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PHYS 191, Fall 2014, Dr. H. Merabet

Solutions to Practice Problems Chapter 4

Responses to Questions

Q4.1 No. For an object to be in equilibrium the net force on it must be zero. If there is one and only one non-zero force on the object, the net force isn't zero.

Q4.13 No, in all the cases the van is accelerating and is therefore an non-inertial frame.

Q4.21 You have the same speed just before impact in either case. But the distance over which you stop is much smaller for the concrete so your acceleration and the force exerted on you is much larger in that case.

Solutions to Problem

P4.2. **IDENTIFY:** We know the magnitudes and directions of three vectors and want to use them to find their components, and then to use the components to find the magnitude and direction of the resultant vector.

SET UP: Let $F_1 = 985\ \text{N}$, $F_2 = 788\ \text{N}$, and $F_3 = 411\ \text{N}$. The angles θ that each force makes with the

$+x$ axis are $\theta_1 = 31°$, $\theta_2 = 122°$, and $\theta_3 = 233°$. The components of a force vector are

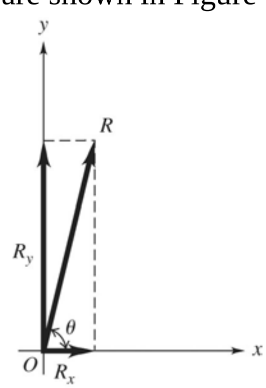
$F_x = F\cos\theta$ and $F_y = F\sin\theta$, and $R = \sqrt{R_x^2 + R_y^2}$ and $\tan\theta = \dfrac{R_y}{R_x}$.

EXECUTE: **(a)** $F_{1x} = F_1\cos\theta_1 = 844\ \text{N}$, $F_{1y} = F_1\sin\theta_1 = 507\ \text{N}$, $F_{2x} = F_2\cos\theta_2 = -418\ \text{N}$,

$F_{2y} = F_2\sin\theta_2 = 668\ \text{N}$, $F_{3x} = F_3\cos\theta_3 = -247\ \text{N}$, and $F_{3y} = F_3\sin\theta_3 = -328\ \text{N}$.

(b) $R_x = F_{1x} + F_{2x} + F_{3x} = 179\ \text{N}$; $R_y = F_{1y} + F_{2y} + F_{3y} = 847\ \text{N}$. $R = \sqrt{R_x^2 + R_y^2} = 886\ \text{N}$; $\tan\theta = \dfrac{R_y}{R_x}$ so

$\theta = 78.1°$. $\vec{R}$ and its components are shown in Figure 4.2 below.



EVALUATE: A graphical sketch of the vector sum should agree with the results found in (b). Adding the forces as vectors gives a very different result from adding their magnitudes.

P4.4. **IDENTIFY:** $F_x = F\cos\theta,\ \ F_y = F\sin\theta.$

SET UP: Let $+x$ be parallel to the ramp and directed up the ramp. Let $+y$ be perpendicular to the ramp and directed away from it. Then $\theta = 30.0°.$

EXECUTE: **(a)** $F = \dfrac{F_x}{\cos\theta} = \dfrac{60.0\text{ N}}{\cos 30°} = 69.3\text{ N}.$

(b) $F_y = F\sin\theta = F_x\tan\theta = 34.6\text{ N}.$

EVALUATE: We can verify that $F_x^2 + F_y^2 = F^2.$ The signs of F_x and F_y show their direction.

P4.10. **IDENTIFY:** Use the information about the motion to find the acceleration and then use $\sum F_x = ma_x$ to calculate *m*.

SET UP: Let $+x$ be the direction of the force. $\sum F_x = 80.0\text{ N}.$

EXECUTE: **(a)** $x - x_0 = 11.0\text{ m},\ \ t = 5.00\text{ s},\ \ v_{0x} = 0.\ \ x - x_0 = v_{0x}t + \tfrac{1}{2}a_x t^2$ gives

$$a_x = \frac{2(x - x_0)}{t^2} = \frac{2(11.0\text{ m})}{(5.00\text{ s})^2} = 0.880\text{ m/s}^2.\ \ m = \frac{\sum F_x}{a_x} = \frac{80.0\text{ N}}{0.880\text{ m/s}^2} = 90.9\text{ kg}.$$

(b) $a_x = 0$ and v_x is constant. After the first 5.0 s,

$$v_x = v_{0x} + a_x t = (0.880\text{ m/s}^2)(5.00\text{ s}) = 4.40\text{ m/s}.\ \ x - x_0 = v_{0x}t + \tfrac{1}{2}a_x t^2 = (4.40\text{ m/s})(5.00\text{ s}) = 22.0\text{ m}.$$

EVALUATE: The mass determines the amount of acceleration produced by a given force. The block moves farther in the second 5.00 s than in the first 5.00 s.

P4.13. **IDENTIFY:** The force and acceleration are related by Newton's second law.

SET UP: $\sum F_x = ma_x$, where $\sum F_x$ is the net force. $m = 4.50\text{ kg}.$

EXECUTE: **(a)** The maximum net force occurs when the acceleration has its maximum value. $\sum F_x = ma_x = (4.50\text{ kg})(10.0\text{ m/s}^2) = 45.0\text{ N}.$ This maximum force occurs between 2.0 s and 4.0 s.

(b) The net force is constant when the acceleration is constant. This is between 2.0 s and 4.0 s.

(c) The net force is zero when the acceleration is zero. This is the case at $t = 0$ and $t = 6.0\text{ s}.$

EVALUATE: A graph of $\sum F_x$ versus *t* would have the same shape as the graph of a_x versus *t*.

P4.15. **IDENTIFY:** The net force and the acceleration are related by Newton's second law. When the rocket is near the surface of the earth the forces on it are the upward force $\vec{F}$ exerted on it because of the burning fuel and the downward force $\vec{F}_{\text{grav}}$ of gravity.

$F_{\text{grav}} = mg.$

SET UP: Let $+y$ be upward. The weight of the rocket is $F_{\text{grav}} = (8.00\text{ kg})(9.80\text{ m/s}^2) = 78.4\text{ N}.$

EXECUTE: **(a)** At $t=0$, $F=A=100.0\text{ N}$. At $t=2.00\text{ s}$, $F=A+(4.00\text{ s}^2)B=150.0\text{ N}$ and $B=\dfrac{150.0\text{ N}-100.0\text{ N}}{4.00\text{ s}^2}=12.5\text{ N/s}^2$.

(b) (i) At $t=0$, $F=A=100.0\text{ N}$. The net force is $\sum F_y=F-F_{\text{grav}}=100.0\text{ N}-78.4\text{ N}=21.6\text{ N}$. $a_y=\dfrac{\sum F_y}{m}=\dfrac{21.6\text{ N}}{8.00\text{ kg}}=2.70\text{ m/s}^2$. (ii) At $t=3.00\text{ s}$, $F=A+B(3.00\text{ s})^2=212.5\text{ N}$. $\sum F_y=212.5\text{ N}-78.4\text{ N}=134.1\text{ N}$. $a_y=\dfrac{\sum F_y}{m}=\dfrac{134.1\text{ N}}{8.00\text{ kg}}=16.8\text{ m/s}^2$.

(c) Now $F_{\text{grav}}=0$ and $\sum F_y=F=212.5\text{ N}$. $a_y=\dfrac{212.5\text{ N}}{8.00\text{ kg}}=26.6\text{ m/s}^2$.

EVALUATE: The acceleration increases as F increases.

P4.20. **IDENTIFY:** Weight and mass are related by $w=mg$. The mass is constant but g and w depend on location.

SET UP: On earth, $g=9.80\text{ m/s}^2$.

EXECUTE: **(a)** $\dfrac{w}{g}=m$, which is constant, so $\dfrac{w_{\text{E}}}{g_{\text{E}}}=\dfrac{w_{\text{A}}}{g_{\text{A}}}$. $w_{\text{E}}=17.5\text{ N}$, $g_{\text{E}}=9.80\text{ m/s}^2$, and $w_{\text{A}}=3.24\text{ N}$. $g_{\text{A}}=\left(\dfrac{w_{\text{A}}}{w_{\text{E}}}\right)g_{\text{E}}=\left(\dfrac{3.24\text{ N}}{17.5\text{ N}}\right)(9.80\text{ m/s}^2)=1.81\text{ m/s}^2$.

(b) $m=\dfrac{w_{\text{E}}}{g_{\text{E}}}=\dfrac{17.5\text{ N}}{9.80\text{ m/s}^2}=1.79\text{ kg}$.

EVALUATE: The weight at a location and the acceleration due to gravity at that location are directly proportional.

P4.23. **IDENTIFY:** The system is accelerating so we use Newton's second law.

SET UP: The acceleration of the entire system is due to the 100-N force, but the acceleration of box B is due to the force that box A exerts on it. $\sum F=ma$ applies to the two-box system and to each box individually.

EXECUTE: For the two-box system: $a_x=\dfrac{100\text{ N}}{25\text{ kg}}=4.0\text{ m/s}^2$. Then for box B, where F_A is the force exerted on B by A, $F_A=m_Ba=(5.0\text{ kg})(4.0\text{ m/s}^2)=20\text{ N}$.

EVALUATE: The force on B is less than the force on A.

P4.25. **IDENTIFY:** Apply Newton's second law to the earth.

SET UP: The force of gravity that the earth exerts on her is her weight, $w=mg=(45\text{ kg})(9.8\text{ m/s}^2)=441\text{ N}$. By Newton's third law, she exerts an equal and opposite force on the earth.

Apply $\sum\vec{F}=m\vec{a}$ to the earth, with $\left|\sum\vec{F}\right|=w=441\text{ N}$, but must use the mass of the earth for m.

EXECUTE: $a=\dfrac{w}{m}=\dfrac{441\text{ N}}{6.0\times10^{24}\text{ kg}}=7.4\times10^{-23}\text{ m/s}^2$.

EVALUATE: This is *much* smaller than her acceleration of $9.8\ \text{m/s}^2$. The force she exerts on the earth equals in magnitude the force the earth exerts on her, but the acceleration the force produces depends on the mass of the object and her mass is *much* less than the mass of the earth.

P4.27. IDENTIFY: Identify the forces on each object.
SET UP: In each case the forces are the noncontact force of gravity (the weight) and the forces applied by objects that are in contact with each crate. Each crate touches the floor and the other crate, and some object applies $\vec{F}$ to crate *A*.
EXECUTE: **(a)** The free-body diagrams for each crate are given in Figure 4.27.
F_{AB} (the force on m_A due to m_B) and F_{BA} (the force on m_B due to m_A) form an action-reaction pair.
(b) Since there is no horizontal force opposing *F*, any value of *F*, no matter how small, will cause the crates to accelerate to the right. The weight of the two crates acts at a right angle to the horizontal, and is in any case balanced by the upward force of the surface on them.
EVALUATE: Crate *B* is accelerated by F_{BA} and crate *A* is accelerated by the net force $F - F_{AB}$. The greater the total weight of the two crates, the greater their total mass and the smaller will be their acceleration.

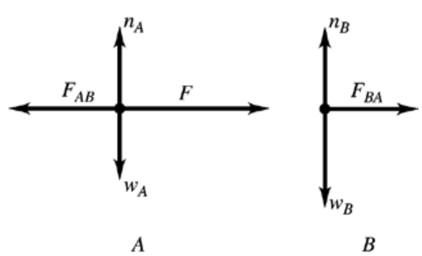


Figure 4.27

P4.52. IDENTIFY: Apply $\sum \vec{F} = m\vec{a}$ to the hammer head. Use a constant acceleration equation to relate the motion to the acceleration.
SET UP: Let $+y$ be upward.
EXECUTE: **(a)** The free-body diagram for the hammer head is sketched in Figure 4.52.
(b) The acceleration of the hammer head is given by $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ with $v_y = 0$, $v_{0y} = -3.2\ \text{m/s}^2$ and $y - y_0 = -0.0045\ \text{m}$. $a_y = v_{0y}^2/2(y - y_0) = (3.2\ \text{m/s})^2/2(0.0045\ \text{cm}) = 1.138\times10^3\ \text{m/s}^2$.
The mass of the hammer head is its weight divided by g, $(4.9\ \text{N})/(9.80\ \text{m/s}^2) = 0.50\ \text{kg}$, and so the net force on the hammer head is $(0.50\ \text{kg})(1.138\times10^3\ \text{m/s}^2) = 570\ \text{N}$. This is the sum of the forces on the hammer head: the upward force that the nail exerts, the downward weight and the downward 15-N force. The force

that the nail exerts is then 590 N, and this must be the magnitude of the force that the hammer head exerts on the nail.

(c) The distance the nail moves is 0.12 m, so the acceleration will be $4267\ \text{m/s}^2$, and the net force on the hammer head will be 2133 N. The magnitude of the force that the nail exerts on the hammer head, and hence the magnitude of the force that the hammer head exerts on the nail, is 2153 N, or about 2200 N.

EVALUATE: For the shorter stopping distance the acceleration has a larger magnitude and the force between the nail and hammer head is larger.

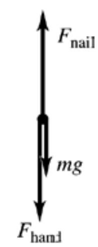


Figure 4.52