1

(a) By Principle of Conservation of Linear Momentum

$(0.50)(2.0) + 0 = 0.50v_1 + 0.20v_2$

Using relative speed of approach = relative speed of separation

$u_1 - u_2 = v_2 - v_1$

$2.0 = v_2 - v_1$

$v_2 = 2.86\ m\ s^{-1}$

(b) By Principle of Conservation of Energy

$GPE_i + KE_i = GPE_f + KE_f$

$GPE_i - GPE_f = KE_f - KE_i$

$mgh = \frac{1}{2}mv^2$

$h = \frac{2.857^2}{2(9.81)}$

$= 0.416\ m$

$h = L - L\cos\theta$

$0.416 = 1.5(1 - \cos\theta)$

$\theta = 43.7°$

(c) There is an external resultant force acting on the bob provided by the tension in the string and weight.

2

(a) No resultant external force acting on the two colliding objects.

(b) **(i)** Force on B = rate of change of momentum of B

$= \frac{(24 - 20) \times 10^3}{3.0 - 1.5}$

$= 2670\ N$

(ii) Gradient is equal to the rate of change of momentum of the truck and this is also equal to the impact force exerted on the trucks according to Newton's 2nd law.

Since the impact forces between the two trucks are an action-reaction pair and are of equal magnitude but in opposite directions, the gradients have the same magnitude but opposite signs.

(iii) Impulse acting on each truck (during the collision) is equal to the change in momentum of the truck.

Since the impulse on the two trucks are equal and opposite, it follows that the gain in momentum of one truck must be equal to the lost in momentum of the other truck. Hence total momentum is conserved.

(iv) Total KE before collision

$= \frac{20000^2}{2 \times 4000} + \frac{16000^2}{2 \times 2000}$

$= 114\ kJ$

Total KE after collision

$$= \frac{24000^2}{2 \times 4000} + \frac{12000^2}{2 \times 2000}$$
$$= 108\ kJ$$

Change in KE = $-6000\ J$

Perfectly inelastic collision (they have the same final velocity)

3

(a) The principle of conservation of momentum states that when bodies in a system interact, the total momentum of the system remains constant, provided no net external force acts on it.

(b) Taking velocity to the right as positive.
By the principle of conservation of momentum for bodies A and B,

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$
$$(60)(11) + (90)(-5) = 60v_A + 90v_B$$

By relative speed of approach = relative speed of separation

$$u_A - u_B = v_B - v_A$$
$$(11) - (-5.0) = v_B - v_A$$

$$v_A = -8.2\ m\ s^{-1}$$

(c) **(i)** Area under $F_{net} - t$ graph is $\Delta\rho$

$$\frac{1}{2} \times 0.40 \times F_{\max} = 60\big(1 - (-8.2)\big)$$
$$F_{max} = 2760\ N$$

(ii) By adding soft padding to the walls, so that the duration of collision can be lengthened (to reduce the maximum force experienced by the skaters when they hit the walls).

4

(a) **(i)** The linear momentum of a body is defined as the product of its mass and its velocity and it is in the direction of the velocity.

(ii) The total momentum in a system remains the same unless an external net force acts on the system.

(b) **(i)** Applying Conservation of Momentum,

$$m_A v_A + m_B v_B = 0$$
$$v_B = -2.0 v_A$$

By Conservation of Kinetic Energy,

$$\frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B v_B^2 = 12$$
$$v_A^2 + 2.0 v_A^2 = 12$$
$$v_A = 2.0\ m\ s^{-1}$$
$$v_B = -4.0\ m\ s^{-1}$$

(ii) A and B are moving towards each other.
At any instant of time, the speed of B is twice that of A, distance covered by B is twice

that of A when they collide.

$x_A + x_B = 0.90$
$x_A + 2x_A = 0.90$
$x_A = 0.30\ m$

5

(a) The net momentum of a system remains constant provided no external resultant force acts on the system.

(b) **(i)** Taking upwards as positive
$0 = 4.0 \times 6.0 \sin\theta - 12 \times 3.5 \sin 30°$
$\theta = 61°$

(ii) By Conservation of Linear Momentum
$4.0v = 4.0 \times 6.0 \cos 61° + 12 \times 3.5 \cos 30°$
$v = 12\ m\ s^{-1}$

(iii) Initial total KE = $\frac{1}{2}(4)(12)^2 = 288J$
Final total KE = $\frac{1}{2}(4)(6.0)^2 + \frac{1}{2}(12)(3.5)^2 = 145.5\ J$

Since the total kinetic energy before and after collision are different, the collision is inelastic.

6

(a) Total initial momentum of A and B
$= (0.500)(7.40) + (0.350)(-9.60)$
$= 0.34\ kg\ m\ s^{-1}$

No external net force acts on A and B. Hence, total momentum is conserved and always equals to the initial total momentum.

Therefore, both A and B cannot be at rest at the same time since the final momentum is non-zero.

(b) Average force on B is the net force of B

$< F_{net} >= \frac{\Delta\rho}{\Delta t} = \frac{0.350\big(10.4 - (-9.60)\big)}{0.400}$
$= 17.5\ N$

(c) Take right as positive direction.

By Newton's 3rd Law, the force experienced by A is equal in magnitude and opposite in direction to the force experienced by B:

Average force on A = $-17.5\ N$

$< F_{net} > \times\ \Delta t = \Delta\rho$
$(-17.5) \times 0.400 = 0.500(v_A - 7.40)$
$v_A = -6.60\ m\ s^{-1}$

(d) Take right as positive direction.

Relative speed of approach = $u_A - u_B\ =\ 7.40\ -\ (-9.60)\ =\ 17.0\ m\ s^{-1}$

Relative speed of separation = $v_B - v_A$ = $10.4 - (-6.60) = 17.0\ m\ s^{-1}$

Since the relative speed of approach is equal to the relative speed of separation, it implies that total kinetic energy before and after the collision is unchanged, hence it is an elastic collision.

7

(a) **(i)** The Principle of Conservation of Linear Momentum states that the total linear momentum of a system remains constant provided that no resultant external force acts on the system.

(ii) The resultant force acting on a body is proportional to the rate of change of momentum of that body.

(b) **(i)** After collision, the bodies will move along the same line that joins the 2 bodies' centre of mass rightwards.

(ii) By principle of conservation of momentum:

$$mu = 15mv$$
$$v = \frac{1}{15}u$$

Ratio of KE= $\frac{KE_{nitrogen}}{KE_{neutron}} = \frac{15m\left(\frac{v}{15}\right)^2}{mv^2} = \frac{1}{15} = 0.067$

(iii) From **b(ii)**, since initial total KE before collision not equal to final total KE after collision, the collision is inelastic.

8

(a) During the collision, there are no external forces acting on the photon and electron or system, hence linear momentum is conserved.

(b) **(i)** $\sum \rho_x = 7.30 \times 10^{-22}\ kg\ m\ s^{-1}$

(b) **(ii)** $\sum \rho_y = 0\ kg\ m\ s^{-1}$

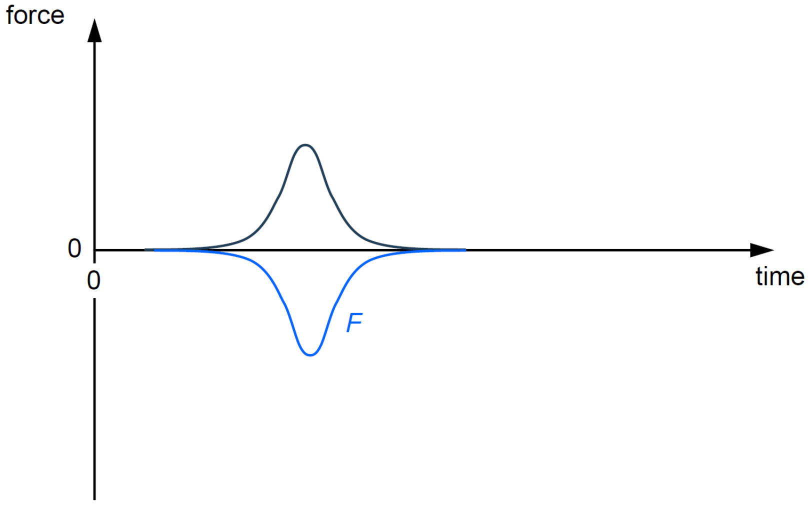
(ii) By Principle of Conservation of Momentum,
$7.3 \times 10^{-22} = p_p \cos 60° + p_e \cos 25°$
$p_e \sin 25° = p_p \sin 60°$
$p_e = 6.35 \times 10^{-22}\ kg\ m\ s^{-1}$

9

(a) **(i)** Impulse on object Y is the product of the force acting on object Y and the time of impact of the force.

(ii) The principle of conservation of linear momentum states that the total momentum of the bodies remain constant if there is no resultant/net external forces acting on it.

(b) **(i)**



(ii) No is it not possible. This is because the total initial momentum of both objects is non zero, hence by the principle of conservation of linear momentum, there will not be any instance where both objects can be at rest at the same time where total momentum is zero.

(iii) The area under the graph = impulse on Y
The change in momentum in Y is then $0.50\ Ns$.

$m_y v_y - m_y u_y = -0.50$
$(0.25)v_y - (0.25)(2.0) = 0.50$
$v_y = 4.0\ m\ s^{-1}$

10

(b) By Principle of Conservation of Momentum
$m_A u_A + m_B u_B = m_A v_A + m_B v_B$
$u_A + u_B = v_A + v_B$
$4.0 + (-1.0) = v_A + v_B$
$v_A + v_B = 3.0$

Since collision is elastic, by relative speed of approach = relative speed of separation
$u_B - u_A = v_A - v_B$
$(-1.0) - 4.0 = v_A - v_B$
$v_A - v_B = -5.0$

$v_B = 4.0\ m\ s^{-1}$

(c) By Newton's second law, the average force on ball B by ball A is

$$F_{net} = \frac{\Delta\rho}{\Delta t}$$
$$= \frac{0.50\big(4.0 - (-1.0)\big)}{0.25}$$
$$= 10\ N$$

By Newton's third law, the average force on ball A by ball B has the same magnitude of 10 N.

(d)