

# General Physics I

## Homework Chapter 9

Jonathan Henrique Maia de Moraes (ID: 1620855)

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# Homework: Chapter 9

## Problem (1)

A  $0.091 \text{ sl}$  ball drops vertically onto a floor, hitting with a speed of  $23 \text{ ft/s}$ . It rebounds with an initial speed of  $17 \text{ ft/s}$ .

### Question (a)

What impulse acts on the ball during the contact?

**R:**

$$\begin{aligned} I &= \Delta p = p_f - p_i \\ &= mv_f - mv_i \\ &= (0.091 \text{ sl})(23 \text{ ft/s}) - (0.091 \text{ sl})(0 \text{ ft/s}) \\ &= 2.093 \text{ sl} \times \text{ft/s} \end{aligned} \tag{1}$$

### Question (b)

If the ball is in contact with the floor for  $0.016 \text{ s}$ , what is the average force on the ball from the floor?

**R:**

$$\begin{aligned}
 I &= F_{ave} \Delta t \\
 F_{ave} &= \frac{I}{\Delta t} \\
 &= \frac{2.093 \text{ sl} \times \text{ft/s}}{0.016 \text{ s}} \\
 &= 130.8125 \text{ lb}
 \end{aligned} \tag{2}$$

## Problem (2)

A  $2.5 \text{ kg}$  toy car can move along an  $x$  axis; the figure gives  $F_x$  of the force acting on the car, which begins at rest at time  $t = 0$ . The scale on the  $F_x$  axis is such that the point  $F_{xs} = 20.0 \text{ N}$ .

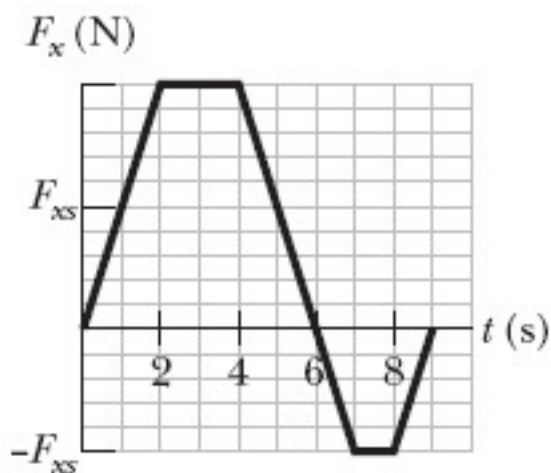


Figure 1: Illustration of Problem 2

### Question (a)

What is  $p$  at  $t = 1.0 \text{ s}$ ?

**R:**

$$\begin{aligned}
p_i &= (2.5 \text{ kg})(0 \text{ m/s}) = 0 \\
p_f &= I = F_{ave} \Delta t \\
p_{1.0 \text{ s}} &= \left( \frac{F_{xs}}{2} \right) (1 \text{ s}) \\
&= 10.0 \text{ N} \times \text{s}
\end{aligned} \tag{3}$$

**Question (b)**

What is  $p$  at  $t = 2.0 \text{ s}$ ?

**R:**

$$\begin{aligned}
p_{2.0 \text{ s}} &= \left( \frac{F_{xs} + 2F_{xs}}{3} \right) (2 \text{ s}) \\
&= (20.0 \text{ N})(2 \text{ s}) \\
&= 40.0 \text{ N} \times \text{s}
\end{aligned} \tag{4}$$

**Question (c)**

What is  $v$  at  $t = 5.0 \text{ s}$ ?

**R:**

$$\begin{aligned}
p_{5.0 \text{ s}} &= \left( \frac{F_{xs} + 2F_{xs} + 2F_{xs} + 2F_{xs} + F_{xs}}{6} \right) (5 \text{ s}) \\
&= (26.\bar{6} \text{ N})(5 \text{ s}) \\
&= 133.\bar{3} \text{ N} \times \text{s} \\
v_{5.0 \text{ s}} &= \frac{p_{5.0 \text{ s}}}{m} \\
&= \frac{133.\bar{3} \text{ N} \times \text{s}}{2.5 \text{ kg}} \\
&= 53.\bar{3} \text{ m/s}
\end{aligned} \tag{5}$$

### Problem (3)

The fig. 2 shows an approximate plot of force magnitude  $F$  versus time  $t$  during the collision of a 42 g Superball with a wall. The initial velocity of the ball is 35 m/s perpendicular to the wall; It rebounds directly back with approximately the same speed, also perpendicular to the wall. What is  $F_{\max}$ , the maximum magnitude of the force on the ball from the wall during the collision?

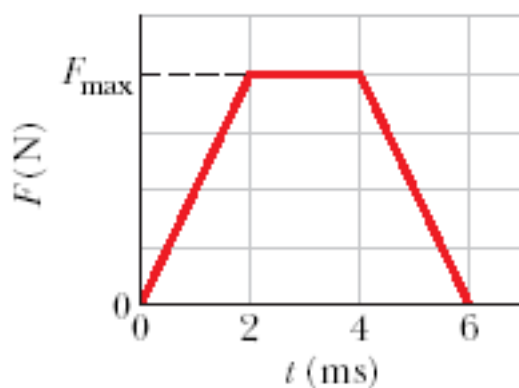


Figure 2: Illustration of Problem 3

**R:**

$$m = 42 \text{ g} \times \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right) = 0.042 \text{ kg}$$

$$\begin{aligned} p_i &= (0.042 \text{ kg})(35 \text{ m/s}) \\ &= 1.47 \text{ N} \times \text{s} \end{aligned}$$

$$\begin{aligned} p_f &\approx (0.042 \text{ kg})(-35 \text{ m/s}) \\ &= -1.47 \text{ N} \times \text{s} \end{aligned}$$

$$\begin{aligned}
I &= \Delta p = (-1.47 \text{ N} \times s) - (1.47 \text{ N} \times s) \\
&= -2.94 \text{ N} \times s \\
I &= F_{ave} \Delta t \\
(-2.94 \text{ N} \times s) &= F_{max} [(4 \text{ ms}) - (2 \text{ ms})] \\
F_{max} &= \frac{|-2.94 \text{ N} \times s|}{0.002 \text{ s}} \\
&= 1470 \text{ N}
\end{aligned} \tag{6}$$

### Problem (4)

A 150 *lb* man lying on a surface of negligible friction shoves a 9.0 *lb* stone away from himself, giving it a speed of 6.5 *ft/s*. What speed does the man acquire as a result?

**R:**

$$\begin{aligned}
m_m &= \frac{150 \text{ lb}}{32.2 \text{ ft/s}^2} = 4.6584 \text{ sl} \\
m_s &= \frac{9 \text{ lb}}{32.2 \text{ ft/s}^2} = 0.2795 \text{ sl} \\
\Delta p &= 0 \\
p_i &= p_f \\
MV_i &= m_m v_{mf} + m_s v_{sf} \\
[(4.6584 \text{ sl}) + (0.2795 \text{ sl})](0 \text{ ft/s}) &= (4.6584 \text{ sl})v_{mf} + (0.2795 \text{ sl})(6.5 \text{ ft/s}) \\
v_{mf} &= \frac{(0.2795 \text{ sl})(6.5 \text{ ft/s})}{4.6584 \text{ sl}} \\
&= 0.39 \text{ ft/s}
\end{aligned} \tag{7}$$

### Problem (5)

A 9.7 *kg* sled is coasting across frictionless ice at a speed of 2.3 *m/s* when a 19.1 *kg* package is dropped into it from above. What is the new speed of the sled?

**R:**

$$\begin{aligned}
 \Delta p &= 0 \\
 p_i &= p_f \\
 m_s v_{si} &= (m_s + m_p) V_f \\
 V_f &= \frac{m_s v_{si}}{m_s + m_p} \\
 &= \frac{(9.7 \text{ kg})(2.3 \text{ m/s})}{(9.7 \text{ kg}) + (19.1 \text{ kg})} \\
 &= 0.775 \text{ m/s}
 \end{aligned} \tag{8}$$

### Problem (6)

In the fig. 3, block  $A$  (mass  $1.5 \text{ sl}$ ) slides into block  $B$  (mass  $2.5 \text{ sl}$ ), along a frictionless surface. The directions of velocities before and after the collision are indicated; the corresponding speeds are  $v_{Ai} = 4.0 \text{ ft/s}$ ,  $v_{Bi} = 2.4 \text{ ft/s}$ , and  $v_{Bf} = 3.2 \text{ ft/s}$ . What is velocity  $v_{Af}$  (including sign, where positive denotes motion to the right)?

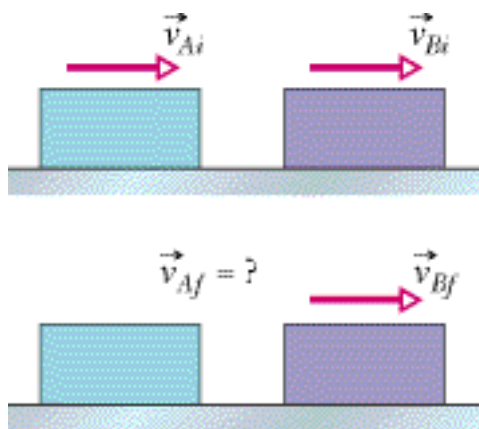


Figure 3: Illustration of Problem 6

**R:**

$$\begin{aligned}
\Delta p &= 0 \\
p_i &= p_f \\
m_A \vec{v}_{Ai} + m_B \vec{v}_{Bi} &= m_A \vec{v}_{Af} + m_B \vec{v}_{Bf} \\
\vec{v}_{Af} &= \frac{m_A \vec{v}_{Ai} + m_B \vec{v}_{Bi} - m_B \vec{v}_{Bf}}{m_A} \\
&= \vec{v}_{Ai} + \frac{m_B (\vec{v}_{Bi} - \vec{v}_{Bf})}{m_A} \\
&= (4.0 \text{ ft/s}) + \frac{(2.5 \text{ sl})[(2.4 \text{ ft/s}) - (3.2 \text{ ft/s})]}{1.5 \text{ sl}} \\
&= (4.0 \text{ ft/s}) + (1.\bar{6})(-0.8 \text{ ft/s}) \\
&= (4.0 \text{ ft/s}) - (1.\bar{3} \text{ ft/s}) \\
&= +2.\bar{6} \text{ ft/s}
\end{aligned} \tag{9}$$

## Problem (7)

Two 3.0 kg bodies,  $A$  and  $B$ , collide. The velocities before the collision are  $\vec{v}_A = (35\hat{i} + 22\hat{j}) \text{ m/s}$  and  $\vec{v}_B = (-12\hat{i} + 11\hat{j}) \text{ m/s}$ . After the collision,  $\vec{v}'_A = (18\hat{i} + 16\hat{j}) \text{ m/s}$ .

### Question (a)

What is the  $x$ -component of the final velocity of  $B$ ?

**R:** Assuming  $\Delta p = 0$

$$\begin{aligned}
m_A &= m_B = m \\
p_i &= p_f \\
m\vec{v}_A + m\vec{v}_B &= m\vec{v}'_A + m\vec{v}'_B \\
\vec{v}_A + \vec{v}_B &= \vec{v}'_A + \vec{v}'_B \\
\vec{v}'_B &= \vec{v}_A + \vec{v}_B - \vec{v}'_A \\
v'_{Bx} &= v_{Ax} + v_{Bx} - v'_{Ax} \\
&= (35 \text{ m/s}) + (-12 \text{ m/s}) - (18 \text{ m/s}) \\
&= 5 \text{ m/s}
\end{aligned} \tag{10}$$



**Question (b)**

What is the  $y$ -component of the final velocity of  $B$ ?

**R:**

$$\begin{aligned}
 v'_{By} &= v_{Ay} + v_{By} - v'_{Ay} \\
 &= (22 \text{ m/s}) + (11 \text{ m/s}) - (16 \text{ m/s}) \\
 &= 17 \text{ m/s}
 \end{aligned}
 \tag{11}$$

**Question (c)**

What is the change in the total kinetic energy (including sign)?

**R:**

$$\begin{aligned}
 \vec{V}_i &= \vec{v}_A + \vec{v}_B \\
 &= (35\hat{i} + 22\hat{j}) \text{ m/s} + (-12\hat{i} + 11\hat{j}) \text{ m/s} \\
 &= (23\hat{i} + 33\hat{j}) \text{ m/s} \\
 V_i &= \sqrt{23^2 + 33^2} \text{ m/s} \\
 &= \sqrt{529 + 1089} \text{ m/s} = 40.224 \text{ m/s} \\
 \vec{V}_f &= \vec{v}'_A + \vec{v}'_B \\
 &= (18\hat{i} + 16\hat{j}) \text{ m/s} + (5\hat{i} + 17\hat{j}) \text{ m/s} \\
 &= (23\hat{i} + 33\hat{j}) \text{ m/s} \\
 V_f &= \sqrt{23^2 + 33^2} \text{ m/s} \\
 &= \sqrt{529 + 1089} \text{ m/s} = 40.224 \text{ m/s} \\
 V_f &= V_i = V \\
 \Delta K &= K_f - K_i \\
 &= \frac{1}{2}MV^2 - \frac{1}{2}MV^2 \\
 &= 0
 \end{aligned}
 \tag{12}$$

## Problem (8)

The fig. 4 shows a three-particle-system, with masses  $m_1 = 2.8 \text{ kg}$ ,  $m_2 = 4.0 \text{ kg}$ , and  $m_3 = 9.6 \text{ kg}$ .

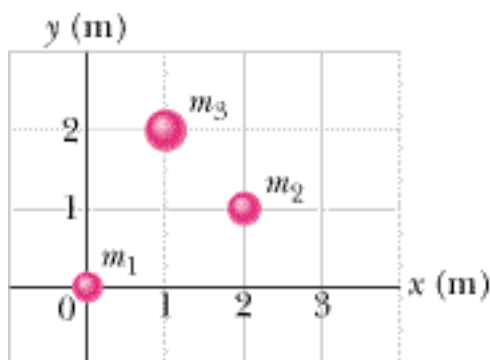


Figure 4: Illustration of Problem 8

### Question (a)

What is the  $x$  coordinate of the system's center of mass?

**R:**

$$\begin{aligned}
 X_{CM} &= \frac{\sum_{i=1}^3 m_i x_i}{\sum_{i=1}^3 m_i} \\
 &= \frac{(2.8 \text{ kg})(0) + (4.0 \text{ kg})(2 \text{ m}) + (9.6 \text{ kg})(1 \text{ m})}{(2.8 \text{ kg}) + (4.0 \text{ kg}) + (9.6 \text{ kg})} \\
 &= \frac{17.6 \text{ kg} \times \text{m}}{16.4 \text{ kg}} \\
 &= 1.0731 \text{ m}
 \end{aligned} \tag{13}$$

### Question (b)

What is the  $y$  coordinate of the system's center of mass?

**R:**

$$\begin{aligned}
 Y_{CM} &= \frac{\sum_{i=1}^3 m_i y_i}{\sum_{i=1}^3 m_i} \\
 &= \frac{(2.8 \text{ kg})(0) + (4.0 \text{ kg})(1 \text{ m}) + (9.6 \text{ kg})(2 \text{ m})}{16.4 \text{ kg}} \\
 &= \frac{23.2 \text{ kg} \times \text{m}}{16.4 \text{ kg}} \\
 &= 1.41463 \text{ m}
 \end{aligned} \tag{14}$$

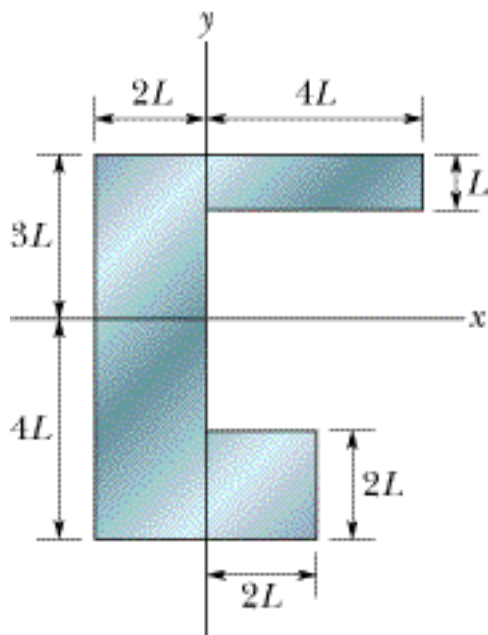
**Problem (9)**

Figure 5: Illustration of Problem 9

**Question (a)**

What is the  $x$  coordinate of the center of mass for the uniform plate shown in the figure if  $L = 5.0$  inches?

**R:**

$$\begin{aligned}
 m_1 &= 6L^2 \\
 x_1 &= -1L \\
 m_2 &= 4L^2 \\
 x_2 &= 2L \\
 m_3 &= 4L^2 \\
 x_3 &= 1L \\
 m_4 &= 8L^2 \\
 x_4 &= -1L \\
 X_{cm} &= \frac{(6L^2)(-1L) + (4L^2)(2L) + (4L^2)(1L) + (8L^2)(-1L)}{6L^2 + 4L^2 + 4L^2 + 8L^2} \\
 &= \frac{-2L^3}{22L^2} = \frac{-1}{11}L = \frac{-5}{11} \text{ in} \\
 &= -0.45 \text{ in}
 \end{aligned} \tag{15}$$

**Question (a)**

What is the  $y$  coordinate of the center of mass for the uniform plate shown in the figure if  $L = 5.0$  inches?

**R:**

$$y_1 = 1.5L$$

$$y_2 = 2.5L$$

$$y_3 = -3L$$

$$y_4 = -2L$$

$$\begin{aligned} Y_{cm} &= \frac{(6L^2)(1.5L) + (4L^2)(2.5L) + (4L^2)(-3L) + (8L^2)(-2L)}{22L^2} \\ &= \frac{-9L^3}{22L^2} = \frac{-9}{22}L = \frac{-45}{22} \text{ in} \\ &= -2.04\overline{5} \text{ in} \end{aligned} \tag{16}$$