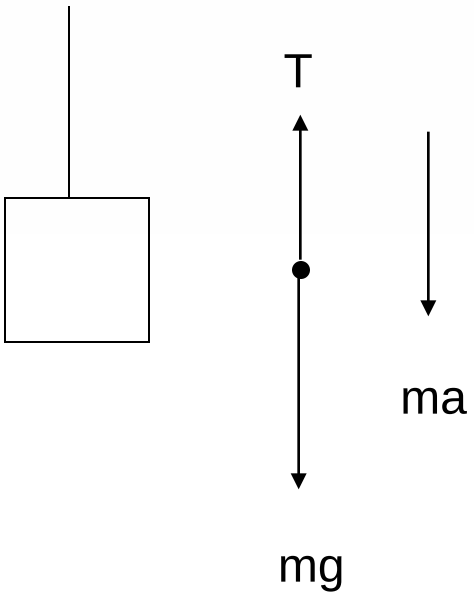
Selected Problems from Chapter 5

1) A 700-kg elevator accelerates downward at 3.8 m/s**2. The tension force of the cable on the elevator is:

A1 4.2 kN, up
A2 2.1 kN, down
A3 2.1 kN, up
A4 4.8 kN, down
A5 9.0 kN, up



F=ma

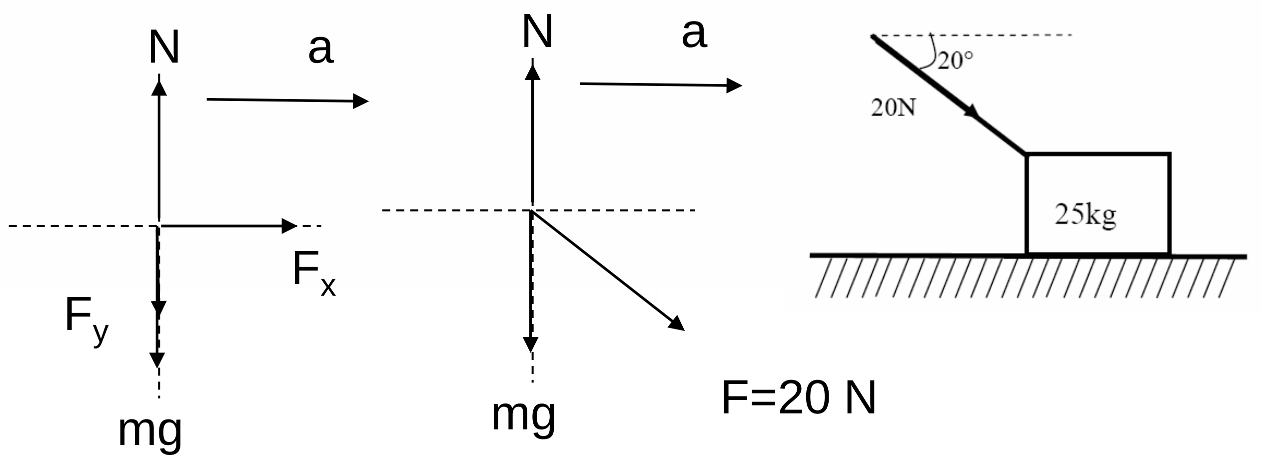
mg-T=ma

T=m(g-a)

T=700(9.8-3.8)= 4200 = **4.2 kN up**

2) As shown in Fig. , a 25-kg box is pushed across a frictionless horizontal floor with a force of 20 N, directed at an angle of 20 degrees below the horizontal. The magnitude of the acceleration of the box is:

A1 0.75 m/s**2
A2 0.27 m/s**2
A3 17 m/s**2
A4 21 m/s**2
A5 0.82 m/s**2



$F_x = F\cos 20^{\circ} = 20\cos 20^{\circ} = 18.79$ N

$F_y = F\sin 20^{\circ} = 20\sin 20^{\circ} = 6.84$ N

along the x-axis:

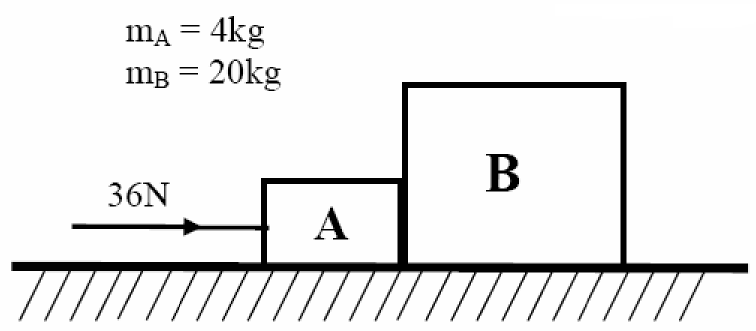
$F_y = ma \quad a = F_y/m = 18.79/25 = 0.75\ m/s^2$

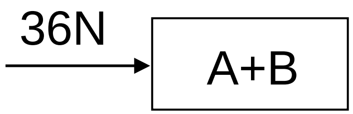
along the y-axis:

$N = mg + F_y$

3) Two blocks A (MA = 4 kg)and B (MB = 20 kg) are in contact with each other and are placed on a horizontal frictionless surface. A 36-N constant force is applied to A as shown in Fig. The magnitude of the force exerted on A by B is

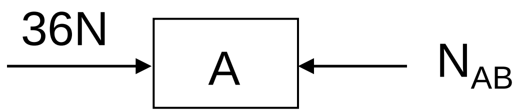
A1 30 N
A2 0 N
A3 36 N
A4 15 N
A5 3.6 N





$M=m_A+m_B=24$ kg

$F=Ma \quad a=F/M=36/24=1.5\ m/s^2$

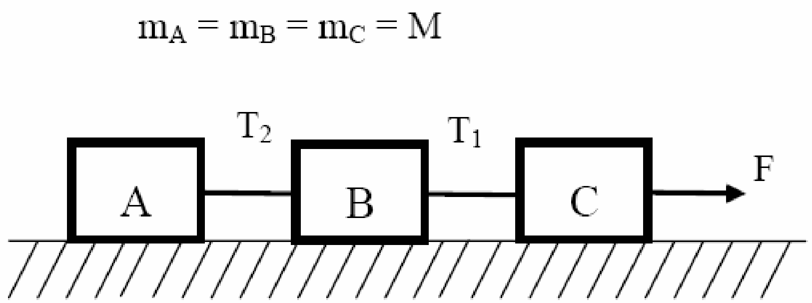


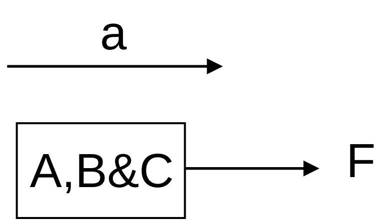
$F-N_{AB}=m_A a$

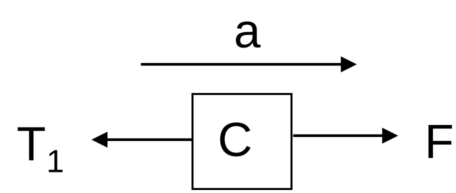
$N_{AB}=F-m_A a=36-4x1.5=30$ N

4) Three blocks (A,B,C), each having mass M, are connected by strings as shown in Fig. Block C is pulled to the right by a force F that causes the entire system to accelerate. Neglecting friction, the tension T1 between blocks B and C is:

A1 2F/3
A2 zero
A3 F/2
A4 F/3
A5 F







(consider A,B,C as one object M=3m)

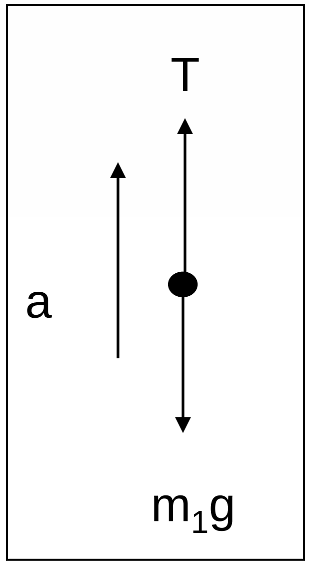
$F=3ma$ hence, $a=F/3m$

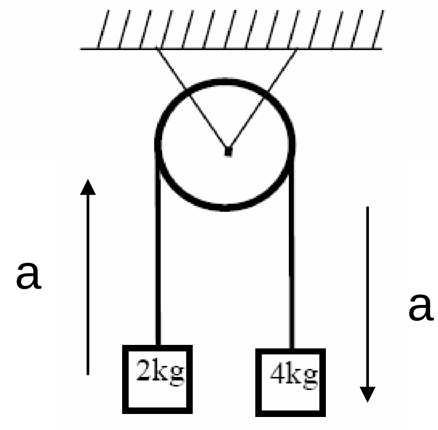
$F-T_1=ma$ (for block C)

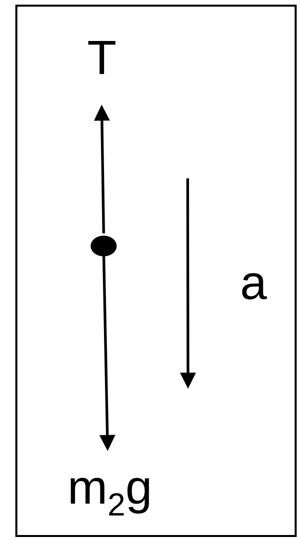
$T_1=F-ma=F-m(F/3m)=2F/3$

5) Two masses m1 = 2kg, m2 = 4 kg are connected by a light string that passes over a frictionless and massless pulley (see Fig.). Find the magnitude of the acceleration of the masses.

A1 3.27 m/s**2
A2 2.15 m/s**2
A3 10.5 m/s**2
A4 0.75 m/s**2
A5 1.23 m/s**2







$T - m_1 g = m_1 a \quad (1)$

$m_2 g - T = m_2 a \quad (2)$

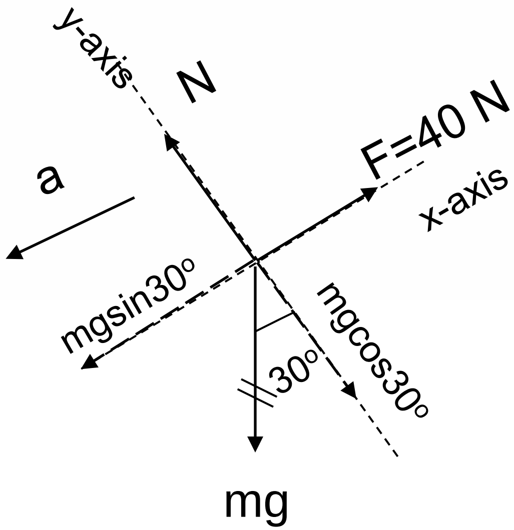
add (1) & (2):

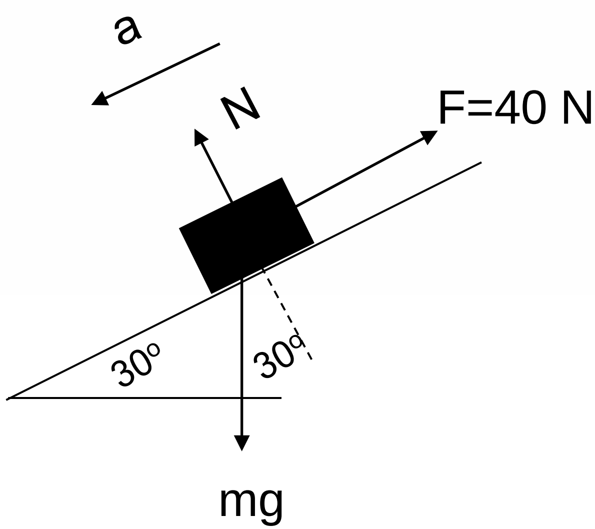
$(m_2 - m_1)g = (m_1 + m_2)a$

$a = (m_2 - m_1)g/(m_1 + m_2) = (2/6) \times 9.80 = 3.27 \ m/s^2$

6) When a 40-N force, parallel to the incline and directed up the incline, is applied to a crate on a frictionless incline that is 30 degrees above the horizontal, the acceleration of the crate is 2.0 m/s**2, down the incline. The mass of the crate is:

A1	14	kg
A2	4.1	kg
A3	5.8	kg
A4	10	kg
A5	6.2	kg





Along the x-axis:

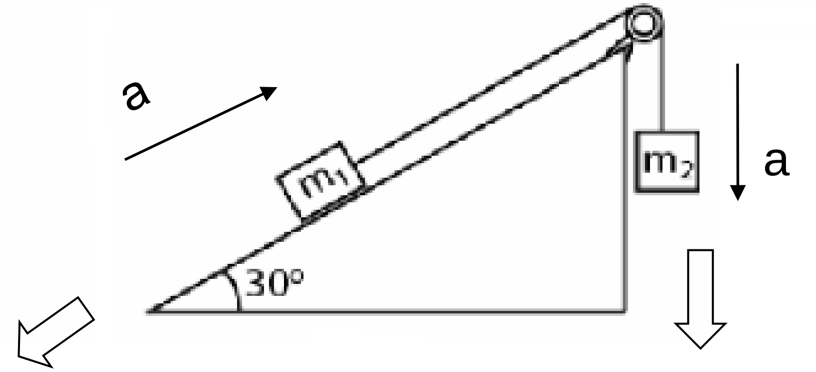
$mg\sin 30^o - F = ma$

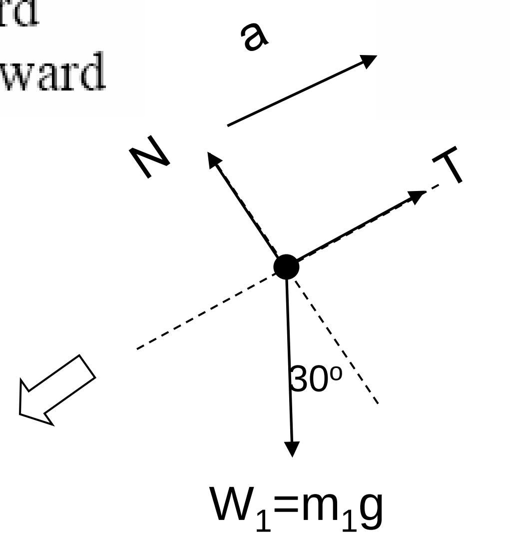
$m(g\sin 30^o - a) = F$

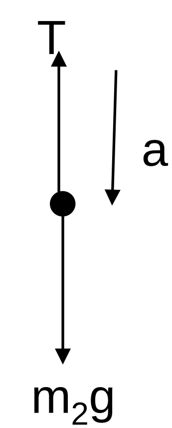
$m = F/(g\sin 30^o - a) = 40/(9.80 \times 0.5 - 2.0) = 14$ kg

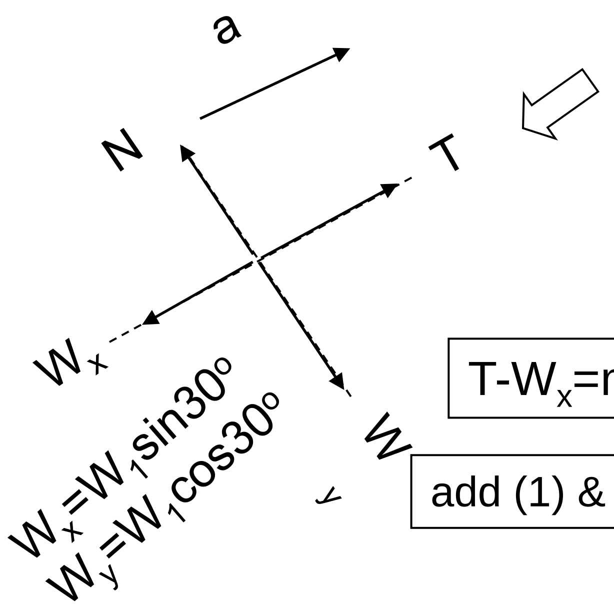
7) A block of mass m_1=5.7 kg on a frictionless 30° inclined plane is connected by a cord over a massless, frictionless pulley to a second block of mass m_2=3.5 kg hanging vertically as shown in Fig 4. The acceleration of m_2 is:

A) 0.69 m/s^2 downward
B) 0.54 m/s^2 upward
C) 0.36 m/s^2 downward
D) 0.78 m/s^2 upward
E) 0.93 m/s^2 downward









$T - W_x = m_1 a$ (1)

$m_2 g - T = m_2 a$ (2)

add (1) & (2): and substitute to get the answer: $a = 0.69\ m/s^2$ down

••5 There are two forces on the 2.00 kg box in the overhead view of Fig. 5-32, but only one is shown. For $F_1 = 20.0$ N, $a = 12.0$ m/s^2, and $\theta = 30.0°$, find the second force (a) in unit-vector notation and as (b) a magnitude and (c) an angle relative to the positive direction of the x axis. SSM

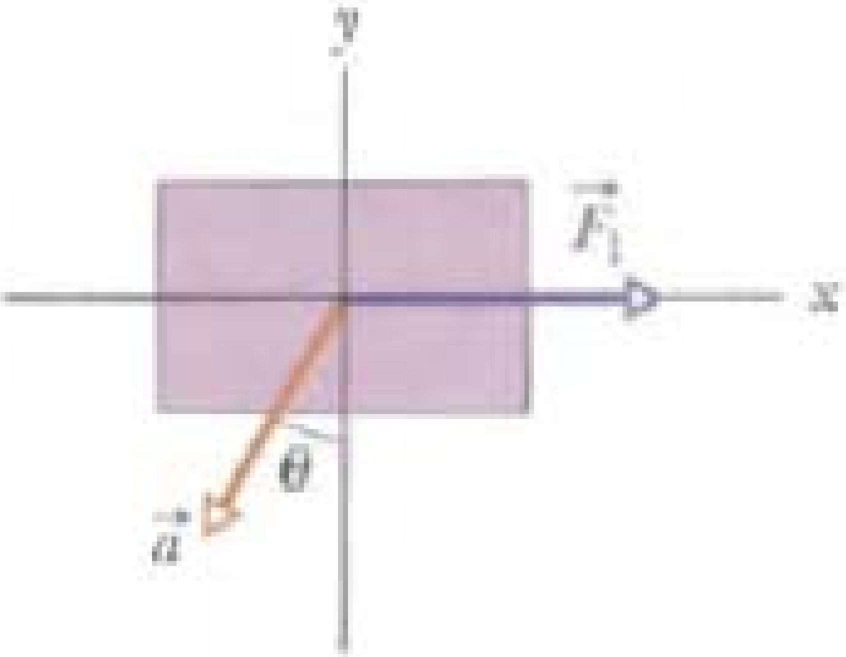


Fig. 5-32 Problem 5.

5. We denote the two forces $\vec{F}_1$ and $\vec{F}_2$. According to Newton's second law, $\vec{F}_1 + \vec{F}_2 = m\vec{a}$, so $\vec{F}_2 = m\vec{a} - \vec{F}_1$.

(a) In unit vector notation $\vec{F}_1 = (20.0\text{ N})\hat{\text{i}}$ and

$$\vec{a} = -(12.0 \sin 30.0°\text{ m/s}^2)\hat{\text{i}} - (12.0 \cos 30.0°\text{ m/s}^2)\hat{\text{j}} = -(6.00\text{ m/s}^2)\hat{\text{i}} - (10.4\text{ m/s}^2)\hat{\text{j}}.$$

Therefore,

$$\begin{aligned}\vec{F}_2 &= (2.00\text{kg})(-6.00\text{ m/s}^2)\hat{\text{i}} + (2.00\text{ kg})(-10.4\text{ m/s}^2)\hat{\text{j}} - (20.0\text{ N})\hat{\text{i}} \\ &= (-32.0\text{ N})\hat{\text{i}} - (20.8\text{ N})\hat{\text{j}}.\end{aligned}$$

(b) The magnitude of $\vec{F}_2$ is

$$|\vec{F}_2| = \sqrt{F_{2x}^2 + F_{2y}^2} = \sqrt{(-32.0)^2 + (-20.8)^2} = 38.2\text{ N}.$$

(c) The angle that $\vec{F}_2$ makes with the positive x axis is found from

$$\tan\theta = (F_{2y}/F_{2x}) = [(-20.8)/(-32.0)] = 0.656.$$

Consequently, the angle is either 33.0° or 33.0° + 180° = 213°. Since both the x and y components are negative, the correct result is 213°. An alternative answer is $213° - 360° = -147°$.

•10 A block with a weight of 3.0 N is at rest on a horizontal surface. A 1.0 N upward force is applied to the block by means of an attached vertical string. What are the (a) magnitude and (b) direction of the force of the block on the horizontal surface?

10. Three vertical forces are acting on the block: the earth pulls down on the block with gravitational force 3.0 N; a spring pulls up on the block with elastic force 1.0 N; and, the surface pushes up on the block with normal force F_N. There is no acceleration, so

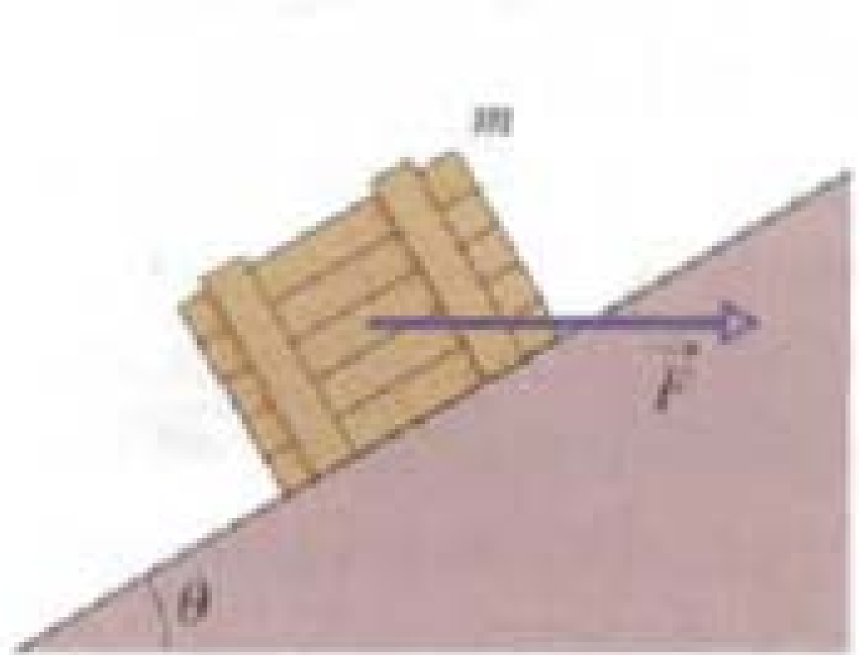
$$\sum F_y = 0 = F_N + (1.0\,\text{N}) + (-3.0\,\text{N})$$

yields $F_N = 2.0$ N.

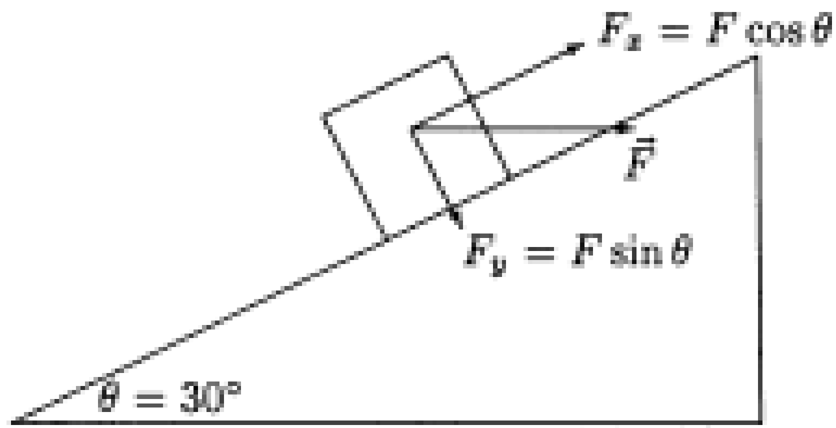
(a) By Newton's third law, the force exerted by the block on the surface has that same magnitude but opposite direction: 2.0 N.

(b) The direction is down.

•24 In Fig. 5-39, 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?



24. We resolve this horizontal force into appropriate components.



(a) Newton's second law applied to the *x* axis produces

$$F\cos\theta - mg\sin\theta = ma.$$

For $a = 0$, this yields $F = 566$ N.

(b) Applying Newton's second law to the *y* axis (where there is no acceleration), we have

$$F_N - F\sin\theta - mg\cos\theta = 0$$

which yields the normal force $F_N = 1.13 \times 10^3$ N.

••34 A lamp hangs vertically from a cord in a descending elevator that decelerates at 2.4 m/s^2. (a) If the tension in the cord is 89 N, what is the lamp's mass? (b) What is the cord's tension when the elevator ascends with an upward acceleration of 2.4 m/s^2?

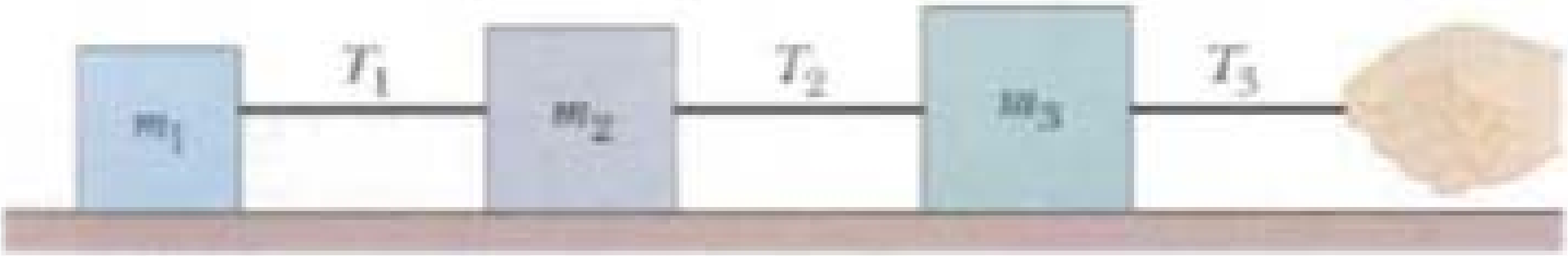
34. (a) The term "deceleration" means the acceleration vector is in the direction opposite to the velocity vector (which the problem tells us is downward). Thus (with $+y$ upward) the acceleration is $a = +2.4 \text{ m/s}^2$. Newton's second law leads to

$$T - mg = ma \quad \Rightarrow \quad m = \frac{T}{g + a}$$

which yields $m = 7.3$ kg for the mass.

(b) Repeating the above computation (now to solve for the tension) with $a = +2.4 \text{ m/s}^2$ will, of course, lead us right back to $T = 89$ N. Since the direction of the velocity did not enter our computation, this is to be expected.

**45 In Fig. 5-49, 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.



45. We apply Newton's second law first to the three blocks as a single system and then to the individual blocks. The $+x$ direction is to the right in Fig. 5-49.

(a) With $m_{sys} = m_1 + m_2 + m_3 = 67.0$ kg, we apply Eq. 5-2 to the x motion of the system – in which case, there is only one force $\vec{T}_3 = +T_3\,\hat{i}$. Therefore,

$$T_3 = m_{sys}a \quad \Rightarrow \quad 65.0\,\text{N} = (67.0\,\text{kg})a$$

which yields $a = 0.970\ \text{m/s}^2$ for the system (and for each of the blocks individually).

(b) Applying Eq. 5-2 to block 1, we find

$$T_1 = m_1 a = (12.0\text{kg})(0.970\,\text{m/s}^2) = 11.6\text{N}.$$

(c) In order to find T_2, we can either analyze the forces on block 3 or we can treat blocks 1 and 2 as a system and examine its forces. We choose the latter.

$$T_2 = (m_1 + m_2)\,a = (12.0 + 24.0)\,(0.970) = 34.9\ \text{N}\ .$$

••47 Figure 5-51 shows two blocks connected by a cord (of negligible mass) that passes over a frictionless pulley (also of negligible mass). The arrangement is known as *Atwood's machine*. One block has mass $m_1 = 1.3$ kg; the other has mass $m_2 = 2.8$ kg. What are (a) the magnitude of the blocks' acceleration and (b) the tension in the cord?

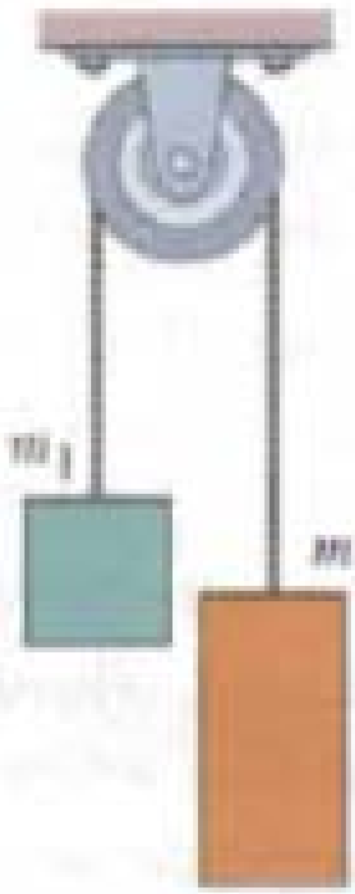
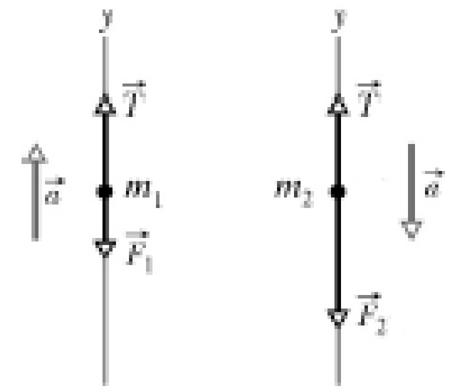


Fig. 5-51 Problem 47.

47. The free-body diagrams for m_1 and m_2 are shown in the figures below. The only forces on the blocks are the upward tension $\vec{T}$ and the downward gravitational forces $\vec{F}_1 = m_1 g$ and $\vec{F}_2 = m_2 g$. Applying Newton's second law, we obtain:

$$T - m_1 g = m_1 a$$

$$m_2 g - T = m_2 a$$



which can be solved to yield

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$

Substituting the result back, we have

$$T = \left(\frac{2m_1 m_2}{m_1 + m_2}\right) g$$

(a) With $m_1 = 1.3$ kg and $m_2 = 2.8$ kg, the acceleration becomes

$$a = \left(\frac{2.8 - 1.3}{2.8 + 1.3}\right)(9.8) = 3.6 \text{ m/s}^2.$$

(b) Similarly, the tension in the cord is

$$T = \frac{2(1.3)(2.8)}{1.3 + 2.8}(9.8) = 17 \text{ N}.$$

••51 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 hanging vertically (Fig. 5-54). 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? ILW

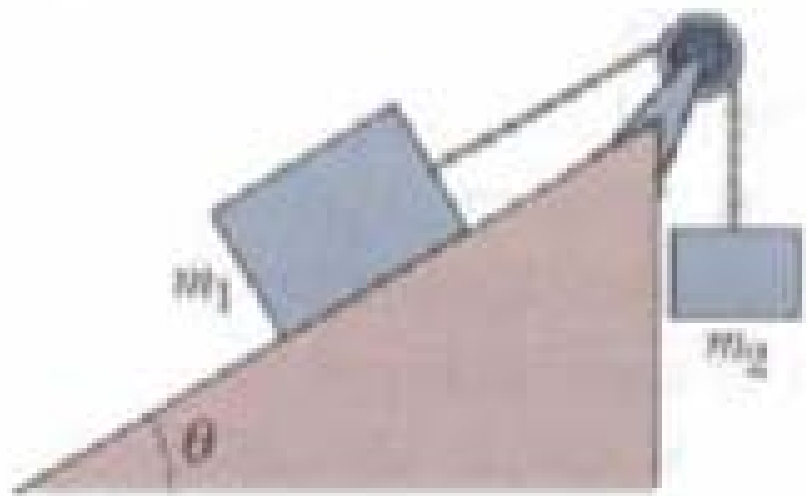


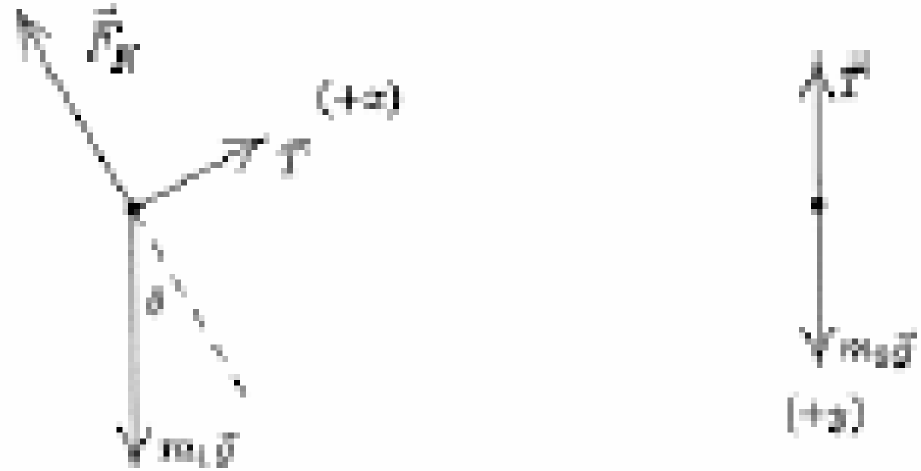
Fig. 5-54 Problem 51.

51. The free-body diagram for each block is shown below. T is the tension in the cord and $\theta = 30°$ is the angle of the incline. For block 1, we take the $+x$ direction to be up the incline and the $+y$ direction to be in the direction of the normal force $\vec{F}_N$ that the plane exerts on the block. For block 2, we take the $+y$ direction to be down. In this way, the accelerations of the two blocks can be represented by the same symbol a, without ambiguity. Applying Newton's second law to the x and y axes for block 1 and to the y axis of block 2, we obtain

$$T - m_1 g \sin\theta = m_1 a$$
$$F_N - m_1 g \cos\theta = 0$$
$$m_2 g - T = m_2 a$$

respectively. The first and third of these equations provide a simultaneous set for obtaining values of a and T. The second equation is not needed in this problem, since the normal force is neither asked for nor is it needed as part of some further computation (such as can occur in formulas for friction).

Continued……



(a) We add the first and third equations above:

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

Consequently, we find

$$a = \frac{(m_2 - m_1 \sin\theta)\, g}{m_1 + m_2} = \frac{(2.30 - 3.70 \sin 30.0^\circ)(9.80)}{3.70 + 2.30} = 0.735 \text{m/s}^2.$$

(b) The result for a is positive, indicating that the acceleration of block 1 is indeed up the incline and that the acceleration of block 2 is vertically down.

(c) The tension in the cord is

$$T = m_1 a + m_1 g \sin\theta = (3.70)(0.735) + (3.70)(9.80) \sin 30.0^\circ = 20.8 \text{N}.$$