ 2.2 m/s^2 up the plane.

   The acceleration is up the plane because the answer is positive.

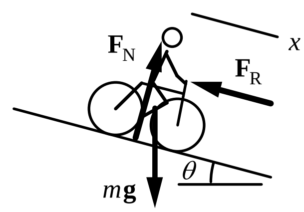
63. With the block moving up the plane, we find the coefficient of kinetic friction required for zero acceleration from

   $a = (m_2 - m_1 \sin\theta - \mu_k m_1 \cos\theta)g/(m_1 + m_2)$;

   $0 = [2.7 \text{ kg} - (2.7 \text{ kg}) \sin 25° - \mu_k(2.7 \text{ kg}) \cos 25°](9.80 \text{ m/s}^2)/(2.7 \text{ kg} + 2.7 \text{ kg})$.

   which gives $\mu_k = 0.64$.

64. Both motions have constant velocity, so the acceleration is zero. From the force diagram for the motion coasting down the hill, we can write ·$\mathbf{F} = m\mathbf{a}$:



   x-component: $mg \sin\theta - F_R = 0$, or $F_R = mg \sin\theta$.

   From the force diagram for the motion climbing up the hill, we can write ·$\mathbf{F} = m\mathbf{a}$:

   x-component: $F - mg \sin\theta - F_R = 0$, so

   $F = F_R + mg \sin\theta = 2mg \sin\theta$

   $= 2(65 \text{ kg})(9.80 \text{ m/s}^2) \sin 6.0° =$ 1.3×10^2 N.

65. The acceleration can be found from the blood's one-dimensional motion:

   $v = v_0 + at$;

   $0.35 \text{ m/s} = (0.25 \text{ m/s}) + a(0.10 \text{ s})$, which gives $a = 1.00 \text{ m/s}^2$.

   We apply Newton's second law to find the required force

   ·$F = ma$;

   $F = (20 \times 10^{-3} \text{ kg})(1.00 \text{ m/s}^2) =$ 2.0×10^{-2} N.

66. We apply Newton's second law to the person:

   ·$F = ma$;

   $F = (70 \text{ kg})(-30)(9.80 \text{ m/s}^2) =$ -2.1×10^4 N (opposite to motion).

   We find the distance from

   $v^2 = v_0^2 + 2a(x - x_o)$

   $0 = [(90 \text{ km/h})/(3.6 \text{ ks/h})]^2 + 2(-30)(9.80 \text{ m/s}^2)(x - x_o)$, which gives $x - x_o =$ 1.1 m.

67. (*a*) For the object to move with the ground, the static friction force must provide the same acceleration. With the standard coordinate system, for ·**F** = m**a** we have

x-component: $F_{sfr} = ma$;

y-component: $F_N - mg = 0$.

For static friction, $F_{sfr}\ ^2\ \mu_s F_N$, or $ma\ ^2\ \mu_s mg$; thus $\mu_s\ ^3\ a/g$.

(*b*) For the greatest acceleration, the minimum required coefficient is

$\mu_s = a/g = (4.0 \text{ m/s}^2)/(9.80 \text{ m/s}^2) = 0.41$.

Because this is greater than 0.25, the chair will slide.

68. From the force diagram for the car we have

x-component: $F - F_T = m_{car}a$;

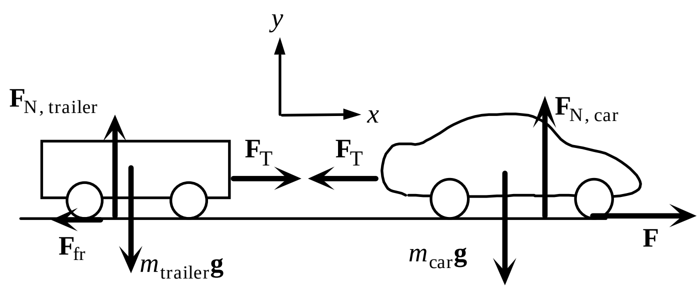
y-component : $F_{N,car} - m_{car}g = 0$.

From the force diagram for the trailer we have

x-component: $F_T - \mu_k F_{N,trailer} = m_{trailer}a$;

y-component: $F_{N,trailer} - m_{trailer}g = 0$,

or $F_{N,trailer} = m_{trailer}g$.



If we add the two x-equations, we get

$F - \mu_k m_{trailer}g = m_{car}a + m_{trailer}a$;

$3.5 \times 10^3 \text{ N} - (0.15)(450 \text{ kg})(9.80 \text{ m/s}^2) = (1000 \text{ kg} + 450 \text{ kg})a$, which gives $a = 1.96 \text{ m/s}^2$.

We can find the force on the trailer from the x-equation for the trailer:

$F_T - \mu_k m_{trailer}g = m_{trailer}a$;

$F_T - (0.15)(450 \text{ kg})(9.80 \text{ m/s}^2) = (450 \text{ kg})(1.96 \text{ m/s}^2)$, which gives $F_T = 1.5 \times 10^3$ N.

69. On a level road, the normal force is $F_N = mg$. The kinetic friction force is the only force slowing the automobile. We find the acceleration from the horizontal component of ·**F** = m**a**:

$-\mu_k mg = ma$, which gives

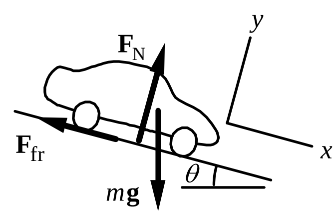
$a = -\mu_k g = -(0.80)(9.80 \text{ m/s}^2) = -7.84 \text{ m/s}^2$.

For the motion until the automobile stops, we have

$v^2 = v_0^2 + 2a(x - x_0)$;

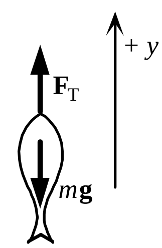
$0 = v_0^2 + 2(-7.84 \text{ m/s}^2)(80 \text{ m})$, which gives $v_0 =$ 35 m/s (130 km/h).

70. We find the angle of the hill from
$\sin\theta = 1/4$, which gives $\theta = 14.5°$.
The kinetic friction force will be up the hill to oppose the motion. From the force diagram for the car, we have $\Sigma\mathbf{F} = m\mathbf{a}$:
x-component: $mg\sin\theta - F_{fr} = ma$;
y-component: $F_N - mg\cos\theta = 0$.
When we combine these, we get
$a = g\sin\theta - \mu_k g\cos\theta = g(\sin\theta - \mu_k\cos\theta)$.



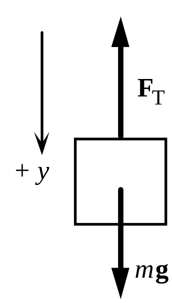
(*a*) If there is no friction, we have
$a = g\sin\theta = (9.80\ m/s^2)\sin 14.5° = 2.45\ m/s^2$.
We find the car's speed from
$v^2 = v_0^2 + 2a(x - x_0)$;
$v^2 = 0 + 2(2.45\ m/s^2)(50\ m)$, which gives $v =$ 16 m/s.
(*b*) If there is friction, we have
$a = g(\sin\theta - \mu_k\cos\theta) = (9.80\ m/s^2)[\sin 14.5° - (0.10)\cos 14.5°] = 1.50\ m/s^2$.
We find the car's speed from
$v^2 = v_0^2 + 2a(x - x_0)$;
$v^2 = 0 + 2(1.50\ m/s^2)(50\ m)$, which gives $v =$ 12 m/s.

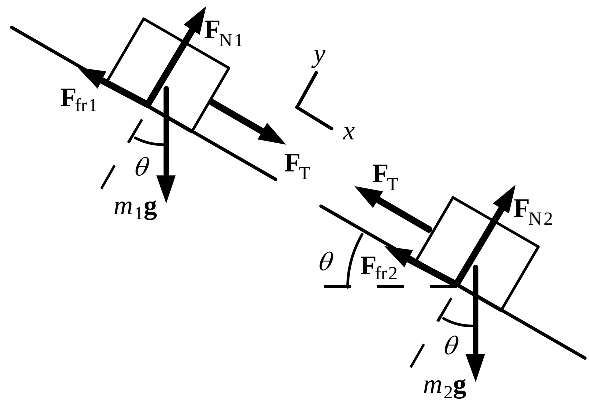
71. We write $\Sigma\mathbf{F} = m\mathbf{a}$ from the force diagram for the fish:
y-component: $F_T - mg = ma$, or $F_T = m(a + g)$.



(*a*) At constant speed, $a = 0$, so we have
$F_{Tmax} = m_{max}g$;
$45\ N = m_{max}(9.80\ m/s^2)$, which gives $m_{max} = 4.6$ kg.
(*b*) For an upward acceleration, we have
$F_{Tmax} = m_{max}(a + g)$;
$45\ N = m_{max}(2.0\ m/s^2 + 9.80\ m/s^2)$, which gives $m_{max} = 3.8$ kg.
Note that we have ignored any force from the water.

72. For the motion until the elevator stops, we have
$v^2 = v_0^2 + 2a(x - x_0)$;
$0 = (3.5\ m/s)^2 + 2a\,(3.0\ m)$, which gives $a = -2.04\ m/s^2$.
We write $\Sigma\mathbf{F} = m\mathbf{a}$ from the force diagram for the elevator:
y-component: $mg - F_T = ma$; or
$(1300\ kg)(9.80\ m/s^2) - F_T = (1300\ kg)(-2.04\ m/s^2)$,
which gives
$F_T =$ 1.5×10^4 N.





73. (*a*) We assume that the block will slide down; friction will be up the plane, opposing the motion. From the force diagram for box 1, without the tension, we have $\Sigma\mathbf{F} = m\mathbf{a}$:

x-component: $m_1g \sin\theta - \mu_{k1}F_{N1} = m_1a_1$.

y-component: $F_{N1} - m_1g \cos\theta = 0$.

Combining these, we get the acceleration:

$a_1 = (\sin\theta - \mu_{k1}\cos\theta)g$

$= [\sin 30° - (0.10)\cos 30°](9.80\ \text{m/s}^2)$

$= 4.1\ \text{m/s}^2$.

From the force diagram for box 2, without the tension, we have $\Sigma\mathbf{F} = m\mathbf{a}$:

x-component: $m_2g \sin\theta - \mu_{k2}F_{N2} = m_2a_2$.

y-component: $F_{N2} - m_2g \cos\theta = 0$.

Combining these, we get the acceleration:

$a_2 = (\sin\theta - \mu_{k2}\cos\theta)g$

$= [\sin 30° - (0.20)\cos 30°](9.80\ \text{m/s}^2) = 3.2\ \text{m/s}^2$.

(*b*) We see from part (*a*) that the upper box will have a greater acceleration. Any tension in the string would increase this effect. Thus the upper box will slide faster than the lower box and the string will become lax, with no tension. Until the upper box reaches the lower box, when a normal force is created, the accelerations will be the same as in part (*a*):

$a_1 = 4.1\ \text{m/s}^2$, and $a_2 = 3.2\ \text{m/s}^2$.

(*c*) In this configuration, we see that the lower box will try to pull away from the upper one, creating a tension in the string. Because the two boxes are tied together, they will have the same acceleration. The x-components of the force equation will be

box 1 (lower): $m_1g \sin\theta - F_T - \mu_{k1}m_1g \cos\theta = m_1a$;

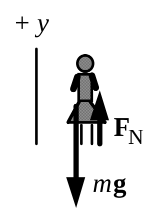
box 2 (upper): $m_2g \sin\theta + F_T - \mu_{k2}m_2g \cos\theta = m_2a$.

We add these equations to eliminate F_T, and get the acceleration:

$a = \{\sin\theta - [(\mu_{k1}m_1 + \mu_{k2}m_2)/(m_1 + m_2)]\cos\theta\}g$

$= (\sin 30° - \{(0.10)(1.0\ \text{kg}) + (0.20)(2.0\ \text{kg})]/(1.0\ \text{kg} + 2.0\ \text{kg})\}\cos 30°)(9.80\ \text{m/s}^2) = 3.5\ \text{m/s}^2$.

74. We take the positive direction upward.



The scale reads the force the person exerts on the scale. From Newton's third law, this is also the magnitude of the normal force acting on the person. The effective mass on the scale is

$m_{scale} = F_N/g$.

We write $\Sigma\mathbf{F} = m\mathbf{a}$ from the force diagram for the person:

y-component: $F_N - mg = ma$, or

$m_{scale} = F_N/g = m(a + g)/g$.

(*a*) When the elevator is at rest, $a = 0$:

$m_{scale} = m(0 + g)/g = m = 75.0\ \text{kg}$.

(*b*) When the elevator is climbing at constant speed, $a = 0$:

$m_{scale} = m(0 + g)/g = m = 75.0\ \text{kg}$.

(*c*) When the elevator is falling at constant speed, $a = 0$:

$m_{scale} = m(0 + g)/g = m = 75.0\ \text{kg}$.

(*d*) When the elevator is accelerating upward, a is positive:

$m_{scale} = m(a + g)/g = (75.0\ \text{kg})(3.0\ \text{m/s}^2 + 9.80\ \text{m/s}^2)/(9.80\ \text{m/s}^2) = 98.0\ \text{kg}$.

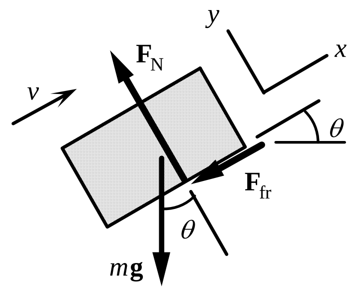
(*e*) When the elevator is accelerating downward, a is negative:

$m_{scale} = m(a + g)/g = (75.0\ \text{kg})(-3.0\ \text{m/s}^2 + 9.80\ \text{m/s}^2)/(9.80\ \text{m/s}^2) = 52.0\ \text{kg}$.

75. (*a*) We select the origin at the bottom of the ramp, with up positive. We find the acceleration from the motion up the ramp:

$v^2 = v_0^2 + 2a(x - x_0)$;

$0 = v_0^2 + 2a(d - 0)$, which gives $a = -v_0^2/2d$.



When the block slides up the ramp, kinetic friction will be down, opposing the motion. From the force diagram for the block, we have $\cdot\mathbf{F} = m\mathbf{a}$:

x-component: $-mg \sin\theta - \mu_k F_N = ma$;

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

When we eliminate F_N from the two equations and use the result for a, we get

$-mg\sin\theta - \mu_k mg\cos\theta = m(-v_0^2/2d)$, which gives

$\mu_k = (v_0^2/2gd\cos\theta) - \tan\theta$.

(*b*) Once the block stops, the friction becomes static and will be up the plane, to oppose the impending motion down. If the block remains at rest, the acceleration is zero. The static friction force must be $^2\,\mu_s F_N$ and we have

x-component: $-mg\sin\theta + F_{frs} = 0$, or $F_{frs} = mg\sin\theta\ ^2\ \mu_s mg\cos\theta$.

Thus we know that $\mu_s\ ^3\ \tan\theta$.

76. On a level road, the normal force is $F_N = mg$. The kinetic friction force is the only force slowing the motorcycle. We find the acceleration from the horizontal component of $\cdot\mathbf{F} = m\mathbf{a}$:

$-\mu_k mg = ma$, which gives

$a = -\mu_k g = -(0.80)(9.80\ \text{m/s}^2) = -7.84\ \text{m/s}^2$.

For the motion through the sandy stretch, we have

$v^2 = v_0^2 + 2a(x - x_0)$;

$v^2 = (17\ \text{m/s})^2 + 2(-7.84\ \text{m/s}^2)(15\ \text{m})$, which gives $v = \pm 7.3$ m/s.

The negative sign corresponds to the motorcycle going beyond the sandy stretch and returning, assuming the same negative acceleration after the motorcycle comes to rest. This will not occur, so the motorcycle emerges with a speed of 7.3 m/s.
If the motorcycle did not emerge, we would get a negative value for v^2, indicating that there is no real value for v.

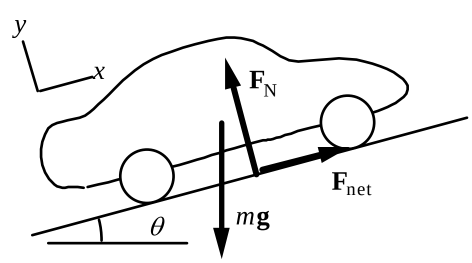
77. We find the acceleration of the car on the level from

$v = v_0 + at$;

$(21\ \text{m/s}) = 0 + a(14.0\ \text{s})$, which gives $a = 1.5\ \text{m/s}^2$.

This acceleration is produced by the net force:

$F_{net} = ma = (1100\ \text{kg})(1.5\ \text{m/s}^2) = 1650$ N.



If we assume the same net force on the hill, with no acceleration on the steepest hill, from the force diagram we have

x-component: $F_{net} - mg\sin\theta = 0$;

1650 N – (1100 kg)(9.80 m/s^2) $\sin\theta = 0$, which gives $\sin\theta = 0.153$, or $\theta = 8.8°$.

78. The velocity is constant, so the acceleration is zero.

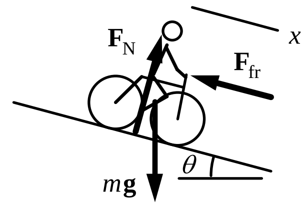
(*a*) From the force diagram for the bicycle, we can write ·**F** = m**a**:

x-component: $mg \sin \theta - F_R = 0$, or

$mg \sin \theta = cv$;

(80 kg)(9.80 m/s^2) sin 5.0° = c(6.0 km/h)/(3.6 m/s), which gives

c = 41 kg/s.



(*b*) We have an additional force in ·**F** = m**a**:

x-component: $F + mg \sin \theta - F_R = 0$, so

$F = cv - mg \sin \theta$

= [(41 kg/s)(20 km/h)/(3.6 m/s)] – (80 kg)(9.80 m/s^2) sin 5.0° = 1.6×10^2 N.

79. From the force diagram for the watch, we have ·**F** = m**a**:

x-component: $F_T \sin \theta = ma$;

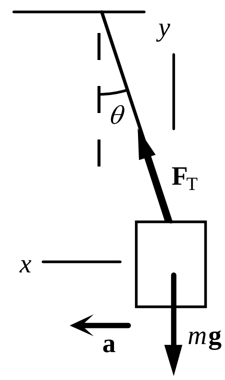
y-component: $F_T \cos \theta - mg = 0$, or $F_T \cos \theta = mg$.

If we divide the two equations, we find the acceleration:

$a = g \tan \theta$ = (9.80 m/s^2) tan 25° = 4.56 m/s^2.

For the motion of the aircraft, we find the takeoff speed from

$v = v_0 + at$ = 0 – (4.56 m/s^2)(18 s) = 82 m/s (300 km/h).



80. There are only three tensions. The tension in the rope that goes around both pulleys is constant:

$F_{T1} = F_{T2} = F$.

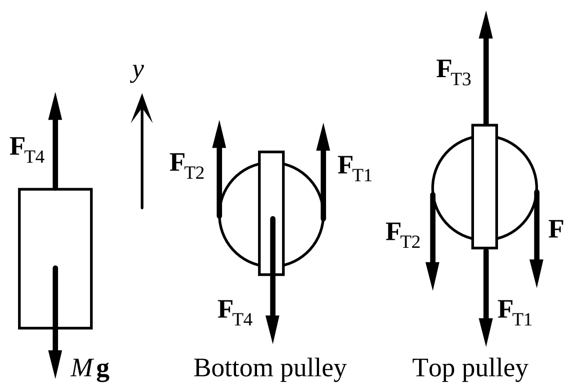
We choose up positive and assume that the piano is lifted with no acceleration.

If the masses of the pulleys are negligible, we can write ·$F_y = ma_y$.

(*a*) If we select the piano and bottom pulley as the system, we have

$F_{T2} + F_{T1} - Mg = 0$, which gives

$2F_{T1} = Mg$, or F_{T1} = F = !Mg.



(*b*) For the individual elements, we have

piano: $F_{T4} - Mg = 0$, which gives

$F_{T4} = Mg$.

bottom pulley: $F_{T2} + F_{T1} - F_{T4} = 0$, which gives

$2F_{T1} = Mg$, or $F_{T1} = F_{T2}$ = !Mg.

top pulley: $F_{T3} - F_{T1} - F_{T2} - F = 0$, which gives

$F_{T3} = 3F_{T1}$ = 8Mg.

81. (*a*) If motion is just about to begin, the static friction force on the block will be maximum: $F_{\mathrm{sfr,max}} = \mu_s F_N$

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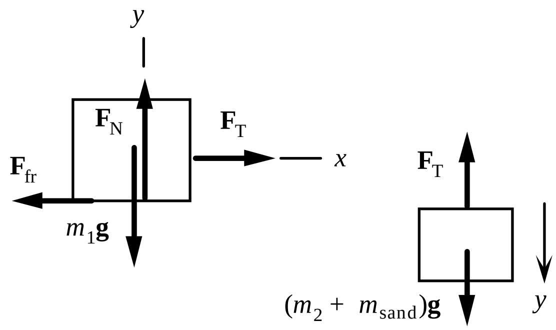

and the acceleration will be zero. We write $\cdot\mathbf{F} = m\mathbf{a}$ from the force diagram for each object:

x-component (block): $F_T - \mu_s F_N = 0$;

y-component (block): $F_N - m_1 g = 0$;

y-component (bucket): $(m_2 + m_{\mathrm{sand}})g - F_T = 0$.

When we combine these equations, we get

$(m_2 + m_{\mathrm{sand}})g = \mu_s m_1 g$, which gives

$m_{\mathrm{sand}} = \mu_s m_1 + m_2 = (0.450)(28.0\ \mathrm{kg}) - 1.00\ \mathrm{kg}$

$=$ 11.6 kg.

(*b*) When the system starts moving, the friction becomes kinetic, and the tension changes. The force equations become

x-component (block): $F_{T2} - \mu_k F_N = m_1 a$;

y-component (block): $F_N - m_1 g = 0$;

y-component (bucket): $(m_2 + m_{\mathrm{sand}})g - F_{T2} = m_2 a$.

When we combine these equations, we get

$(m_2 + m_{\mathrm{sand}} - \mu_k m_1)g = (m_1 + m_2 + m_{\mathrm{sand}})a$, which gives

$a = [1.00\ \mathrm{kg} + 11.6\ \mathrm{kg} - (0.320)(28.0\ \mathrm{kg})](9.80\ \mathrm{m/s^2})/(28.0\ \mathrm{kg} + 1.00\ \mathrm{kg} + 11.6\ \mathrm{kg}) =$ $0.879\ \mathrm{m/s^2}$.