Physics 112

Worksheet: 42-53 → Introduction to Momentum

Momentum

1. $\vec{p} = ?$
   $m = 0.250\text{ kg}$
   $\vec{v} = +46.1\text{ m/s}$

   ⇒ [E]

   $\vec{p} = m\vec{v}$
   $\vec{p} = (0.250)(46.1)$
   $\vec{p} = 11.5\text{ kgm/s}$ ✓

   The momentum of the baseball is 11.5 kgm/s [E]

2. $\vec{p} = 5.0\times10^4\text{ kgm/s}$
   $\vec{v} = 25.9\text{ m/s}$
   $m = ?$

   ⇒ [E]

   $\vec{p} = m\vec{v}$
   $m = \frac{\vec{p}}{\vec{v}}$
   $m = \frac{5.0\times10^4}{25.9}$
   $m = 1.9\times10^3\text{ kg}$ ✓

   The mass of the car is 1.9×10^3 kg.

3. $m = 9.11\times10^{-31}\text{ kg}$
   $\vec{v} = +6.45\times10^6\text{ m/s}$
   $\vec{p} = ?$

   ⇒ [N]

   $\vec{p} = m\vec{v}$
   $\vec{p} = (9.11\times10^{-31})(6.45\times10^6)$
   $\vec{p} = 5.88\times10^{-24}\text{ kgm/s}$ ✓

   The momentum of the electron is 5.88×10^{-24} kgm/s, north.

4. $\vec{p} = -3.0 \times 10^4$ kgm/s
$m = 1.50 \times 10^3$ kg
$\vec{v} = ?$

⇓ [S]

$\vec{p} = m\vec{v}$

$\vec{v} = \frac{\vec{p}}{m}$

$\vec{v} = \frac{-3.0 \times 10^4}{1.50 \times 10^3}$

$\vec{v} = -20$ m/s ✓

The velocity of the car is 20 m/s, South.

Impulse

1. $\vec{F} = 257$ N
$t = 0.23$ s
$\vec{J} = ?$

$\vec{J} = \vec{F}t$

$\vec{J} = (257)(0.23)$

$\vec{J} = 59$ Ns

⇒ E

The impulse is 59 Ns, E. ✓

2. $m = 1.00 \times 10^3$ kg
$\vec{J} = -4.6 \times 10^3$ Ns
$\vec{F} = -2.1 \times 10^3$ N
$t = ?$

⇓ [S]

$\vec{J} = \vec{F}t$

$t = \frac{\vec{J}}{\vec{F}}$

$t = \frac{-4.6 \times 10^3}{-2.1 \times 10^3}$

$t = 2.2$ s ✓

It takes the car 2.2 s to stop.

3. $m = 3.00 kg$
$t = 4.00 s$
$F = ?$
$\vec{J} = 80.0 Ns$

$\Rightarrow$ E.

$\vec{J} = \vec{F}t$

$\vec{F} = \frac{\vec{J}}{t}$

$\vec{F} = \frac{80.0}{4.00}$

$\vec{F} = 20.0 N$

The magnitude of the forces is 20.0 N.

Impulse-Momentum Theorem

1. $m = 1.20 \times 10^3 kg$
$\vec{v}_i = 20.0 m/s$
$\vec{v}_f = 30.0 m/s$

$\Rightarrow$ E.
$\vec{J} = ?$

$\vec{J} = \vec{F}t = \Delta p$

$\vec{J} = m\vec{v}_f - m\vec{v}_i$

$\vec{J} = m(\vec{v}_f - \vec{v}_i)$

$\vec{J} = 1.20 \times 10^3 (30.0 - 20.0)$

$\vec{J} = 1.20 \times 10^4 kg\, m/s$ ✓

The impulse is $1.20 \times 10^4 kg\, m/s$ [E]

2. $t = ?$
$\vec{F} = 5.50 \times 10^2 N$
$\vec{v}_i = 0 m/s$
$\vec{v}_f = 2.0 m/s$
$m = 1.20 \times 10^3 kg$
(forward)

$\vec{J} = \vec{F}t = \Delta\vec{p}$

~~$\vec{J} = \vec{F}t = \Delta\vec{p}$~~

$\vec{F}t = m(\vec{v}_f - \vec{v}_i)$

$t = \frac{m(\vec{v}_f - \vec{v}_i)}{\vec{F}}$

$t = \frac{(1.20 \times 10^3)(2.0 - 0)}{5.50 \times 10^2}$

$t = 4.4 s$ ✓

The force must act for 4.4 s.

3. $m = 1.2 \times 10^3 kg$
$\vec{v_i} = 25 m/s$
$\vec{v_f} = 10.0 m/s$
$t = 5.0 s$
$\vec{F} = ?$

$\Rightarrow E.$

$\vec{J} = \vec{F}t = \Delta \vec{p}$
$\vec{F}t = m(\vec{v_f} - \vec{v_i})$
$\vec{F} = \frac{m(\vec{v_f} - \vec{v_i})}{t}$
$\vec{F} = \frac{(1.2 \times 10^3)(10.0 - 25)}{5.0}$
$\vec{F} = -3.6 \times 10^3 N$ ✓

The force experienced by the car is $3.6 \times 10^3 N$, west.

Mandatory Problems ✓ $\Rightarrow E$

1.

Softball	baseball.
$m_s = 0.53 kg$	$m_b = 0.31 kg$
$\vec{v_s} = ?$	$\vec{v_b} = 21 m/s$
$\vec{p_s} = 6.51 kgm/s$	$\vec{p_b} = ?$

$\vec{p_s} = m\vec{v_s}$
$\vec{v_s} = \frac{\vec{p_s}}{m}$
$\vec{v_s} = \frac{6.51}{0.53}$
$\vec{v_s} = 12 m/s$

$\vec{p_b} = m\vec{v_b}$
$\vec{p_b} = (0.31)(21)$
$\vec{p_b} = 6.51 kgm/s$

The softball must be moving with a velocity of 12 m/s, E.

Mandatory

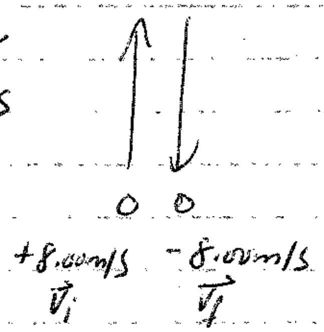
2. $\vec{p} = ?$
$m = 62\,g = 0.062\,kg$
$\vec{v} = -73\,m/s$

$\vec{p} = m\vec{v}$
$\vec{p} = (0.062)(-73)$
$\vec{p} = -4.5\,kg\,m/s$

W ⇐

The momentum of the golf ball is 4.5 kgm/s, west.

3. $m = 1.00\,kg$
$\vec{v}_i = 8.00\,m/s$



$\vec{p}_f = m\vec{v}_f$
$\vec{p}_f = (1.00)(-8.00)$
$\vec{p}_f = -8.00\,kg\,m/s$

As it strikes the ground, the rock's momentum is 8.00 kgm/s, down.

4. a) $m_q = 112\,kg$
$\vec{v} = 4.8\,m/s$

$\vec{p} = m\vec{v}$
$\vec{p} = (112)(4.8)$
$\vec{p} = 5.4 \times 10^2\,kg\,m/s$

⇒ E.

The momentum of the quarterback is 5.4×10^2 kgm/s, E.

b) $\vec{J} = ?$
$\vec{v}_f = 0$.

$\vec{J} = \vec{F}t = \Delta\vec{p}$
$\vec{J} = m(\vec{v}_f - \vec{v}_i)$
$\vec{J} = m(-\vec{v}_i)$
$\vec{J} = (112)(-4.8)$
$\vec{J} = -5.4 \times 10^2\,kg\,m/s$

The impulse imparted is 5.4×10^2 kgm/s, W.

Mandatory

c) $t = 1.2\,s$
$\vec{F} = ?$

tackler on quarterback.

$\vec{J} = -5.4 \times 10^2\,kgm/s$

$\vec{J} = \vec{F}t$

$\vec{F} = \frac{\vec{J}}{t}$

$\vec{F} = -\frac{5.4 \times 10^2\,kgm/s}{1.2}$

$\vec{F} = -4.5 \times 10^2\,N.$

The average force is $4.5 \times 10^2\,N$, W.

5. $\vec{J} = ?$
$m = 0.168\,kg$
$\vec{F} = 126\,N$
$\Delta\vec{v} = 61.8\,m/s.$

$\Rightarrow E.$

$|\vec{J}| = \vec{F}t = \Delta\vec{p} = m\Delta\vec{v}$

$\vec{J} = m\Delta\vec{v}$
$\vec{J} = (0.168)(61.8)$
$\vec{J} = 10.4\,kgm/s.$

The impulse experienced by the ball is 10.4 kgm/s, E.

6. $m = 0.80\,kg$
$\vec{J} = 25\,Ns$
$\Delta\vec{p} = ?$

$\vec{J} = \Delta\vec{p}$
$\vec{J} = 25\,Ns$
$\Delta\vec{p} = 25\,Ns.$

$\Rightarrow E$

The change in momentum is 25 Ns, E.

Mandatory

7. $m = 1.50 \times 10^3 kg$ $\Rightarrow E.$

$\vec{v_i} = 80.0 \frac{km}{h} = 22.2 \frac{m}{s}$

$\vec{v_f} = 0 m/s$

$t = 4.00 s$

$\vec{F_f} = \vec{F} = ?$

$\vec{J} = \vec{F}t = \Delta\vec{p}$

$\vec{F}t = m(\vec{v_f} - \vec{v_i})$

$\vec{F} = \frac{m(\vec{v_f} - \vec{v_i})}{t}$

$\vec{F} = \frac{(1.50 \times 10^3)(0 - 22.2)}{4.00}$

$\vec{F} = -8.33 \times 10^3 N.$

The force of friction is $8.33 \times 10^3 N$, W.

8. $m = 1.00 kg$ O ⟶ [E]

$\vec{v_i} = +5.00 m/s$

$\vec{v_f} = -8.50 m/s$ ⟵ gave speed

$t = 20.0 ms \times \frac{10^{-3} s}{1 ms} = 0.0200 s$

a) The ball's final velocity was 8.50 m/s [W].

b) $\Delta\vec{p} = ?$

$\Delta\vec{p} = m(\vec{v_f} - \vec{v_i})$

$\Delta\vec{p} = (1.00)(-8.50 - 5.00)$

$\Delta\vec{p} = -13.5 kg\frac{m}{s}$

The ball's change in momentum is 13.5 kg m/s [W].

Mandatory.

#8.c) $\vec{F} = ?$

$O \Longrightarrow E$

$\vec{v}_i$

$$\vec{F}t = m(\vec{v}_f - \vec{v}_i)$$
$$\vec{F} = \frac{m(\vec{v}_f - \vec{v}_i)}{t}$$
$$\vec{F} = \frac{(1.00)(-8.50 - 5.00)}{(0.0200)}$$
$$\vec{F} = -675\ N$$

The force applied to the ball was 675 N, W.

9. $m = 5.00\,kg$
$\vec{v}_i = 0\,m/s$
$\vec{a} = 2.0\,m/s^2$
$t = 1.50\,s$
$\vec{p}_f = ?$

$$\vec{p}_f = m\vec{v}_f$$
$$\vec{p}_f = (5.00)(3.0)$$
$$\vec{p}_f = 15.0\,kg\,m/s$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$\vec{v}_f = (2.0)(1.50)$$
$$\vec{v}_f = 3.0\,m/s$$

$\Rightarrow E$ The ball's momentum after the acceleration is 15.0 kg m/s, E.

10. $m = 2.00\,kg$
$\vec{v}_i = 0\,m/s$
$\vec{d} = -30.0\,m$
$\vec{a} = -9.80\,m/s^2$
$\vec{p}_f = ?$
↓
need $\vec{v}_f$

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d}$$
$$\vec{v}_f = \sqrt{2\vec{a}\vec{d}}$$
$$\vec{v}_f = \sqrt{2(-9.80)(-30.0)}$$
$$\vec{v}_f = -24.25\,m/s$$

$$\vec{p}_f = m\vec{v}_f$$
$$\vec{p}_f = (2.00)(-24.25)$$
$$\vec{p}_f = -48.5\,kg\,m/s$$

The ball's momentum is 48.5 kg m/s, down.

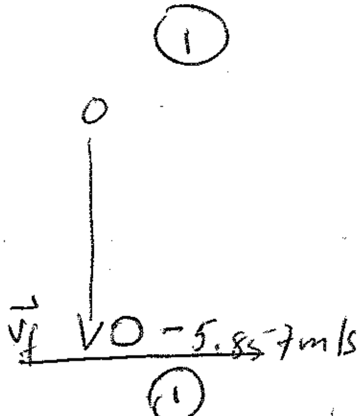
Mandatory

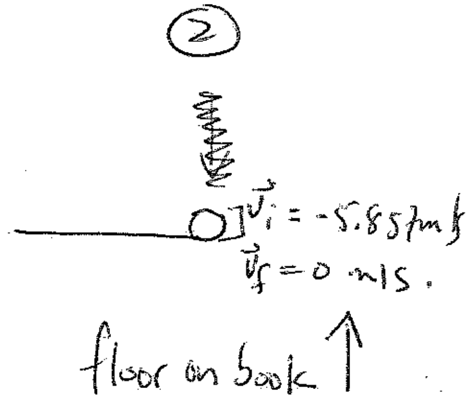
11. $\vec{v}_i = 0\ m/s$

$\vec{d} = -1.75\ m$

$\vec{a} = -9.80\ m/s^2$

$m = 1.5\ kg$





①

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d}$

$\vec{v}_f = \sqrt{2\vec{a}\vec{d}}$

$\vec{v}_f = \sqrt{2(-9.80)(-1.75)}$

$\vec{v}_f = -5.857\ m/s$

②

$\vec{J} = m\vec{v}_f - m\vec{v}_i$

$\vec{J} = -(1.5)(-5.857)$

$\vec{J} = +8.8\ kg\frac{m}{s}$

The impulse on the book is 8.8 kg m/s, up.

12. $m = 1.50\ kg$

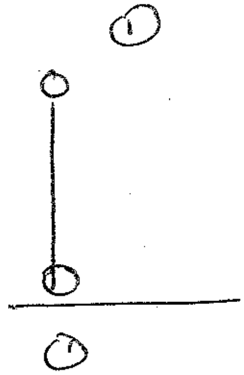
$\vec{v}_i = 0\ m/s.$

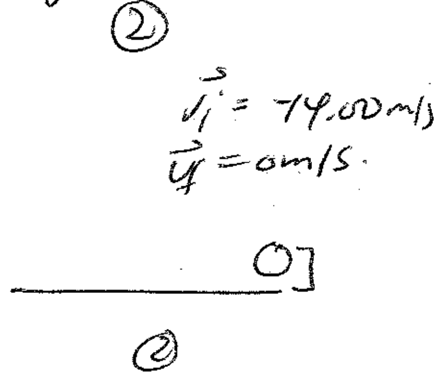
$\vec{d} = -10.0\ m$

$\vec{a} = -9.80\ m/s^2$

$\vec{F} = ?$

$t = 0.350\ s$





①

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d}$

$\vec{v}_f = \sqrt{2\vec{a}\vec{d}}$

$\vec{v}_f = \sqrt{2(-9.80)(-10.0)}$

$\vec{v}_f = -14.00\ m/s$

②

$\vec{F}t = m\vec{v}_f - m\vec{v}_i$

$\vec{F} = \frac{-m\vec{v}_i}{t}$

$\vec{F} = \frac{-(1.50)(-14.00)}{0.350}$

$\vec{F} = +60.0\ N$

The force of the ground on the rock is 60.0 N, up.

Mandatory.

13. club head ($m = 0.170$ kg) of golf club.

golf ball ($m = 0.046$ kg)

a) greatest force? Same (3rd Law)

b) greatest impulse? Same ($\vec{J} = \underbrace{\vec{F} t}_{\text{same}}$)

c) greatest $\Delta\vec{p}$? Same ($\vec{J} = \Delta\vec{p}$)

d) greatest $\vec{a}$? golf ball ($\vec{F}_{net} = m\vec{a}$; m → smallest, $\vec{a}$ → greatest)

Introduction to Momentum

Extra Problems

1\.

golf ball

$m_g = 5.0 \times 10^{-3}$ kg

$\vec{p}_g = 30.0$ kg m/s

② $\vec{p}_g = m_g \vec{v}_g$

$\vec{v}_g = \dfrac{\vec{p}_g}{m_g}$

$\vec{v}_g = \dfrac{30.0}{5.0 \times 10^{-3}}$

$\vec{v}_g = 6.0 \times 10^{3}$ m/s

bowling ball

$m_b = 5.0$ kg

$\vec{v}_b = 6.0$ m/s

⇒ forward

① $\vec{p}_b = m_b \vec{v}_b$

$\vec{p}_b = (5.0)(6.0)$

$\vec{p}_b = 30.0$ kg $\frac{m}{s}$

The golf ball would have to have a speed of 6.0×10^{3} m/s.
(speed → how fast)

2\. $\vec{F} = 55$ N

$\vec{J} = 2.0$ Ns

$t = ?$

⇒ E

$\vec{J} = \vec{F}t$

$t = \dfrac{\vec{J}}{\vec{F}}$

$t = \dfrac{2.0}{55}$

$t = 3.6 \times 10^{-2}$ s.

The duration of the contact is 3.6×10^{-2} s.

Extra

3. a) $\vec{J} = ?$

$m = 0.300 kg$

$\vec{v}_i = +44 m/s$

$\vec{v}_f = -9.2 m/s$

⇑ N
⇓ S

a) $\vec{J} = m(\vec{v}_f - \vec{v}_i)$

$\vec{J} = 0.300(-9.2 - 44)$

$\vec{J} = -16 \; kg\frac{m}{s}$

The impulse is $16 \; kg\frac{m}{s}$, S.

b) $\vec{F} = -2.5 \times 10^3 N$

$t = ?$

$\vec{J} = \vec{F}t$

$t = \frac{\vec{J}}{\vec{F}}$

$t = \frac{-16}{-2.5 \times 10^3}$

$t = 6.4 \times 10^{-3} s$

The duration of the interaction was $6.4 \times 10^{-3} s$.

4. $m = 2.5 kg$

$\vec{v}_i = -3.5 m/s$

$\vec{F} = ?$

$\vec{v}_f = 0$

$t = 3.5 \times 10^{-4} s$

$\vec{F}t = m(\vec{v}_f - \vec{v}_i)$

$\vec{F} = \frac{-m\vec{v}_i}{t}$

$\vec{F} = \frac{-(2.5)(-3.5)}{3.5 \times 10^{-4}}$

$\vec{F} = +2.5 \times 10^4 N$

W ⇐

A force of $2.5 \times 10^4 N$, E would be needed.

Extra

5. $m = 6.5 kg$ $\Rightarrow E$
$\vec{v}_i = 2.0 m/s$
$\vec{v}_f = 8.0 m/s$
$t = 5.0 s$

a) $\vec{p}_i = m\vec{v}_i$
$\vec{p}_i = (6.5 \times 2.0)$
$\vec{p}_i = 13 kg\frac{m}{s}$

$\vec{p}_f = m\vec{v}_f$
$\vec{p}_f = 6.5(8.0)$
$\vec{p}_f = 52 kg\frac{m}{s}$.

The initial momentum of the body is $13 kg\frac{m}{s}$. E and the final momentum is $52 kg\frac{m}{s}$.

b) $\vec{J} = ?$

$\vec{J} = m(\vec{v}_f - \vec{v}_i)$
$\vec{J} = (6.5)(8.0 - 2.0)$
$\vec{J} = 39 kg\frac{m}{s}$

The impulse was 39 kgm/s, E.

c) $\vec{F} = ?$
$t = 5.0 s$

$\vec{J} = \vec{F}t$
$\vec{F} = \frac{\vec{J}}{t}$
$\vec{F} = \frac{39}{5.0}$
$\vec{F} = 7.8 N$

The net force was 7.8 N, E.

Extra

6. $\vec{F} = 8.0 \times 10^3 N$
$m = 80.3 kg$
$\Delta\vec{v} = 10.0 m/s$
$\vec{J} = ?$

$\vec{J} = m\Delta\vec{v}$
$\vec{J} = (80.3)(10.0)$
$\vec{J} = 803 kg\frac{m}{s}$.

$\Rightarrow E$

The impulse was 803 kgm/s. E.

7. $\Delta\vec{p} = ?$
$\vec{F} = 35 N$
$t = 7.6 s$

$\vec{F}t = \Delta\vec{p}$
$\Delta\vec{p} = (35)(7.6)$
$\Delta\vec{p} = 2.7 \times 10^2$ Ns. or kgm/s

$\Rightarrow R$

The change in momentum is 2.7×10^2 Ns, right.

8.

Ball A	Ball B
$m_A = 5.0 kg$	$m_B = 10.0 kg$
$\vec{v}_{iA} = 0 m/s$	$\vec{v}_{iB} = 0 m/s$
$\vec{d}_A = -2.0 m$	$\vec{d}_B = -2.0 m$
$\vec{a} = -9.80 m/s^2$	$\vec{a} = -9.80 m/s^2$

a) Accelerations of both balls was $9.80 m/s^2$, down
b) The momentum of Ball B is greater. Both have the same final velocity, but Ball B has a greater mass.

$\vec{p}_f = m\vec{v}_f$

10.0 kg for Ball B

Extra.

9. $m = 10.0 kg$ $\Rightarrow E$
$\vec{v}_i = 4.9 m/s$
$\vec{v}_f = -1.0 m/s$

a) $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$
$\Delta\vec{v} = -1.0 - 4.9$
$\Delta\vec{v} = -5.9 m/s$

The change in velocity is 5.9 m/s, W.

b) $\Delta\vec{p} = ?$

$\Delta\vec{p} = m\Delta\vec{v}$
$\Delta\vec{p} = (10.0)(-5.9)$
$\Delta\vec{p} = -59 kg\,m/s$

The change in momentum is 59 kg m/s, W.

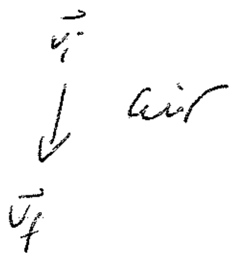
c) $t = 0.22 s$
$\vec{F} = ?$

$\vec{F}t = \Delta\vec{p}$
$\vec{F} = \frac{\Delta\vec{p}}{t}$
$\vec{F} = \frac{-59}{0.22}$
$\vec{F} = -2.7 \times 10^2 N.$

The force is $2.7 \times 10^2 N$, W.

10. $m = 2.56 kg$
$\vec{d} = \ominus 13.0 m$
$\vec{a} = -9.80 m/s^2$
$\vec{J} = ?$
$\vec{v}_i = 0 m/s$

$\vec{v}_f^{\,2} = \cancel{\vec{v}_i^{\,2}} + 2\vec{a}\vec{d}$
$\vec{v}_f = \sqrt{2(-9.80)(\ominus 13.0)}$
$\vec{v}_f = -15.96 m/s$



rock + ground
$\vec{v}_i = -15.96 m/s$
$\downarrow$
$\vec{v}_f = 0 m/s$

$\vec{J} = m(\cancel{\vec{v}_f} - \vec{v}_i)$
$\vec{J} = 2.56(-(-15.96))$
$\vec{J} = +40.9 kg\,m/s$

The impulse experienced by the rock is 40.9 kg m/s, up.