CSD2301 Practice Solutions
9. **Momentum and Collisions**
Part 1

LIN QINJIE

Practice Question 1

A baseball with mass 0.145 kg is moving in the +y direction with a speed of 1.30 m/s, and a tennis ball with mass 0.0570 kg is moving in the -y direction with a speed of 7.80 m/s. What are the magnitude and direction of the total momentum of the system consisting of the two balls?

The y-component of the total momentum is

$$(0.145\ \text{kg})(1.30\ \text{m/s}) + (0.0570\ \text{kg})(-7.80\ \text{m/s}) = -0.256\ \text{kg} \cdot \text{m/s}.$$

This quantity is negative, so the total momentum of the system is in the $-y$ -direction.

Practice Question 2

A 0.160 kg hockey puck is moving on an icy, frictionless, horizontal surface. At t = 0 the puck is moving to the right at 3.00 m/s. a) Calculate the velocity of the puck (magnitude and direction) after a force of 25.0 N directed to the right has been applied for 0.050 s. b) If instead, a force of 12.0 N directed to the left is applied from t = 0 to t = 0.050 s, what is the final velocity of the puck?

$J = Ft$

$p_2 = mv$

$v = \frac{p_2}{m}$

momentum

a) Considering the $+x$-components,

$p_2 = p_1 + J = (0.16\text{ kg})(3.00\text{ m/s}) + (25.0\text{ N}) \times (0.05\text{ s}) = 1.73\text{ kg}\cdot\text{m/s}$, and the velocity is 10.8 m/s in the $+x$-direction. b) $p_2 = 0.48\text{ kg}\cdot\text{m/s} + (-12.0\text{ N})(0.05\text{ s}) = -0.12\text{ kg}\cdot\text{m/s}$, and the velocity is $+0.75\text{ m/s}$ in the $-x$-direction.

Practice Question 3

On a frictionless, horizontal air table, puck A (with mass 0.250 kg) is moving towards puck B (with mass 0.350 kg), that is initially at rest. After the collision, puck A has a velocity of 0.120 m/s to the left, and puck B has velocity 0.650 m/s to the right. a) What was the speed of puck A before the collision? b) Calculate the change in the total kinetic energy of the system that occurs during the collision.

a) The final momentum is

$$(0.250\text{ kg})(-0.120\text{ m/s}) + (0.350)(0.650\text{ m/s}) = 0.1975\text{ kg}\cdot\text{m/s},$$

taking positive directions to the right. a) Before the collision, puck B was at rest, so all of the momentum is due to puck A's motion, and

$$v_{A1} = \frac{p}{m_A} = \frac{0.1975\text{ kg}\cdot\text{m/s}}{0.250\text{ kg}} = 0.790\text{ m/s}.$$

b)

$$\Delta K = K_2 - K_1 = \frac{1}{2}m_A v_{A2}^2 + \frac{1}{2}m_B v_{B2}^2 - \frac{1}{2}m_A v_{A1}^2$$

$$= \frac{1}{2}(0.250\text{ kg})(-0.120\text{ m/s})^2 + \frac{1}{2}(0.350\text{ kg})(0.650\text{ m/s})^2$$

$$-\frac{1}{2}(0.250\text{ kg})(-0.7900\text{ m/s})^2$$

$$= -0.0023\text{ J}$$

Practice Question 4

On a greasy, essentially frictionless lunch counter, a 0.500 kg submarine sandwich, moving 3.00 m/s to the left, collides with an 0.250 kg grilled cheese sandwich moving 1.20 m/s to the right. a) If the two sandwiches stick together, what is the final velocity? b) How much mechanical energy dissipates in the collision?

a) From $m_1 v_1 + m_2 v_2 = m_1 v + m_2 v = (m_1 + m_2)v$, $v = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$. Taking positive velocities to the right, $v_1 = -3.00\,\text{m/s}$ and $v_2 = 1.20\,\text{m/s}$, so $v = -1.60\,\text{m/s}$.

If you get a +ve value, that is also reasonable because question asks for energy **dissipated**. So question is abit unclear.

But if question asks for **change in energy**, then it must be –ve value.

b) $$\Delta K = \frac{1}{2}(0.500\,\text{kg} + 0.250\,\text{kg})(-1.60\,\text{m/s})^2 - \frac{1}{2}(0.500\,\text{kg})(-3.00\,\text{m/s})^2 - \frac{1}{2}(0.250\,\text{kg})(1.20\,\text{m/s})^2 = -1.47\,\text{J}.$$

Practice Question 5

Two cars, one a compact with mass 1200 kg and the other a large car with mass 3000 kg collide head-on at typical highway speeds. a) Which car has a greater magnitude of momentum change? Which car has a greater velocity change? Calculate the change in the velocity of the small car relative to that of the large car. b) Which car's occupants would you expect to sustain greater injuries? Explain.

(a) Momentum conservation tells us that both cars have the same change in momentum, but the smaller car has a greater velocity change because it has a smaller mass.

$$M\Delta V = m\Delta v$$

$$\Delta v\,(\text{small car}) = \frac{M}{m}\Delta V\ (\text{large car})$$

$$= \frac{3000\,\text{kg}}{1200\,\text{kg}}\Delta V = 2.5\Delta V\ (\text{large car})$$

(b) The occupants of the small car experience 2.5 times the velocity change of those in the large car, so they also experience 2.5 times the acceleration. Therefore they feel 2.5 times the force, which causes whiplash and other serious injuries.

Practice Question 6

A ball with mass M, moving horizontally at 5.00 m/s, collides elastically with a block of mass 3M that is initially hanging at rest from the ceiling on the end of a 50.0 cm wire. Find the maximum angle through which the block swings after it is hit.

Collision: Momentum conservation gives

v_0 is initial velocity of ball.
v_1 is final velocity of ball.
v_3 is final velocity of block.

$$mv_0 = mv_1 + (3m)v_3$$
$$v_0 = v_1 + 3v_3 \qquad (1)$$

Energy Conservation:

$$\frac{1}{2}mv_0^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(3m)v_3^2 \qquad (2)$$
$$v_0^2 = v_1^2 + 3v_3^2$$

Solve (1) and (2) for $v_3 : v_3 = 2.50$ m/s

Energy conservation after collision:

$$\frac{1}{2}(3m)v_3^2 = (3m)gh = (3m)gl(1-\cos\theta)$$

Solve for $\theta : \theta = 68.8°$