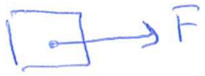
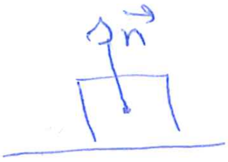
Newton's Laws (Part 1)
(No friction)

Force is the cause of change in the motion

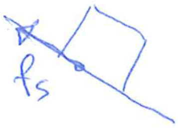
Contact Forces:



tension

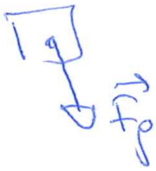


normal force



friction force

Non-contact Force



gravitational force $|\vec{F_g}|$ = weight

1st Law:

Equilibrium = constant velocity

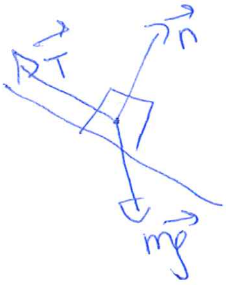
If no force acts on an object, its velocity remains constant in inertial reference frames

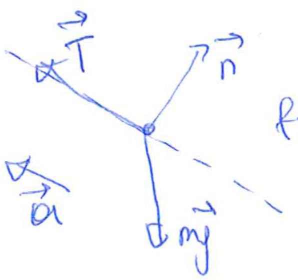
2nd Law:

$$\sum \vec{F} = m\vec{a}$$

↓ inertia

$$\sum F_x = m a_x \quad , \quad \sum F_y = m a_y \quad , \quad \sum F_z = m a_z$$

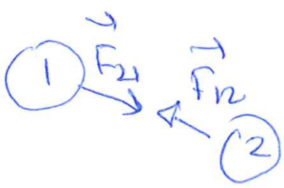




free-body diagrams

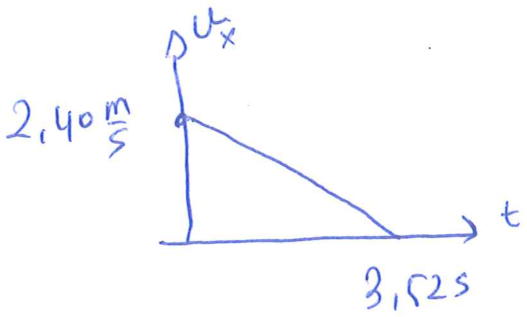
3rd Law:

Action - Reaction (they act on different objects)

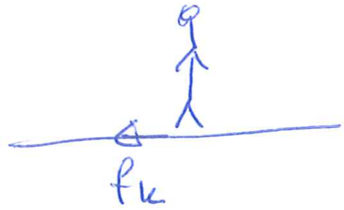


$$\vec{F_{12}} = -\vec{F_{21}}$$

A 68.5 kg skater moving initially at 2.40 m/s on rough horizontal ice comes to rest uniformly in 3.52 s due to friction from the ice. What force does friction exert on the skater?



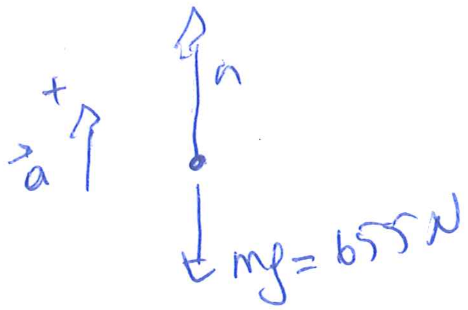
$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{-2{,}40}{3.52} \frac{m}{s^2}$$



$$|f_k| = |ma| = 68.5 \frac{2{,}40}{3.52}$$

$$|f_k| = 46.7 N$$

You walk into a lift, step onto a scale, and push the "up" button. You recall that your normal weight is 655 N. Draw a free-body diagram. (a) When the lift has an upward acceleration of magnitude 2.46 m/s^2, what does the scale read? (b) If you hold a 3.65-kg package by a light vertical string, what will be the tension in this string when the lift accelerates



(a) $\Sigma F_y = n - mg = ma_y$

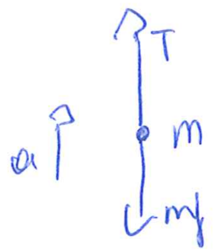
$n - mg = ma$

$n = mg + ma$

$n = mg\left(1 + \frac{a}{g}\right)$

$n = 655\left(1 + \frac{2.46}{9.80}\right) = 819\ N$

(b)



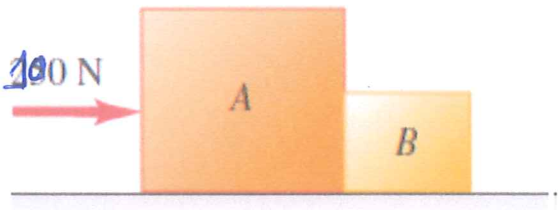
$T = mg\left(1 + \frac{a}{g}\right) = mg + ma$

$= m(g + a) = 3.65 \cdot (9.80 + 2.46)$

$T = 44.8\ N$

4.23 •• Boxes A and B are in contact on a horizontal, frictionless surface (**Fig. E4.23**). Box A has mass 25.0 kg and box B has mass 8.0 kg. A horizontal force of 100 N is exerted on box A. What is the magnitude of the force that box A exerts on box B?

Figure E4.23



$\vec{F}_{AB} = -\vec{F}_{BA}$

$|\vec{F}_{AB}| = |\vec{F}_{BA}| = F$

100N A $\vec{F}_{BA}$

25kg

$\vec{a}$

$\vec{F}_{AB}$ B

8kg

$\vec{a}$

a: common

$$100 - F = 25a$$

$$F = 8a$$

$$+$$

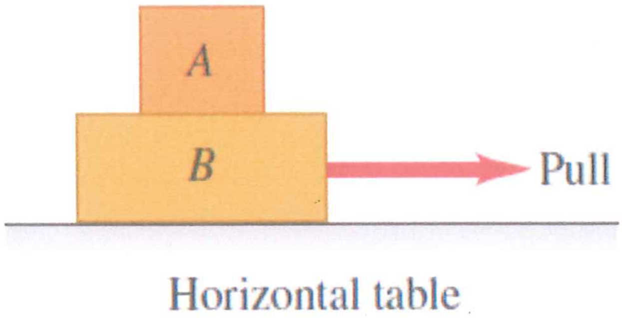
$$a = \frac{100}{33}$$

$$F = 8a = \frac{800}{33}\,N = 24.\overline{24}\,N = 24N$$

two significant figures

4.34 •• Block *A* rests on top of block *B* as shown in Fig. E4.26. The table is frictionless but there is friction (a horizontal force) between blocks *A* and *B*. Block *B* has mass 6.00 kg and block *A* has mass 2.00 kg. If the horizontal pull applied to block *B* equals 12.0 N, then block *B* has an acceleration of 1.80 m/s^2. What is the acceleration of block *A*?

Figure E4.26



A $\rightarrow f$: friction force

$\rightarrow a = 1.80 \ m/s^2$

$f \leftarrow$ B(6kg) $\rightarrow$ 12N

action-reaction pair

For B $\quad \Sigma F_x = m a_x$

$$12 - f = 6 \cdot 1{,}80$$

$$f = 12 - 10.80 = 1.20 \ N$$

For A $\quad \Sigma F_x = m a_A$

$$f = m a_A$$

$$1{,}20 = 2 \cdot a_A$$

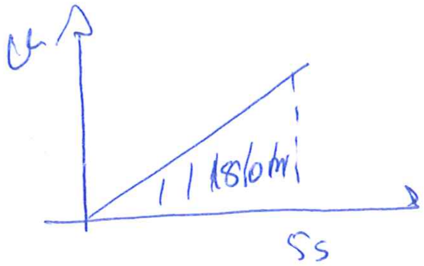
$$a_A = 0.60 \ m/s^2$$

Acceleration is different. B slips on A

4.38 •• CP Two blocks connected by a light horizontal rope sit at rest on a horizontal, frictionless surface. Block A has mass 15.0 kg, and block B has mass m. A constant horizontal force $F = 60.0$ N is applied to block A (**Fig. P4.38**). In the first 5.00 s after the force is applied, block A moves 18.0 m to the right. (a) While the blocks are moving, what is the tension T in the rope that connects the two blocks? (b) What is the mass of block B?

Figure P4.38

(a)



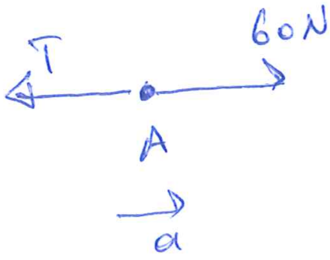
$$v_{xf}^2 = \underset{0}{\underset{||}{v_{xi}^2}} + 2a_x\Delta x$$

$$a_x = \frac{v_{xf}^2}{2\Delta x} =$$

or

$$x_f = \underset{0}{\underset{||}{x_i}} + \underset{0}{\underset{||}{v_{xi}}}t + \frac{1}{2}a_x t^2$$

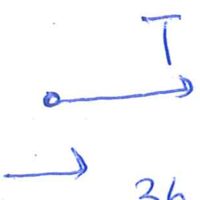
$$a_x = \frac{2x_f}{t^2} = \frac{2\cdot 18}{25} = \frac{36}{25}\ \mathrm{m/s^2}$$



$$60 - T = \overset{3}{\cancel{15}}\cdot\frac{36}{\cancel{25}\,5}$$

$$T = 60 - \frac{108}{5} = 38.4\ \mathrm{N}$$

(b)



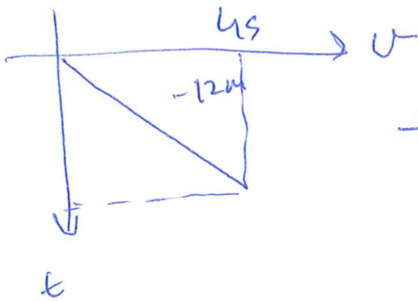
$$a = \frac{36}{25}\ \mathrm{m/s^2}$$

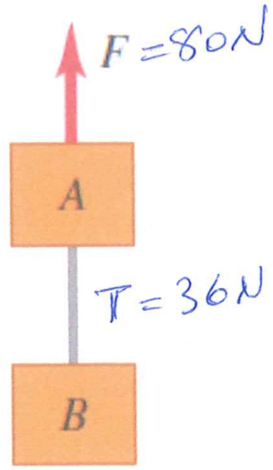
$$T = m_B a$$

$$m_B = \frac{T}{a} = \frac{192/5}{\frac{36}{25}} = \frac{192}{36}\cdot 5$$

$$m_B = \frac{80}{3}\ \mathrm{kg} = 26.7\ \mathrm{kg}$$

4.45 •• **CP** Boxes A and B are connected to each end of a light vertical rope (**Fig. P4.45**). A constant upward force $F = 80.0$ N is applied to box A. Starting from rest, box B descends 12.0 m in 4.00 s. The tension in the rope connecting the two boxes is 36.0 N. What are the masses of (a) box B, (b) box A?





$-12 = \frac{1}{2} a_y t^2$

$a_y = -\frac{24}{t^2}$

$a_y = -\frac{\cancel{24}^{6}}{\cancel{16}_{4}} = -1{,}5 \frac{m}{s^2}$ $\vec{a}$

(a) T m_B $m_B g$ $-1{,}5\, m/s$

$T - m_B g = -1{,}5\, m_B$

$T = m_B(9{,}80 - 1{,}5)$

$m_B = \frac{T}{8{,}30} = \frac{36}{8{,}30} = 4{,}34$ kg

(b) F m_A T $m_A g$ $-1{,}5$

$F - T - m_A g = -1{,}5\, m_A$

$= m_A(9{,}8 - 1{,}5)$

$80 - 36 = 8{,}3\, m_A$

$m_A = \frac{44}{8{,}3} = 5{,}30$ kg

••4 While two forces act on it, a particle is to move at the constant velocity $\vec{v} = (3\ \text{m/s})\hat{\imath} - (4\ \text{m/s})\hat{\jmath}$. One of the forces is $\vec{F}_1 = (2\ \text{N})\hat{\imath} + (-6\ \text{N})\hat{\jmath}$. What is the other force?

Since constant velocity

$$\sum \vec{F} = 0$$

$$\vec{F}_2 = F_{2x}\hat{\imath} + F_{2y}\hat{\jmath}$$

$$\sum \vec{F} = 2\hat{\imath} + (-6)\hat{\jmath} + \vec{F}_2 = 0$$

$$\vec{F}_2 = -2\hat{\imath} + 6\hat{\jmath}$$

••8 A 2.00 kg object is subjected to three forces that give it an acceleration $\vec{a} = -(8.00\ \text{m/s}^2)\hat{\imath} + (6.00\ \text{m/s}^2)\hat{\jmath}$. If two of the three forces are $\vec{F}_1 = (30.0\ \text{N})\hat{\imath} + (16.0\ \text{N})\hat{\jmath}$ and $\vec{F}_2 = -(12.0\ \text{N})\hat{\imath} + (8.00\ \text{N})\hat{\jmath}$, find the third force..

$$\sum \vec{F} = m\vec{a} = 2\left(-8\hat{\imath} + 6\hat{\jmath}\right) = -16\hat{\imath} + 12\hat{\jmath}$$

$$\sum \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = -16\hat{\imath} + 12\hat{\jmath}$$

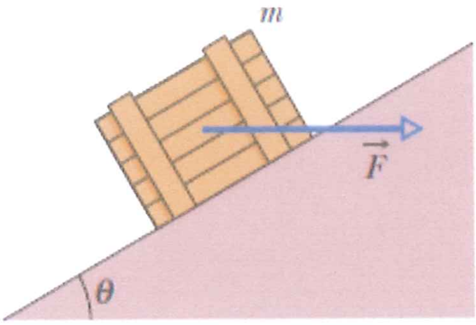
$$30\hat{\imath} + 16\hat{\jmath} - 12\hat{\imath} + 8\hat{\jmath} + \vec{F}_3 = -16\hat{\imath} + 12\hat{\jmath}$$

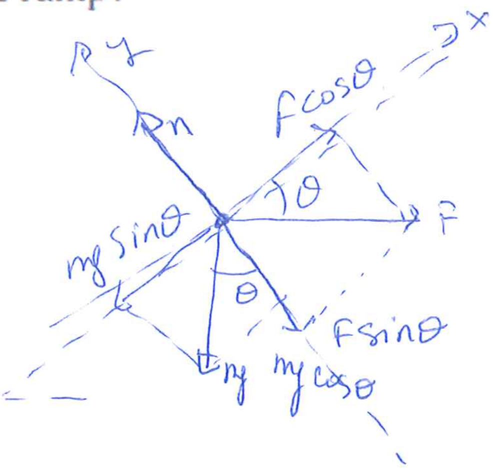
$$\vec{F}_3 + 18\hat{\imath} + 24\hat{\jmath} = -16\hat{\imath} + 12\hat{\jmath}$$

$$\vec{F}_3 = -16\hat{\imath} + 12\hat{\jmath} - 18\hat{\imath} - 24\hat{\jmath}$$

$$\vec{F}_3 = (-34\hat{\imath} - 12\hat{\jmath})\ N$$

••34 GO In Fig. 5-40, a crate of mass $m = 100$ kg is pushed at constant speed up a frictionless ramp ($\theta = 30.0°$) by a horizontal force $\vec{F}$. What are the magnitudes of (a) $\vec{F}$ and (b) the force on the crate from the ramp?





(a) $\Sigma F_x = 0$

$F \cos\theta = mg \sin\theta$

$F = mg \tan\theta$

$F = 100 \cdot 9{,}80 \cdot \tan(30°)$

$f = 565{,}8\ N$

$\boxed{F = 566\ N}$

(b) $\Sigma F_y = 0$

$n = mg\cos\theta + f\sin\theta$

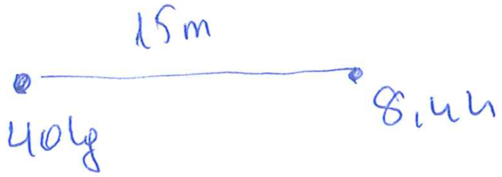
$= mg\cos\theta + mg\dfrac{\sin\theta}{\cos\theta}\sin\theta$

$n = mg\dfrac{\cos^2\theta + \sin^2\theta}{\cos\theta} = \dfrac{mg}{\cos\theta}$

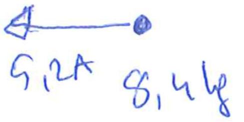
$n = \dfrac{100 \cdot 9{,}80}{\cos(30°)} = 1131{,}61\ N$

$= 1{,}13 \times 10^3\ N$

••37 A 40 kg girl and an 8.4 kg sled are on the frictionless ice of a frozen lake, 15 m apart but connected by a rope of negligible mass. The girl exerts a horizontal 5.2 N force on the rope. What are the acceleration magnitudes of (a) the sled and (b) the girl? (c) How far from the girl's initial position do they meet?



(a)



$|a| = \frac{5,2}{8,4}\ m/s^2 = 0,62\ m/s^2$

(b) Due to action-reaction principle, the rope exerts 5.2N on the girl

$|\vec{a}| = \frac{5,2N}{40} = 0,13\ m/s^2$

(c) Both moves $\frac{1}{2} 0,62 t^2 + \frac{1}{2} 0,13 t^2 = 15$

$t^2 = \frac{30}{0,75}$

$t = \sqrt{\frac{30}{0,75}}$

Girl moves $\frac{1}{2} 0,13 \cdot t^2 = \frac{1}{\cancel{2}} \cdot 0,13 \cdot \frac{\overset{15}{\cancel{30}}}{0,75}$

$= \frac{15 \times 0,13}{0,75} \approx 2.6\ m$

inversely proportional to mass

••50 GO In Fig. 5-46, three ballot boxes are connected by cords, one of which wraps over a pulley having negligible friction on its axle and negligible mass. The three masses are $m_A = 30.0$ kg, $m_B = 40.0$ kg, and $m_C = 10.0$ kg. When the assembly is released from rest, (a) what is the tension in the cord connecting B and C, and (b) how far does A move in the first 0.250 s (assuming it does not reach the pulley)?

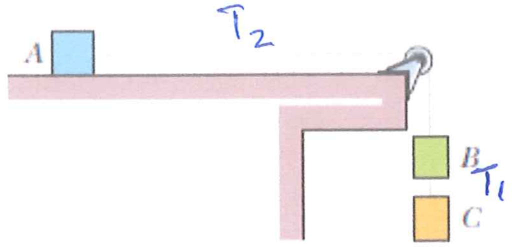


Figure 5-46 Problem 50.

(a)

A: T_2, $30g$, a

B: T_2, $40g$, T_1, $40g$, a

C: T_1, $10g$, $10g$, a

$\cancel{T_2} = 30a$

$T_1 + 40g - T_2 = 40a$

$10g - T_1 = 10a$

$T_1 = 10g - 10a$

$\cancel{T_1} + 40g - \cancel{T_2} = 40a$

$10g - \cancel{T_1} = 10a$ +

$50g = 80a$

$a = \frac{5g}{8} =$

$T_1 = 10g - 10\,\frac{5g}{8} = \frac{30g}{8} = 36.75N$

$T_1 = 36.8N$

(b) $\frac{1}{2}at^2 = \frac{1}{2}\cdot\frac{5g}{8}\left(\frac{1}{4}\right)^2 = \frac{5g}{252} = 0,194$ m

$= 0,194$ m

••53 In Fig. 5-48, three connected blocks are pulled to the right on a horizontal frictionless table by a force of magnitude $T_3 = 65.0$ N. If $m_1 = 12.0$ kg, $m_2 = 24.0$ kg, and $m_3 = 31.0$ kg, calculate (a) the magnitude of the system's acceleration, (b) the tension T_1, and (c) the tension T_2.

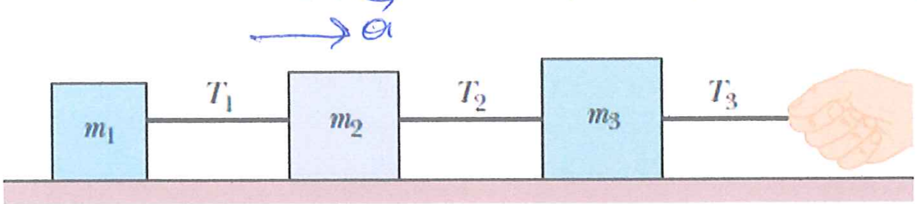


Figure 5-48 Problem 53.

m_1: $T_1 = m_1 a$

$T_2 - T_1 = m_2 a$

$T_2 = T_1 + m_2 a$

$T_2 = m_1 a + m_2 a$

$T_2 = (m_1 + m_2) a$

$T_3 - T_2 = m_3 a$

$T_3 = (m_1 + m_2) a + m_3 a$

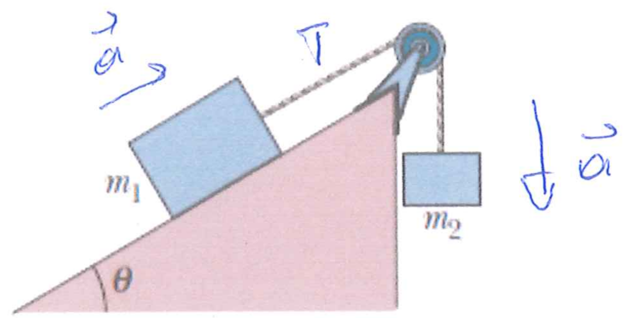
$T_3 = (m_1 + m_2 + m_3) a$

(a) $a = \dfrac{T_3}{m_1 + m_2 + m_3} = \dfrac{65}{12+24+31} = \dfrac{65}{67}\ m/s^2 = 0{,}970\ \frac{m}{s^2}$

(b) $T_1 = m_1 a = 12 \cdot \dfrac{65}{67} = 11{,}6\ N$

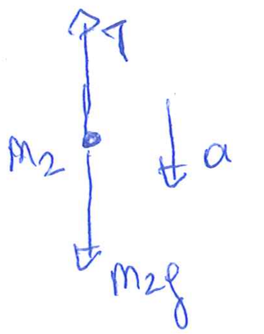
(c) $T_2 = (m_1 + m_2) a = 36 \cdot \dfrac{65}{67} = 34{,}9\ N$

••57 ILW A block of mass $m_1 = 3.70$ kg on a frictionless plane inclined at angle $\theta = 30.0°$ is connected by a cord over a massless, frictionless pulley to a second block of mass $m_2 = 2.30$ kg (Fig. 5-52). What are (a) the magnitude of the acceleration of each block, (b) the direction of the acceleration of the hanging block, and (c) the tension in the cord?



assume a direction if we get negative a then it is the opposite

(a)

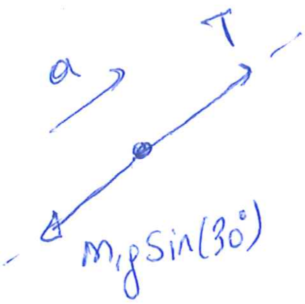


$$m_2 g - T = m_2 a$$

$$T = m_2 g - m_2 a$$

$$m_2 g - \cancel{T} = m_2 a$$

$$+\ \ \cancel{T} - m_1 g \sin\theta = m_1 a$$



$$a = \frac{m_2 - m_1 \sin\theta}{m_1 + m_2} g = \frac{2{,}30 - 3.70 \cdot \frac{1}{2}}{2{,}30 + 3.70} g$$

$$a = 0{,}735 \text{ m/s}^2$$

direction was correct

(b) m_2 ↓ acceleration is down

(c) $T = m_2 (g - a) = 2{,}30 (9{,}80 - 0{,}735)$

$$= 20.8 \text{ N}$$

•••67 Figure 5-58 shows three blocks attached by cords that loop over frictionless pulleys. Block B lies on a frictionless table; the masses are $m_A = 6.00$ kg, $m_B = 8.00$ kg, and $m_C = 10.0$ kg. When the blocks are released, what is the tension in the cord at the right?

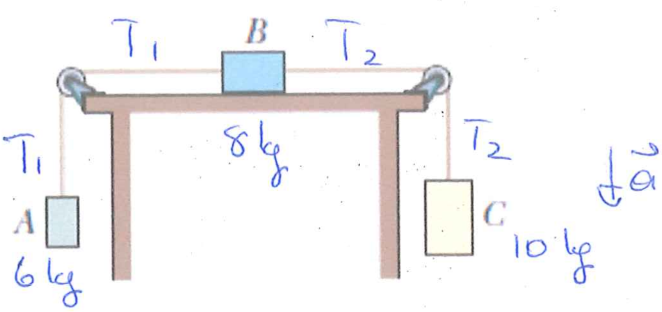
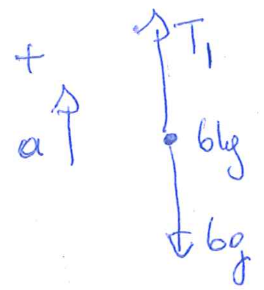
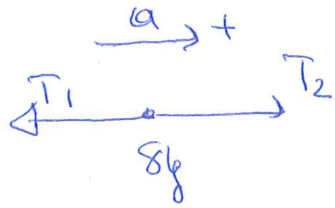
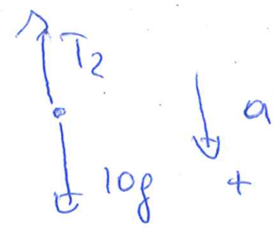


Figure 5-58 Problem 67.







$T_2 - T_1 = 8a$

$10g - T_2 = 10a$

$T_2 = 10g - 10a$

$T_1 - 6g = 6a$

$T_2 - T_1 = 8a$

$+ \quad 10g - T_2 = 10a$

$4g = 24a$

$\boxed{a = \frac{g}{6}}$

$T_2 = 10g - 10a = 10(g-a) = 10\left(g - \frac{g}{6}\right)$

$= \frac{50g}{6}$

$T_2 = \frac{50 \times 9.80}{6} = 81.6\bar{6}$ N

$= 81.7$ N