Q1

$$\text{Impulse} = \int_{t_1}^{t_2} F\,dt$$

= area under the force curve

(a) (Area) impulse = $12 F_0 t_0$

(b) impulse = $12 F_0 t_0$

(c) impulse = $\frac{1}{2}(24) F_0 t_0$

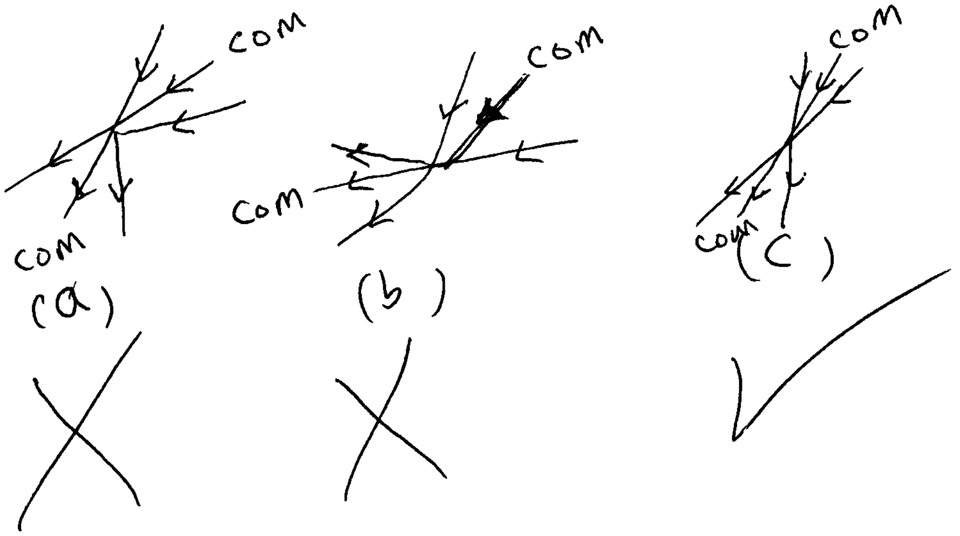
$= 12 F_0 t_0$

All same.

Q.2

Since our system is isolated and closed, the linear momentum of the system is conserved. $V_{com,\,before} = V_{com,\,after}$

so (c) is represent the two bodies and the bath of their center of mass.



5. We take the initial direction of motion to be positive and use F_{avg} to denote the magnitude of the average force, Δt as the duration of the force, m as the mass of the ball, v_i as the initial velocity of the ball, and v_f as the final velocity of the ball. The force is in the negative direction and the impulse-momentum theorem (Eq. 10-4 with Eq. 10-8) yields $-F_{\text{avg}}\Delta t = mv_f - mv_i$. Thus,

$$v_f = \frac{mv_i - F_{\text{avg}}\Delta t}{m} = \frac{(0.40\,\text{kg})(14\,\text{m/s}) - (1200\,\text{N})(27 \times 10^{-3}\,\text{s})}{0.40\,\text{kg}} = -67\,\text{m/s}\ .$$

The final speed of the ball is $67\,\text{m/s}$. The negative sign indicates that the velocity is opposite to the initial direction of travel.

7. We choose $+y$ upward, which means $\vec{v}_i = -25$ m/s and $\vec{v}_f = +10$ m/s. During the collision, we make the reasonable approximation that the net force on the ball is equal to F_{avg} – the average force exerted by the floor up on the ball.

   (a) Using the impulse momentum theorem (Eq. 10-4) we find

$$\vec{J} = m\vec{v}_f - m\vec{v}_i = (1.2)(10) - (1.2)(-25) = 42 \text{ kg}\cdot\text{m/s} .$$

   (b) From Eq. 10-8, we obtain

$$\vec{F}_{\text{avg}} = \frac{\vec{J}}{\Delta t} = \frac{42}{0.020} = 2.1 \times 10^3 \text{ N} .$$

20. (a) We choose $+x$ along the initial direction of motion and apply momentum conservation:

$$\begin{aligned} m_{\text{bullet}}\vec{v}_i &= m_{\text{bullet}}\vec{v}_1 + m_{\text{block}}\vec{v}_2 \\ (5.2\,\text{g})(672\,\text{m/s}) &= (5.2\,\text{g})(428\,\text{m/s}) + (700\,\text{g})\vec{v}_2 \end{aligned}$$

which yields $v_2 = 1.81$ m/s.

(b) It is a consequence of momentum conservation that the velocity of the center of mass is unchanged by the collision. We choose to evaluate it before the collision:

$$\vec{v}_{\text{com}} = \frac{m_{\text{bullet}}\vec{v}_i}{m_{\text{bullet}} + m_{\text{block}}} = \frac{(5.2\,\text{g})(672\,\text{m/s})}{5.2\,\text{g} + 700\,\text{g}}$$

which gives the result $\vec{v}_{\text{com}} = 4.96$ m/s.

29. Let m_F be the mass of the freight car and v_F be its initial velocity. Let m_C be the mass of the caboose and v be the common final velocity of the two when they are coupled. Conservation of the total momentum of the two-car system leads to $m_F v_F = (m_F + m_C)v$, so $v = v_F m_F/(m_F + m_C)$. The initial kinetic energy of the system is

$$K_i = \frac{1}{2} m_F v_F^2$$

and the final kinetic energy is

$$K_f = \frac{1}{2}(m_F + m_C)v^2 = \frac{1}{2}(m_F + m_C)\frac{m_F^2 v_F^2}{(m_F + m_C)^2} = \frac{1}{2}\frac{m_F^2 v_F^2}{(m_F + m_C)} .$$

Since 27% of the original kinetic energy is lost, we have $K_f = 0.73K_i$. Thus,

$$\frac{1}{2}\frac{m_F^2 v_F^2}{(m_F + m_C)} = (0.73)\left(\frac{1}{2} m_F v_F^2\right) .$$

Simplifying, we obtain $m_F/(m_F + m_C) = 0.73$, which we use in solving for the mass of the caboose:

$$m_C = \frac{0.27}{0.73} m_F = 0.37\, m_F = (0.37)\left(3.18 \times 10^4 \text{ kg}\right) = 1.18 \times 10^4 \text{ kg} .$$

36. We use m_1 for the mass of the electron and $m_2 = 1840m_1$ for the mass of the hydrogen atom. Using Eq. 10-31,

$$v_{2f} = \frac{2m_1}{m_1 + 1840m_1} v_{1i} = \frac{2}{1841} v_{1i}$$

we compute the final kinetic energy of the hydrogen atom:

$$K_{2f} = \frac{1}{2}(1840m_1)\left(\frac{2\,v_{1i}}{1841}\right)^2 = \frac{(1840)(4)}{1841^2}\left(\frac{1}{2}(1840m_1)v_{1i}^2\right)$$

so we find the fraction to be $(1840)(4)/1841^2 \approx 2.2 \times 10^{-3}$, or 0.22%.

41. (a) Let m_1 be the mass of the body that is originally moving, v_{1i} be its velocity before the collision, and v_{1f} be its velocity after the collision. Let m_2 be the mass of the body that is originally at rest and v_{2f} be its velocity after the collision. Then, according to Eq. 10–30,

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i} .$$

We solve for m_2 to obtain

$$m_2 = \frac{v_{1i} - v_{1f}}{v_{1f} + v_{1i}} m_1 .$$

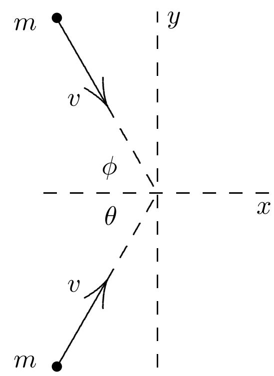
We combine this with $v_{1f} = v_{1i}/4$ to obtain $m_2 = 3m_1/5 = 3(2.0)/5 = 1.2\,\text{kg}$.

(b) The speed of the center of mass is

$$v_{\text{com}} = \frac{m_1 v_{1i} + m_2 v_{2i}}{m_1 + m_2} = \frac{(2.0)(4.0)}{2.0 + 1.2} = 2.5 \text{ m/s} .$$

51. Suppose the objects enter the collision along lines that make the angles $\theta > 0$ and $\phi > 0$ with the x axis, as shown in the diagram below. Both have the same mass m and the same initial speed v.

We suppose that after the collision the combined object moves in the positive x direction with speed V. Since the y component of the total momentum of the two-object system is conserved, $mv \sin\theta - mv \sin\phi = 0$. This means $\phi = \theta$. Since the x component is conserved, $2mv \cos\theta = 2mV$. We now use $V = v/2$ to find that $\cos\theta = 1/2$. This means $\theta = 60°$. The angle between the initial velocities is $120°$.



52. We orient our $+x$ axis along the initial direction of motion, and specify angles in the "standard" way – so $\theta = +60°$ for one ball (1) which is assumed to go into the first quadrant with speed $v'_1 = 1.1$ m/s, and $\phi < 0$ for the other ball (2) which presumably goes into the fourth quadrant. The mass of each ball is m, and the initial speed of one of the balls is $v_0 = 2.2$ m/s. We apply the conservation of linear momentum to the x and y axes respectively.

$$\begin{aligned} mv_0 &= mv'_1 \cos\theta + mv'_2 \cos\phi \\ 0 &= mv'_1 \sin\theta + mv'_2 \sin\phi \end{aligned}$$

The mass m cancels out of these equations, and we are left with two unknowns and two equations, which is sufficient to solve.

(a) With SI units understood, the y-momentum equation can be rewritten as

$$v'_2 \sin\phi = -v'_1 \sin 60° = -0.95$$

and the x-momentum equation yields

$$v'_2 \cos\phi = v_0 - v'_1 \cos 60° = 1.65$$

Dividing these two equations, we find $\tan\phi = -0.577$ which yields $\phi = -30°$. If we choose to measure this as a positive-valued angle (as the textbook does in §10-6), then this becomes 30°. We plug $\phi = -30°$ into either equation and find $v'_2 \approx 1.9$ m/s.

(b) One can check to see if this an elastic collision by computing

$$\frac{2K_i}{m} = v_0^2 \quad \text{and} \quad \frac{2K_f}{m} = {v'_1}^2 + {v'_2}^2$$

and seeing if they are equal (they are), but one must be careful not to use rounded-off values. Thus, it is useful to note that the answer in part (a) can be expressed "exactly" as $v'_2 = \frac{1}{2}v_0\sqrt{3}$ (and of course $v'_1 = \frac{1}{2}v_0$ "exactly" – which makes it clear that these two kinetic energy expressions are indeed equal).