ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. Newton's second law gives the net force acting on the crate as

$$F_{\text{net}} = 95.0\text{ N} - f_k = (60.0\text{ kg})(1.20\text{ m/s}^2) = 72.0\text{ N}$$

This gives the kinetic friction force as $f_k = 23.0$ N, so choice (a) is correct.

2. As the block slides down the frictionless incline, there is a constant net force directed down the incline (i.e., the tangential component of the weight of the block) acting on it. This force will give the block a constant acceleration down the incline, meaning that its speed down the incline will increase at a constant rate. Thus, the only correct choice is (c).

8. Constant velocity means zero acceleration. From Newton's second law, $\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}$, so the total (or resultant) force acting on the object must be zero if it moves at constant velocity. This means that (d) is the correct choice.

10. An object in equilibrium has zero acceleration $(\vec{\mathbf{a}} = 0)$, so both the magnitude and direction of the object's velocity must be constant. Also, Newton's second law states that the net force acting on an object in equilibrium is zero. The only *untrue statement* among the given choices is (d), untrue because the value of the velocity's constant magnitude need not be zero.

16. Only forces which act ***on*** the object should be included in the free-body diagram of the object. In this case, these forces are: (1) the gravitational force (acting vertically downward), (2) the normal force (perpendicular to the incline) exerted on the object by the incline, and (3) the friction force exerted on the object by the incline, and acting *up* the incline to oppose the motion of the object down the incline). Choices (d) and (f) are forces exerted *on the incline* by the object. Choice (b) is the resultant of forces (1), (2), and (3) listed above, and its inclusion in the free-body diagram would duplicate information already present. Thus, correct answers to this question are (b), (d), and (f).

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. If it has a large mass, it will take a large force to alter its motion even when floating in space. Thus, to avoid injuring himself, he should push it gently toward the storage compartment.

4. The coefficient of static friction is larger than that of kinetic friction. To start the box moving, you must counterbalance the maximum static friction force. This force exceeds the kinetic friction force that you must counterbalance to maintain constant velocity of the box once it starts moving.

14. When a tire is rolling, the point on the tire in contact with the ground is momentarily at rest relative to the ground. Thus, static friction exists between the tire and the ground under these conditions. When the brakes lock, the tires begin to skid over the ground and kinetic friction now exists between tires and the ground. Since the kinetic friction force is less than the maximum static friction force ($\mu_k < \mu_s$), the friction force tending to slow the car is less with the brakes locked than while the tires continue to roll.

PROBLEM SOLUTIONS

4.2 From $v = v_0 + at$, the acceleration given to the football is

$$a_{\text{av}} = \frac{v - v_0}{t} = \frac{10 \text{ m/s} - 0}{0.20 \text{ s}} = 50 \text{ m/s}^2$$

Then, from Newton's second law, we find

$$F_{\text{av}} = m\,a_{\text{av}} = (0.50 \text{ kg})(50 \text{ m/s}^2) = \boxed{25 \text{ N}}$$

4.5 The weight of the bag of sugar on Earth is

$$w_E = mg_E = (5.00\ \text{lbs})\left(\frac{4.448\ \text{N}}{1\ \text{lb}}\right) = 22.2\ \text{N}$$

If g_M is the free-fall acceleration on the surface of the Moon, the ratio of the weight of an object on the Moon to its weight when on Earth is $w_M/w_E = mg_M/mg_E = g_M/g_E$, so $w_M = w_E\left(g_M/g_E\right)$. Hence, the weight of the bag of sugar on the Moon is

$$w_M = (22.2\ \text{N})\left(\frac{1}{6}\right) = \boxed{3.70\ \text{N}}$$

On Jupiter, its weight would be

$$w_J = w_E\left(\frac{g_J}{g_E}\right) = (22.2\ \text{N})(2.64) = \boxed{58.6\ \text{N}}$$

The mass is the same at all three locations, and is given by

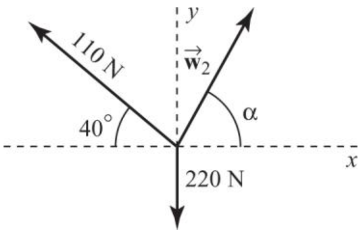
$$m = \frac{w_E}{g_E} = \frac{(5.00\ \text{lb})(4.448\ \text{N/lb})}{9.80\ \text{m/s}^2} = \boxed{2.27\ \text{kg}}$$

4.6 $$a = \frac{\Sigma F}{m} = \frac{7.5\times10^5\ \text{N}}{1.5\times10^7\ \text{kg}} = 5.0\times10^{-2}\ \text{m/s}^2$$

and $v = v_0 + at$ gives

$$t = \frac{v - v_0}{a} = \frac{80\ \text{km/h} - 0}{5.0\times10^{-2}\ \text{m/s}^2}\left(\frac{0.278\ \text{m/s}}{1\ \text{km/h}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = \boxed{7.4\ \text{min}}$$

4.20 If the hip exerts no force on the leg, the system must be in equilibrium with the three forces shown in the free-body diagram.



Thus $\Sigma F_x = 0$ becomes

$$w_2 \cos\alpha = (110\ \text{N})\cos 40° \qquad \textbf{[1]}$$

From $\Sigma F_y = 0$, we find

$$w_2 \sin\alpha = 220\ \text{N} - (110\ \text{N})\sin 40° \qquad \textbf{[2]}$$

Dividing Equation [2] by Equation [1] yields

$$\alpha = \tan^{-1}\left(\frac{220\ \text{N} - (110\ \text{N})\sin 40°}{(110\ \text{N})\cos 40°}\right) = \boxed{61°}$$

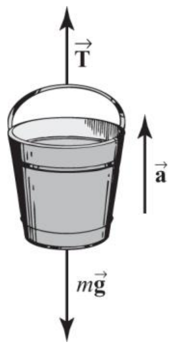
Then, from either Equation [1] or [2], $w_2 = \boxed{1.7 \times 10^2\ \text{N}}$

4.25 The forces on the bucket are the tension in the rope and the weight of the bucket, $mg = (5.0\ \text{kg})(9.80\ \text{m/s}^2) = 49\ \text{N}$. Choose the positive direction upward and use Newton's second law:

$$\Sigma F_y = ma_y$$

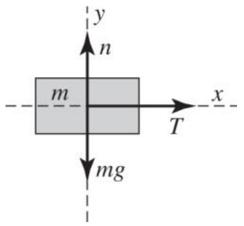
$$T - 49\ \text{N} = (5.0\ \text{kg})(3.0\ \text{m/s}^2)$$

$T = \boxed{64\ \text{N}}$



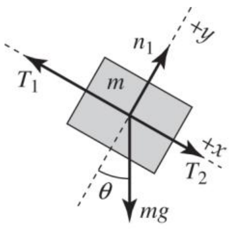
4.26 With the truck accelerating in a forward direction on a horizontal roadway, the acceleration of the crate is the same as that of the truck as long as the cord does not break. Applying Newton's second law to the horizontal motion of the block gives

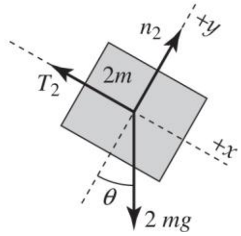
$$\Sigma F_x = ma_x \quad \Rightarrow \quad T = ma \quad \text{or} \quad a = T/m$$



Thus $a_{\text{max}} = \dfrac{T_{\text{max}}}{m} = \dfrac{68\ \text{N}}{32\ \text{kg}} = \boxed{2.1\ \text{m/s}^2}$

4.27 We choose reference axes that are parallel to and perpendicular to the incline as shown in the force diagrams at the right. Since both blocks are in equilibrium, $a_x = a_y = 0$ for each block. Then, applying Newton's second law to each block gives





For Block 1 (mass *m*):

$$\Sigma F_x = ma_x \quad \Rightarrow \quad -T_1 + T_2 + mg\sin\theta = 0$$

or $\quad T_1 = T_2 + mg\sin\theta$ **[1]**

For Block 2 (mass 2*m*):

$$\Sigma F_x = ma_x \quad \Rightarrow \quad -T_2 + 2mg\sin\theta = 0$$

or $\quad T_2 = 2mg\sin\theta$ **[2]**

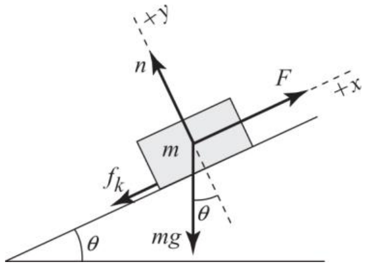
(a) Substituting Equation [2] into Equation [1] gives $\boxed{T_1 = 3mg\sin\theta}$

(b) From Equation [2] above, we have $\boxed{T_2 = 2mg\sin\theta}$

4.30 The figure at the right shows the forces acting on the block. The incline is tilted at $\theta = 25°$, the mass of the block is $m = 5.8$ kg, while the applied force pulling the block up the incline is $F = 32$ N. Since $a_y = 0$ for this block,

$$\Sigma F_y = n - mg\cos\theta = 0$$

and the normal force is $n = mg\cos\theta$



(a) Since the incline is considered frictionless for this part, we take the friction force to be $f_k = 0$ and find

$$\Sigma F_x = F - mg\sin\theta = ma_x \qquad \text{or} \qquad a_x = \frac{F}{m} - g\sin\theta$$

giving $$a_x = \frac{32\ \text{N}}{5.8\ \text{kg}} - \left(9.8\ \text{m/s}^2\right)\sin 25° = \boxed{1.4\ \text{m/s}^2}$$

(b) If the coefficient of kinetic friction between the block and the incline is μ_k, then the friction force is $f_k = \mu_k n = \mu_k mg\cos\theta$, and

$$\Sigma F_x = F - f_k - mg\sin\theta = F - mg\left(\mu_k\cos\theta + \sin\theta\right) = ma_x$$

Thus, $a_x = \dfrac{F}{m} - g\left(\mu_k \cos\theta + \sin\theta\right)$

and $a_x = \dfrac{32\text{ N}}{5.8\text{ kg}} - \left(9.8\text{ m/s}^2\right)\left[(0.10)\cos 25° + \sin 25°\right] = \boxed{0.49\text{ m/s}^2}$

4.40 (a) The static friction force attempting to prevent motion may reach a maximum value of

$$\left(f_s\right)_{\max} = \mu_s n_1 = \mu_s m_1 g = (0.50)(10\text{ kg})\left(9.80\text{ m/s}^2\right) = 49\text{ N}$$

This exceeds the force attempting to move the system, $w_2 = m_2 g = 39$ N. Hence, the system remains at rest and the acceleration is $a = \boxed{0}$.

(b) Once motion begins, the friction force retarding the motion is

$$f_k = \mu_k n_1 = \mu_k m_1 g = (0.30)(10\text{ kg})\left(9.80\text{ m/s}^2\right) = 29\text{ N}$$

This is less than the force trying to move the system,$w_2 = m_2 g$. Hence, the system gains speed at the rate

$$a = \frac{F_{\text{net}}}{m_{\text{total}}} = \frac{m_2 g - \mu_k m_1 g}{m_1 + m_2} = \frac{\left[4.0\text{ kg} - 0.30(10\text{ kg})\right]\left(9.80\text{ m/s}^2\right)}{4.0\text{ kg} + 10\text{ kg}} = \boxed{0.70\text{ m/s}^2}$$

4.63 (a) The force that accelerates the box is $\boxed{\text{the friction force}}$ between the box and truck.

(b) We assume the truck is on level ground. Then, the normal force exerted on the box by the truck equals the weight of the box, $n = mg$. The maximum acceleration the truck can have before the box slides is found by considering the maximum static friction force the truck bed can exert on the box:

$$(f_s)_{\max} = \mu_s n = \mu_s (mg)$$

Thus, from Newton's second law,

$$a_{\max} = \frac{(f_s)_{\max}}{m} = \frac{\mu_s (mg)}{m} = \mu_s g = (0.300)\left(9.80\ \text{m/s}^2\right) = \boxed{2.94\ \text{m/s}^2}$$