Lecture 13

# Collisions

# COLLISIONS

KJF §9.5, 10.9

## 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.

∴ only one equation to solve:

$$\underline{p}_{\text{initial}} = \underline{p}_{\text{final}}$$

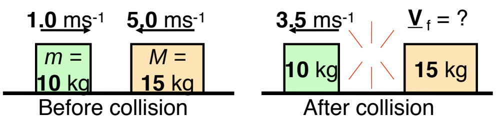
In a perfectly inelastic collision, objects stick together after collision → treat the two objects as a single object after collision: $\underline{p}_{\text{final}} = (m_1+m_2)\, \underline{v}_{\text{final}}$

- Most collisions are inelastic.
- "Perfectly inelastic collisions" usually involve easily deformed objects e.g. wet clay.



KJF §9.5

## Inelastic Collision Examples



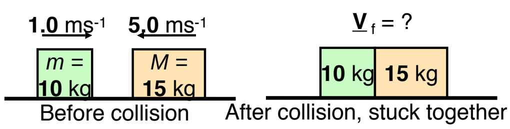

All motions are along x-axis on frictionless surface
+ to the right

Find $V_f$

[2.0 ms$^{-1}$ to the left]



## Perfectly Inelastic Collision




All motions are along x-axis on frictionless surface
+ to the right

Find $V_f$

[2.6 ms$^{-1}$ to the left]

# 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 $5 \times 10^{10}$ kg and its speed 7200 $\text{ms}^{-1}$. Mass of earth = $5.98 \times 10^{24}$ 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.

[$6\times10^{-11}$ $\text{ms}^{-1}$: approx 2mm per year]



# Perfectly **Elastic** Collisions

Kinetic energy is conserved during the collision (no energy is lost to the surroundings or participants).

Of course momentum is conserved during the collision.

∴two sets of equations are true simultaneously:

$$\Sigma K_{\text{initial}} = \Sigma K_{\text{final}}$$
$$p_{\text{initial}} = p_{\text{final}}$$

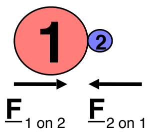
Solve equations simultaneously; quadratic (not in exam)

$$\text{e.g. } \tfrac{1}{2}\, mv_i^2 + \tfrac{1}{2}\, MV_i^2 = \tfrac{1}{2}\, mv_f^2 + \tfrac{1}{2}\, MV_f^2$$
$$\&\ mv_i + MV_i = mv_f + MV_i$$

- *Usually involves sub-atomic particles or highly rigid objects e.g. steel or glass balls.*
- *If both objects are same mass, their velocities swap after perfectly elastic collision e.g. Newton's cradle*



# Collisions and Impulse




During collision, momentum is conserved – none is lost

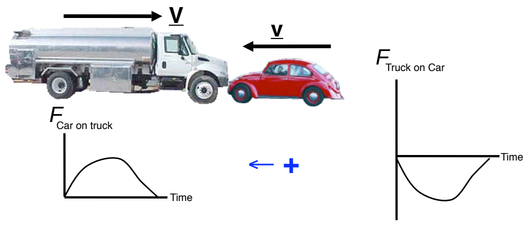
∴ momentum **lost** by 1 = momentum **gained** by 2 *(or vice versa)*

$$\therefore\ \Delta p_1 = -\Delta p_2 \quad \text{i.e.} \quad \underline{J}_1 = -\underline{J}_1$$

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!)*

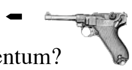


# The impulse approximation

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

Momentum is absolutely conserved

But there usually are external forces on the system (e.g. weight force)



Can we use conservation of momentum?



If the external force is much smaller than the collisional (or explosive) forces, and the collision (or explosion) time is short, so during the collision (or explosion) we can ignore the momentum change due to net external force, then

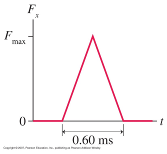
Momentum is very nearly conserved during collisions or explosions even with external forces

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

This is called the impulse approximation.

# Example: Hitting a cricket ball

A 150g cricket ball is bowled with a speed of 20 $ms^{-1}$. The batsman hits it straight back to the bowler at 40 $ms^{-1}$, and the impulsive force of bat on ball has the shape as shown.




(a) What is the maximum force the bat exerts on the ball?

(b) What is the average force the bat exerts on the ball?

*[30 kN, 15 kN]*



# 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$ms^{-1}$; 2.64$ms^{-1}$]*