Lecture Notes

(Conservation of Momentum)

Intro:

- when you throw a ball, shoot a bullet or give someone a push you tend to move backward

- Newton's third law of motion explained that action and reaction were equal and opposite forces

- a study of momentum can describe the motion of interacting bodies mathematically

- the two most common interactions we can study are explosions and collisions; we'll start with explosions because they are a bit simpler

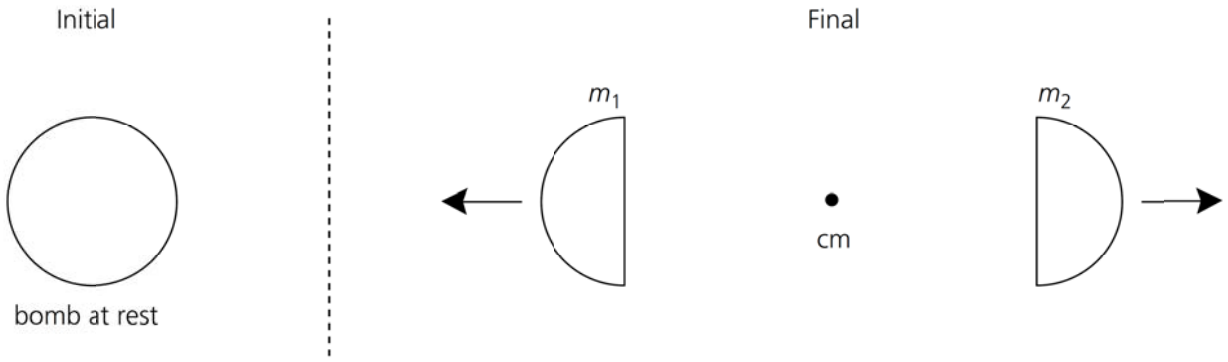
Explosions:

- an explosion can be thought of as a single object separating into two or more fragments

- the word 'explode' was first used to mean 'burst with destructive force' in the nineteenth century when a mathematical treatment of explosions became necessary; prior to that, the Latin verb explodere meant 'to drive off the theatre stage with hisses, boos, loud noises and claps'

- it came from *ex-* meaning 'out' and *plaudere* meaning 'clap'; many scientific words started off meaning something else

- consider a 10 kg bomb at rest that explodes into two fragments

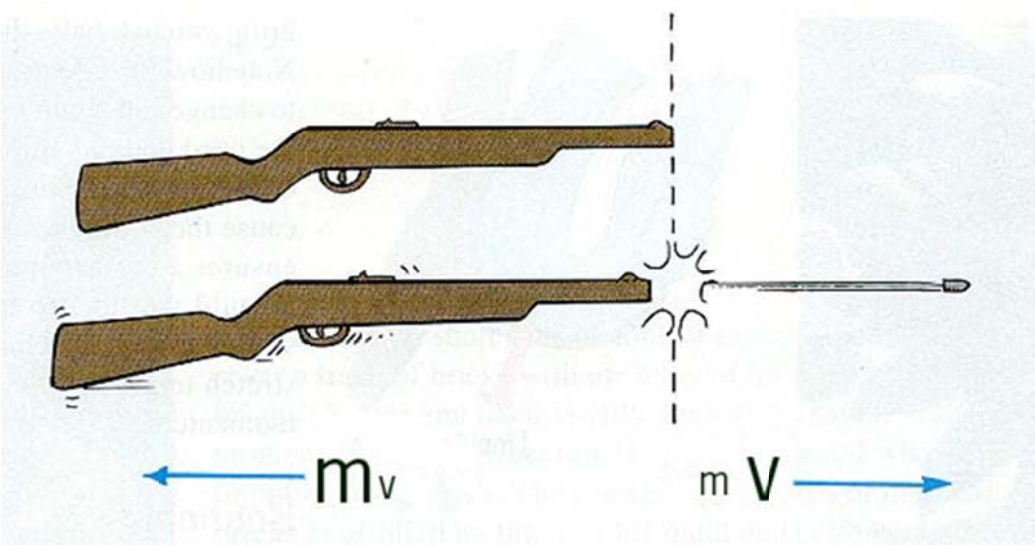


- if a 4 kg piece (m_1) travels west at 15 m/s ($\boldsymbol{v}_1$), then the 6 kg piece (m_2) would have moved in the opposite direction (at a speed $\boldsymbol{v}_2$)

- as there was no external unbalanced forces acting on the bomb (all forces were internal), we have a closed system and there would be no change in the total momentum of the system

- this is called the law of conservation of momentum; in a closed system, the change in momentum is zero

- relationships such as this can be applied to all sorts of explosions, a cannon or rifle being fired, a bomb exploding, a heart pumping a pulse of blood, a hose squirting water and even a nucleus giving off radioactive particles



- the recoiling rifle has just as much momentum as the bullet

- both the gun and the bullet have gained momentum, but since they are in opposite directions, they cancel out leaving the total momentum of the system at zero

- this is exactly the same momentum the system started out as; no momentum was gained or lost

- this example shows us two important qualities of momentum:
  1. momentum is a vector quantity
  2. momentum is conserved (only in a closed, isolated system)

- the forces that are applied to an object, in order to accelerate it, must be external forces, not internal ones

- external forces originate from outside the object you are studying; internal forces occur within the object itself

- for example, the molecular forces within a rock do not change the momentum of the rock; similarly, if you are sitting in a car and push on the dashboard, you cannot change the momentum of the car; these are internal forces

- cases in which the bodies explode in a straight line are not that common, however; explosions in two dimensions will be dealt with later

<u>Airplanes, Balloons, And Rockets</u>:

- conservation of momentum also applies to flight

- with propeller-driven airplanes, the interaction occurs when the propeller pushes against the surrounding air molecules, increasing their momenta in the backward direction

- this is accompanied by an equal change of the airplane's momentum in the forward direction

- releasing an inflated balloon is not like the airplane, because the molecules in the atmosphere are not necessary

- the air molecules in the balloon rush out, acquiring a change in momentum toward the rear; this is accompanied by an equal change in momentum of the balloon in the forward direction

- the air molecules do not need to push on anything; the balloon can fly through a vacuum

- this is also true of rockets and explains why they can be used in space flight

Collisions:

- a collision occurs when objects crash into each other

- some familiar collisions are:
  - meteorite craters
  - a billiard ball being struck by a cue
  - a boxer punching a body bag
  - hammering a nail into a piece of wood
  - gas molecules bouncing off each other

- collisions can be grouped into two types:

  - Elastic (rebound), where objects bounce off each other (ex. gas molecules or billiard balls)

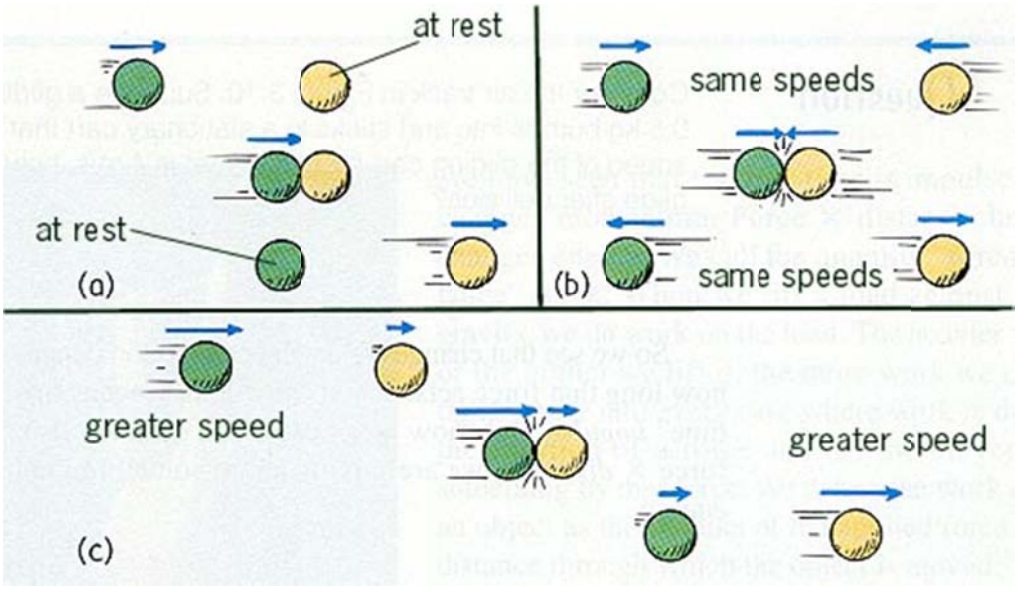
  - Inelastic (coupled), where objects remain locked together (ex. a bullet in a target)

<u>Elastic Collisions</u>:

- momentum is conserved in collisions; that is the total momentum of the system of colliding objects is unchanged before, during, and after the collision

- if you have one billiard ball hitting another ball at rest, head on, then the original moving ball will come to rest and the second ball which was at rest will move with the speed of the colliding ball

- this type of collision is called an elastic collision; the objects collide without deformation or the generation of heat



<u>Inelastic Collisions</u>:

- when objects stick together or are joined together they are said to be coupled (Latin *copula* = 'to bond')

- in a collision where the objects become coupled, the law of conservation of momentum still holds but the mass of the combined body after the collision is equal to the sum of the individual masses of the colliding bodies

- some examples of coupled collisions are arrows sticking into their targets and two cars colliding head-on

- in inelastic collisions, the colliding objects are severely deformed and they generate heat