06 Momentum dan Tumbukan

Momentum

Momentum linier dari sebuah partikel atau obyek yang dapat dimodelkan sebagai partikel dari massa m yang mempunyai kecepatan v didefinisikan sebagai hasil kali massa dan kecepatan

$$\mathbf{p} \equiv m\mathbf{v}$$

Momentum linier adalah kuantitas vektor karena hasil dari kuantitas skalar m dan kuantitas vektor v. Arahnya sesuai arah v. Mempunyai dimensi ML/T dan satuan SI unit kg·m/s.

Jika partikel bergerak dalam arah sembarang, p harus mempunyai 3 komponen,

$$p_x = mv_x \qquad p_y = mv_y \qquad p_z = mv_z$$

Hukum II Newton

$$\sum \mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt}$$

$$\sum \mathbf{F} = \frac{d(m\mathbf{v})}{dt} = \frac{d\mathbf{p}}{dt}$$

Impuls dari gaya F yang bekerja pada sebuah partikel sama dengan perubahan momentum partikel

$$\mathbf{I} = \int_{t_i}^{t_f} \mathbf{F}\, dt$$

A 3.00-kg particle has a velocity of (3.00i - 4.00j) m/s. (a) Find its x and y components of momentum. (b) Find the magnitude and direction of its momentum.

$m = 3.00 \text{ kg}$, $\mathbf{v} = \left(3.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}}\right) \text{ m/s}$

(a) $\mathbf{p} = m\mathbf{v} = \left(9.00\hat{\mathbf{i}} - 12.0\hat{\mathbf{j}}\right) \text{ kg} \cdot \text{m/s}$

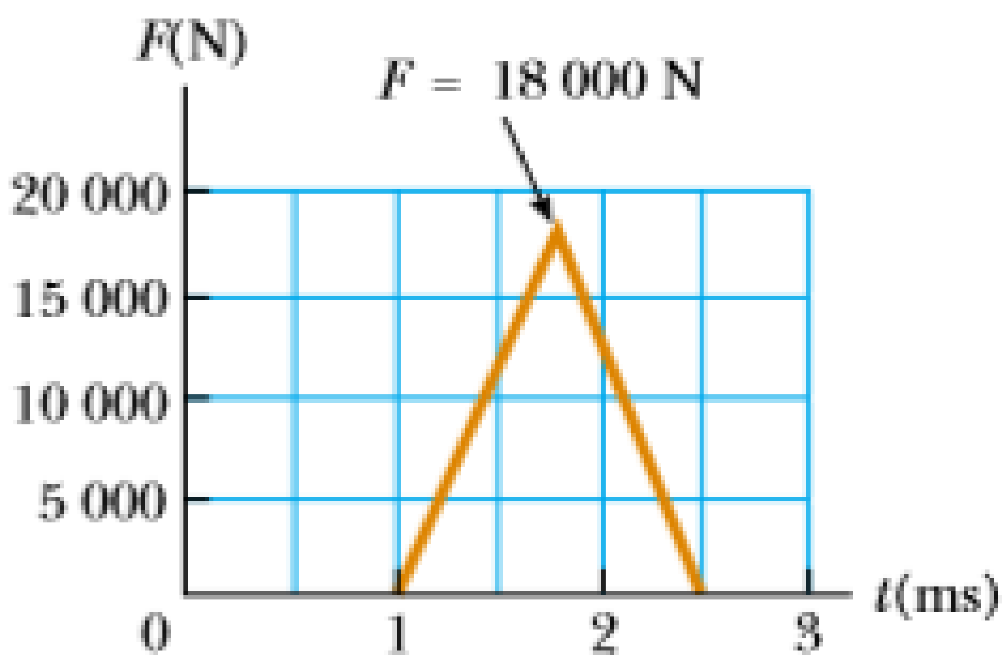
Thus, $\boxed{p_x = 9.00 \text{ kg} \cdot \text{m/s}}$

and $\boxed{p_y = -12.0 \text{ kg} \cdot \text{m/s}}$

(b) $p = \sqrt{p_x^2 + p_y^2} = \sqrt{(9.00)^2 + (12.0)^2} = \boxed{15.0 \text{ kg} \cdot \text{m/s}}$

$$\theta = \tan^{-1}\left(\frac{p_y}{p_x}\right) = \tan^{-1}(-1.33) = \boxed{307°}$$

An estimated force–time curve for a baseball struck by a bat is shown in Figure P. From this curve, determine (a) the impulse delivered to the ball, (b) the average force exerted on the ball, and (c) the peak force exerted on the ball.



(a) $I = \int F dt =$ area under curve

$$I = \frac{1}{2}\left(1.50 \times 10^{-3}\ \text{s}\right)\left(18\,000\ \text{N}\right) = \boxed{13.5\ \text{N} \cdot \text{s}}$$

(b) $$F = \frac{13.5\ \text{N} \cdot \text{s}}{1.50 \times 10^{-3}\ \text{s}} = \boxed{9.00\ \text{kN}}$$

(c) From the graph, we see that $F_{max} = \boxed{18.0\ \text{kN}}$

An object of mass 3.00 kg, moving with an initial velocity of 5.00 i m/s, collides with and sticks to an object of mass 2.00 kg with an initial velocity of -3.00 j m/s. Find the final velocity of the composite object.

$$m_1 \mathbf{v}_{1i} + m_2 \mathbf{v}_{2i} = (m_1 + m_2)\mathbf{v}_f:$$

$$3.00(5.00)\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}} = 5.00\mathbf{v}$$

$$\mathbf{v} = \boxed{(3.00\hat{\mathbf{i}} - 1.20\hat{\mathbf{j}})\ \text{m/s}}$$

A billiard ball moving at 5.00 m/s strikes a stationary ball of the same mass. After the collision, the first ball moves, at 4.33 m/s, at an angle of 30.0° with respect to the original line of motion. Assuming an elastic collision (and ignoring friction and rotational motion), find the struck ball's velocity after the collision.

By conservation of momentum for the system of the two billiard balls (with all masses equal),

$$5.00\ \text{m/s} + 0 = (4.33\ \text{m/s})\cos 30.0° + v_{2fx}$$

$$v_{2fx} = 1.25\ \text{m/s}$$

$$0 = (4.33\ \text{m/s})\sin 30.0° + v_{2fy}$$

$$v_{2fy} = -2.16\ \text{m/s}$$

$$\mathbf{v}_{2f} = \boxed{2.50\ \text{m/s at } -60.0°}$$

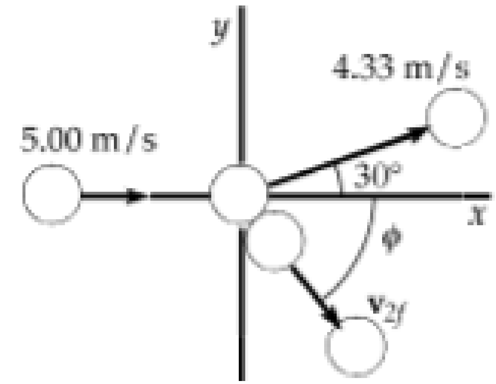


FIG. P9.33

A particle of mass m moves with momentum p.

(a) Show that the kinetic energy of the particle is $K = p^2/2m$.

(b) Express the magnitude of the particle's momentum in terms of its kinetic energy and mass.

(a) The momentum is $p = mv$, so $v = \frac{p}{m}$ and the kinetic energy is $K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \boxed{\frac{p^2}{2m}}$.

(b) $K = \frac{1}{2}mv^2$ implies $v = \sqrt{\frac{2K}{m}}$, so $p = mv = m\sqrt{\frac{2K}{m}} = \boxed{\sqrt{2mK}}$.

A ball of mass 0.150 kg is dropped from rest from a height of 1.25 m. It rebounds from the floor to reach a height of 0.960 m. What impulse was given to the ball by the floor?

The impact speed is given by $\frac{1}{2}mv_1^2 = mgy_1$. The rebound speed is given by $mgy_2 = \frac{1}{2}mv_2^2$. The impulse of the floor is the change in momentum,

$$\begin{aligned} mv_2 \text{ up} - mv_1 \text{ down} &= m(v_2 + v_1) \text{ up} \\ &= m\left(\sqrt{2gh_2} + \sqrt{2gh_1}\right) \text{ up} \\ &= 0.15 \text{ kg}\sqrt{2\left(9.8 \text{ m/s}^2\right)}\left(\sqrt{0.960 \text{ m}} + \sqrt{1.25 \text{ m}}\right) \text{ up} \\ &= \boxed{1.39 \text{ kg}\cdot\text{m/s upward}} \end{aligned}$$

Two shuffleboard disks of equal mass, one orange and the other yellow, are involved in an elastic, glancing collision. The yellow disk is initially at rest and is struck by the orange disk moving with a speed of 5.00 m/s. After the collision, the orange disk moves along a direction that makes an angle of 37.0° with its initial direction of motion. The velocities of the two disks are perpendicular after the collision. Determine the final speed of each disk.

$$p_{xf} = p_{xi}$$

$$mv_O \cos 37.0° + mv_Y \cos 53.0° = m(5.00 \text{ m/s})$$

$$0.799 v_O + 0.602 v_Y = 5.00 \text{ m/s} \quad (1)$$

$$p_{yf} = p_{yi}$$

$$mv_O \sin 37.0° - mv_Y \sin 53.0° = 0$$

$$0.602 v_O = 0.799 v_Y \quad (2)$$

Solving (1) and (2) simultaneously,

$$\boxed{v_O = 3.99 \text{ m/s}} \text{ and } \boxed{v_Y = 3.01 \text{ m/s}}.$$

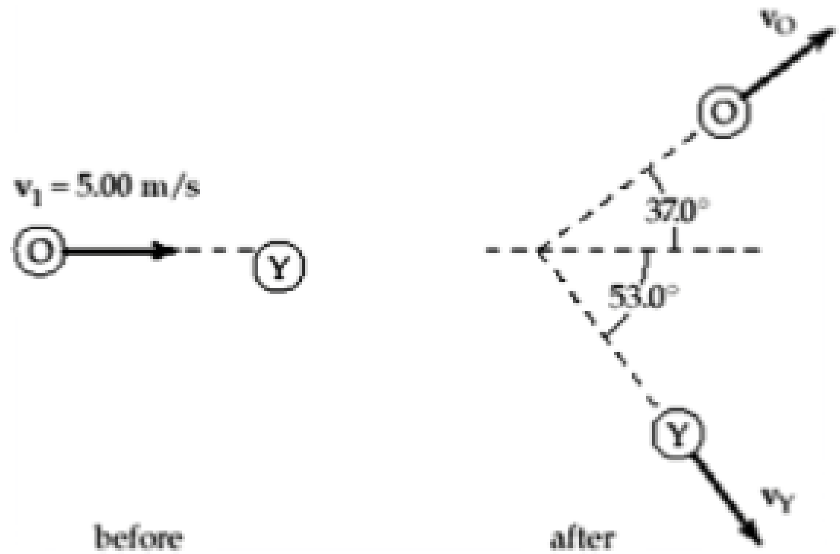


FIG. P9.29