Lecture 13 - Collisions

Inelastic Collision Examples

All motions are along x-axis on frictionless surface

\[
\begin{align*}
\text{Before collision} & \\
\text{Find } v_f & = \frac{(m \cdot 1.0 + M \cdot 5.0)}{m + M} \quad \text{and} \quad v_i = \frac{3.5 \cdot 5.0}{10} = 1.75 \text{ ms}^{-1} \\
\text{After collision} & \\
\text{10 kg} & \quad \quad \quad \text{15 kg} \\
\end{align*}
\]

\[
\begin{align*}
P_i = P_f & \\
\therefore m v_i + M v_i = m v_f + M v_f & \\
\therefore v_f = (m v_i + M v_i) / (M + m) = (10 \cdot 1.0 + 15 \cdot (-5.0)) / (15 + 10) = -2.0 \text{ ms}^{-1} \\
\text{i.e. 2.0 ms}^{-1} & \text{ to the left}
\end{align*}
\]

Hecht §7.5

Perfectly Inelastic Collision

All motions are along x-axis on frictionless surface

\[
\begin{align*}
\text{Before collision} & \\
\text{Find } v_f & = \frac{(m \cdot 1.0 + M \cdot 5.0)}{m + M} \quad \text{and} \quad v_i = \frac{3.5 \cdot 5.0}{10} = 1.75 \text{ ms}^{-1} \\
\text{After collision} & \\
\text{10 kg} & \quad \quad \quad \text{15 kg} \\
\end{align*}
\]

\[
\begin{align*}
P_i = P_f & \\
\therefore m v_i + M v_i = (m + M) v_f & \\
\therefore v_f = (m v_i + M v_i) / (M + m) = (10 \cdot 1.0 + 15 \cdot (-5.0)) / (15 + 10) = -2.6 \text{ ms}^{-1} \\
\text{i.e. 2.6 ms}^{-1} & \text{ to the left}
\end{align*}
\]

Hecht §7.5

Elastic and Plastic

“Elastic” means that an object deformed by an external force rapidly returns to its original shape when the force is removed.

Work done deforming the object is “reversible”.

Little or no thermal energy generated.

e.g. rubber band, steel spring, super ball

“Plastic” means that an object deformed by an external force is permanently deformed even after the force is removed.

Work done deforming the object is “irreversible”.

All or most of work done is converted to thermal energy.

e.g. wet clay, plasticine

Most substances will stretch or bend elastically until they reach their “elastic limit”, beyond that they deform plastically (or just break!).

Inelastic Collisions

Kinetic energy is not conserved during the collision (i.e. some KE converted to heat, or sound, or deformation).

But momentum is conserved during collision.

\[
\therefore \text{ only one equation to solve:}
\]

\[
P_{\text{initial}} = P_{\text{final}}
\]

In a "Perfectly inelastic collision", objects stick together after collision. \therefore treat the two objects as a single object after collision:

\[
P_{\text{final}} = (m_1 + m_2) v_f
\]

• Most collisions are inelastic.

• "Perfectly inelastic collisions" usually involve easily deformed objects e.g. wet clay.

Problem

Try this one at home

A crater in Arizona is thought to have been formed by the impact of a meteorite with the earth over 20,000 years ago. The mass of the meteorite is estimated at 5 x 10^{10} kg and its speed 7200 ms^{-1}. Mass of earth = 5.98 x 10^{24} kg.

Judging from a frame of reference in which the earth is initially at rest, what speed would such a meteor impart to the earth in a head-on collision? Assume the pieces of the shattered meteor stayed with the earth as it moved.

(Hint: i.e. perfectly inelastic - see previous slide)

\[
[6 \times 10^{-11} \text{ ms}^{-1} \text{ approx 2 mm per year}]
\]

Collisions and Impulse

During collision, momentum is conserved - none is lost

\[
\therefore \text{ momentum lost by 1 = momentum gained by 2 (or vice versa)}
\]

\[
\therefore \Delta p_1 = -\Delta p_2 \quad \text{i.e.} \quad \int p_1 dt = -\int p_2 dt
\]

I.e. impulses are "equal and opposite"

Collision of Truck and Car

Which has the greatest magnitude of change in momentum? Which has the greatest magnitude of change in velocity? Which vehicle is it safest to be IN and why? (Write it down!)
Collisions and External Force

During any collision, if **no net external forces on the system**

Momentum is absolutely conserved

*BUT!*

Even is there is a net external force on the system such as gravity, if

the **collisional** (or explosive) forces are large and the collision (or explosion) **time Δt is short**, so during the collision (or explosion) we can ignore momentum change due to net external force, then

**Momentum is very nearly conserved during collisions or explosions even with external forces.**

(e.g. hitting nail with a hammer + gravity, recoiling gun + gravity)

Problem from 1996 Exam

A ball of mass 700g is fastened to a cord 800mm long and fixed at the far end at a support, and is released when the cord is horizontal. At the bottom of its path, the ball strikes a stationary 350g ball suspended from the same support with a cord 800mm long. The two balls stick together after the collision.

a) Calculate the speed of the falling ball just before it hits the stationary ball.

b) Calculate the speed of the two balls immediately after the collision.

\[3.9\text{ms}^{-1}; 2.64\text{ms}^{-1}\]