Physics Grade 11
Unit 4
Dynamics
Part 1

What is Dynamics?

- Dynamics is the study of cause of motion.
- Dynamics comes from the Greek word “dynamikos” meaning force or power

The Force Concept

- Force is a pull or a push exerted on a body which changes the state of motion, or shape and size of a body.

- Force is a vector quantity measured in Newton(N) and causes a body to move, to stop, to change the direction of motion or to change size or shape of the body.

Resolving a force

Basic laws of Dynamics

- Newton's law of motions are the basic law of Dynamics this laws are known as Newton's law of motion and.
  - First Law or law of inertia
  - Newton's second law or law of acceleration
  - Newton's Third law or law of action and reaction

First Law Or Law Of Inertia

- First Law or law of inertia states that “ a body will continue in its state of rest or uniform motion unless a net force act on it.

Newton's second law or law of acceleration

- Newton's second law or law of acceleration states that "the acceleration of a body is directly proportional to the net force acting on the body and inversely proportional to the mass of the body.

$$a = \frac{F}{m}$$

$$F = ma$$

- ✓ In vector form, we can have $F=m(a_x+a_y+a_z)$, $F=ma_x+ma_y+ma_z$, $F_x=ma_x$, $F_y=ma_y$, $F_z=ma_z$

$$F = F_x i + F_y j + F_z k$$

Notice

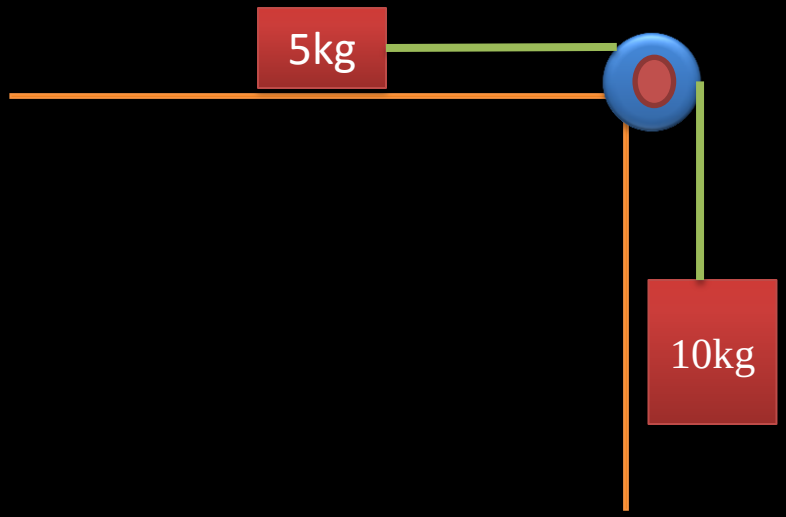
- the direction of the acceleration is always in the direction of the net force.
- When solving problems involving force and newton's second law, it is essential to begin by making a sketch that indicated each and every external force acting on the given body. This type of sketch is referred to as a free-body diagram.
- The second law can also be stated as the “ the rate change of momentum is directly proportional to the force.

$$F=\frac{\nabla P}{\nabla t}$$

Example 1: A body of mass 5kg rests on a frictionless table and is connected to a cable that passes over pulley onto a hanging body of mass 10kg.

find a) Acceleration of each body

b) tension in the cable

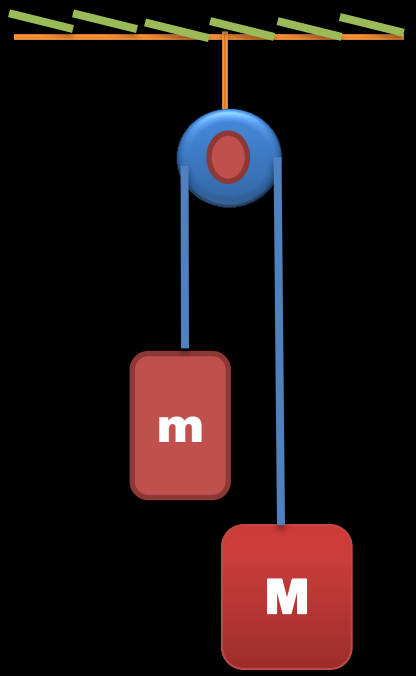


Example 2: a certain force gives mass m1 an acceleration of $12m/s^2$ and mass m2 an acceleration 0f $3.3m/s^2$. what acceleration will the force give to the combined mass?

Example 3: Two block connected by a cord pass over a frictionless pulley. If m=1.5kg and M=3.5kg, find

a) the acceleration

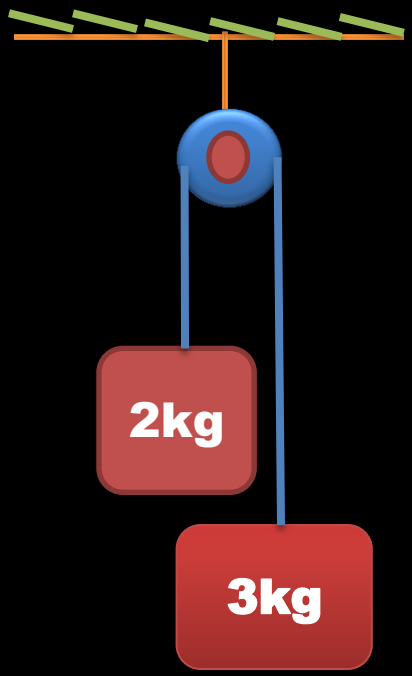
b) the tension in the cord



UEE 2001

Two masses 2kg and 3kg are attached to the end of a light string passing over pulley. What are the tension and acceleration interms of g?

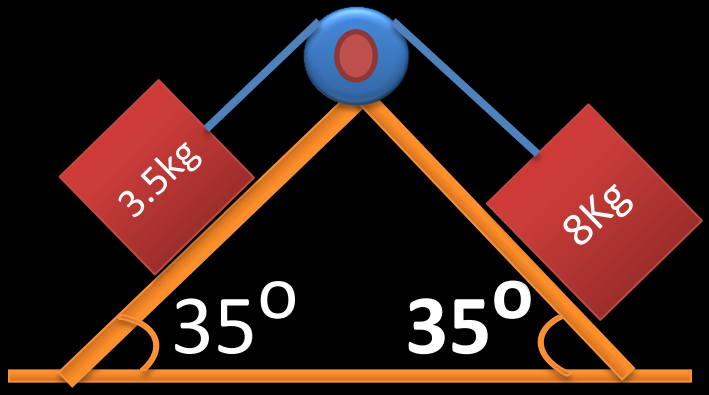
a) $\frac{12}{5}g, \frac{g}{5}$ b) $\frac{7}{8}g, \frac{g}{5}$ c) $\frac{21}{8}g, \frac{g}{8}$ d) $\frac{7}{8}g, \frac{g}{5}$



Example 4: Two block of mass 3.5kg and 8kg are connected by a mass less string passing over a frictionless pulley. If the incline are frictionless. Find the

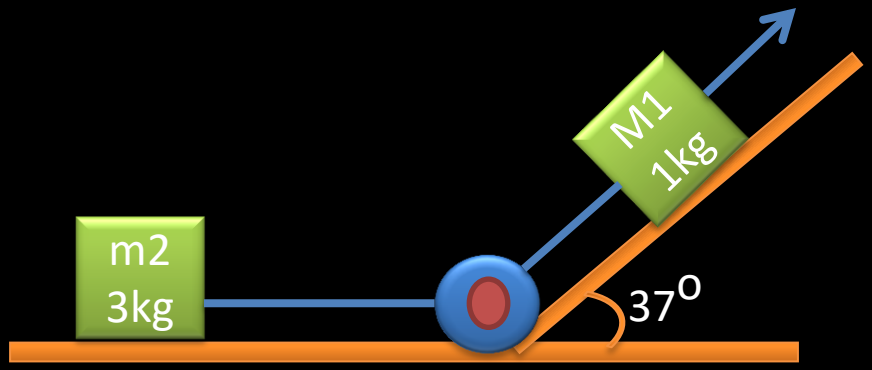
a) acceleration of the block

b) tension in the string



Example 5:A body moves at constant velocity of (3i-4j)m/s when two forces, F_1=(2i-6j)N and F_2 are acting on it. Find F_2

Example 6: assuming the surfaces and the pulley frictionless and F=15N. What is the tension in the connecting cord



Physics Grade 11
Unit 4
Friction
Part 1B

Friction Force

Friction force is a resistive force that opposes the motion of a surface over another surface.

- There are two types of friction force
  - ❖ static friction
  - ❖ kinetic friction

Static friction(F_s)

✓ Static friction(F_s) is the force of friction between two surfaces that are in contact and at rest relative to each other.

➢ Mathematically: $Fs=\mu_s F_N$

- **Normal force (F_N) is the force that is always acting perpendicular to the surfaces in contact.**
- **Remember, the magnitude of static friction is equal to applied force tending to cause the relative motion and its direction is always opposite to that of the applied force.**
- **The maximum static friction is called limiting friction.**

Kinetic friction(F_k)

✓ kinetic friction (F_k) is the fiction force between two surfaces that are relative motion to each other.

- Mathematically: $F_k = \mu_k F_N$

Notice:

- **kinetic friction is usually less than static friction.**
- **Friction doesn't depend on the area of the surfaces in contact.**
- **Friction depends on the nature of the surfaces in contact that is their roughness or smoothness and a normal force.**
- **If a body is at rest on horizontal surface and no external force is applied, the force of friction is zero.**

Kinetic friction(F_k)

✓ kinetic friction (F_k) is the fiction force between two surfaces that are relative motion to each other.

➢ Mathematically: $F_k = \mu_k F_N$

- **Normal force (F_N) is the force that is always acting perpendicular to the surfaces in contact.**
- **Remember, the magnitude of static friction is equal to applied force tending to cause the relative motion and its direction is always opposite to that of the applied force.**
- **The maximum static friction is called limiting friction.**

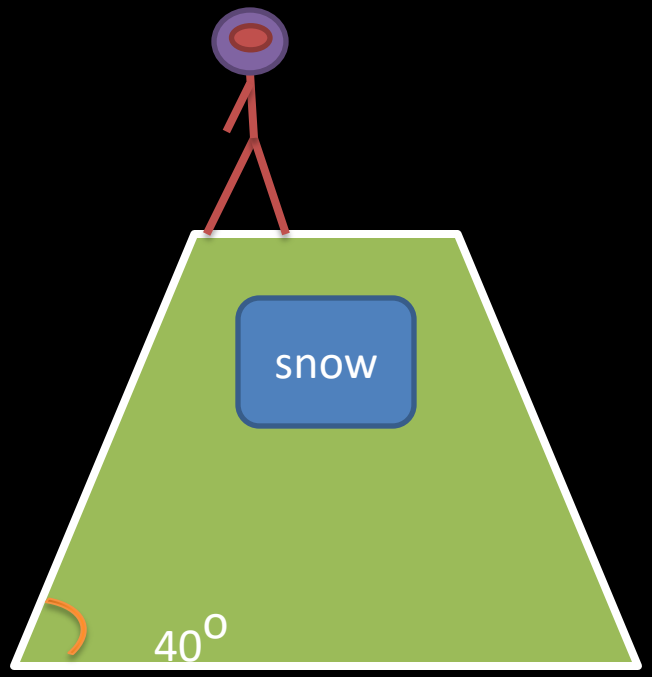
Remember

Remember

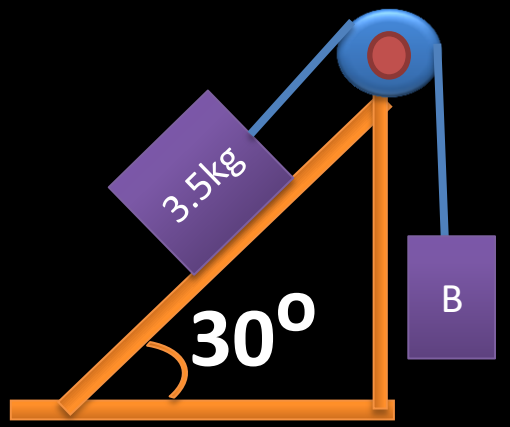
Remember

Remember

Example: A boy slide down a snow mountain starting from rest. If it takes him 3 sec to slide 20m down the 40 slope. What is the coefficient of kinetic friction



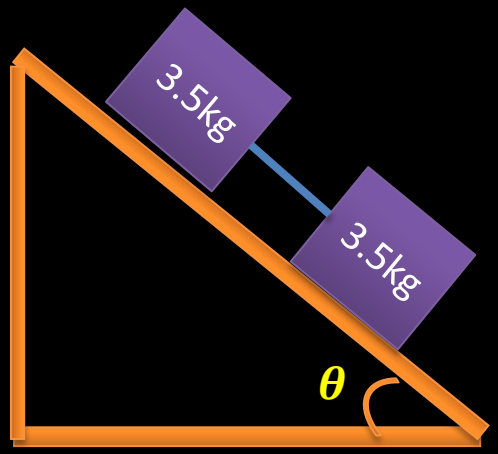
Example: Two block are connected over a frictionless pulley. If block A =10kg, μ_k=0.2, $\theta = 30^o$ and that block A slides down the incline at constant speed, what is the mass of block B?



Example: Two masses m1=1.65kg and m2=3.3kg attached by a mass of less rod if $\theta = 300$, $\mu_{k\,1}$=0.226 and $\mu_{k\,2}$=0.112. compute

a) The tension in the rod

b) the common acceleration of the masses as they travel down



Thank You

End of part 1B

Physics Grade 11
Unit 4
Dynamics
Law of conservation of linear momentum
Part 2

Linear Momentum and its application

- Momentum is a physics term; it refers to the quantity of motion that an object has.
- If an object is in motion (*on the move*) then it has momentum.
- Momentum can be defined as "mass in motion.“

Momentum ($\vec{p}$): is the product of the mass of moving body with its velocity.

$$\vec{p} = \mathrm{m}\vec{v}$$

Notice

- ✓ momentum is a vector quantity.
- ✓ When a body is moving with a velocity of

$$\vec{v}=v_x i+v_y j+v_z k$$

$$\vec{p} = m\vec{v}=m(v_x i+v_y j+v_z k)$$

$$=mv_x i+mv_y j+mv_z k$$

$$\vec{p} = p_x i+ p_y j + yzk$$

Impulse

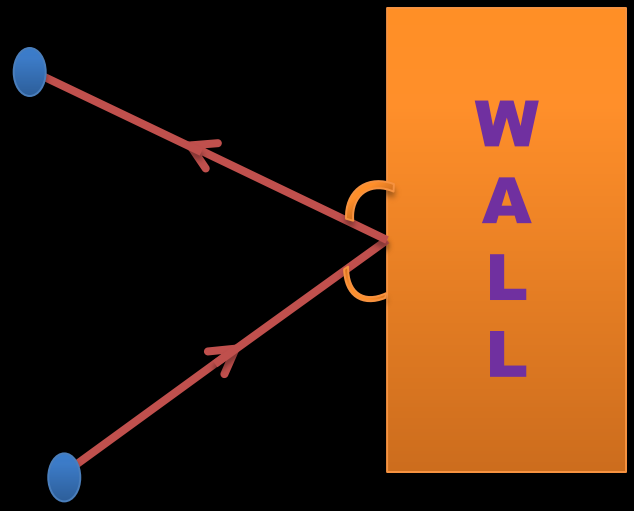
- Impulse is the product 0f an average force and the time interval for which the force acts.
- Impulse is equal to the change in momentum.
- The same impulse may result from a small force acting for a longer time or a larger force acting for a very short period of time.

From newton's 2nd law,

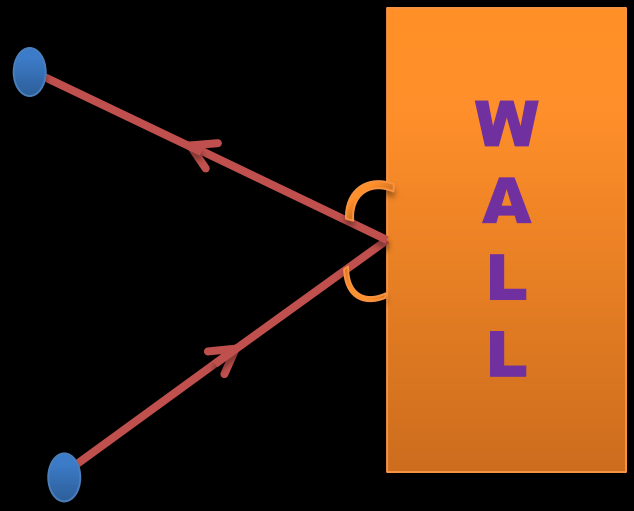
$$\mathbf{F=ma=m\frac{\nabla v}{\nabla t}}$$

$$F\nabla t=\nabla p$$

Example: A 3kg ball strikes a wall at 10m/s at an angle of 60^{o}.it bounces off the wall with the same speed and angle. If the ball is in contact with the wall for 0.2 sec, what is the average force exerted by the wall on the ball?



Example: A 3kg ball strikes a wall at 10m/s at an angle of 60^{o}.it bounces off the wall with the same speed and angle. If the ball is in contact with the wall for 0.2 sec, what is the average force exerted by the wall on the ball?



Example: A ball of mass 4kg falling to the ground with a velocity of (5i-12j) m/s bounce off the ground with (12i+16j) m/s. if the contact time is 0.2 sec. find the :

a) impulse of the ball

b) force it experience

Example: A ball of mass 0.25 kg moving with a speed of 20m/s bounces off a wall with 90% of its initial speed along the same line of motion. What is the change in momentum of a ball?

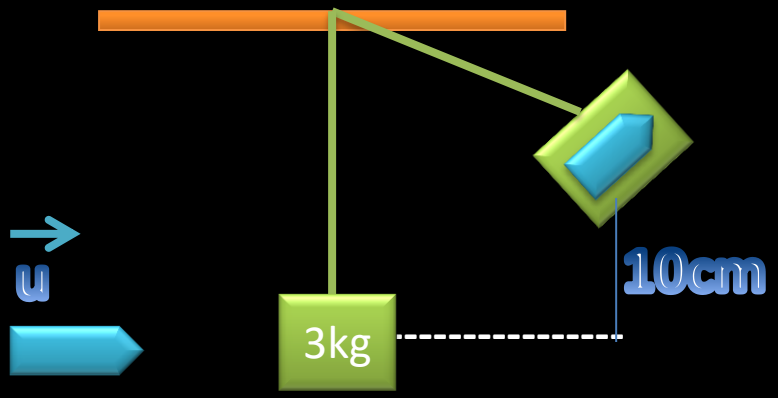
Law of conservation of linear momentum

If the net force acting on an object is zero, its momentum is conserved therefore, the law of conservation of linear momentum states that

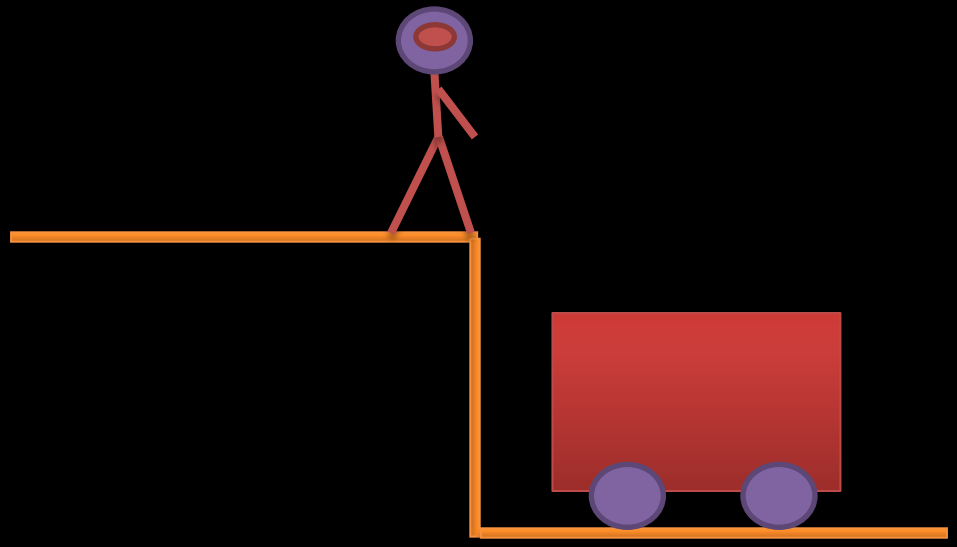
"the total linear momentum of an isolated system remains constant."

$$\sum P_i = \sum P_f$$

Example: a bullet of 15g is fired horizontally into 3kg block of wood suspended by a cord. The bullet sticks in the block and into swing 10cm above its initial level compute the initial speed of the bullet?



Example: a 60kg person running at initial speed of 4m/s jumps onto a 120kg cart that is initially at rest. Find the velocity of the person and the cart after impact.



Elastic and in elastic collision

✓ Collision is an event where two or more bodies make physical contact for a very short time and experience impulsive forces.

- Types of collisions

  A) based on conservation of kinetic energy

  B) based on dimension

A: based on conservation of kinetic energy

- Based on what happens to the kinetic energy, Collisions classified as elastic and inelastic.
- **Elastic collision**: is a collision in which both momentum and kinetic energy of the system are conserved.

$$KE_i = KE_F$$

- **Inelastic collision**: is a collision in which momentum is conserved, but the kinetic energy is not conserved.

$$KE_i \neq KE_F$$

Notice

- ✓ for both elastic and inelastic collisions, momentum is conserved.
- ✓ when two bodies collide and stick together, the collision is said to be perfectly inelastic collision.
- ✓ Kinetic energy may change during collision. Usually, it decreases due to losses associated with sound, heat, vibration and deformation. Sometimes it increases, if the collision sets off an explosion.

Newton's Experimental law of impact

- ✓ It states that the ratio of the relative speed of two objects in direct impact is constant. This constant is called coefficient of restitution e and given by

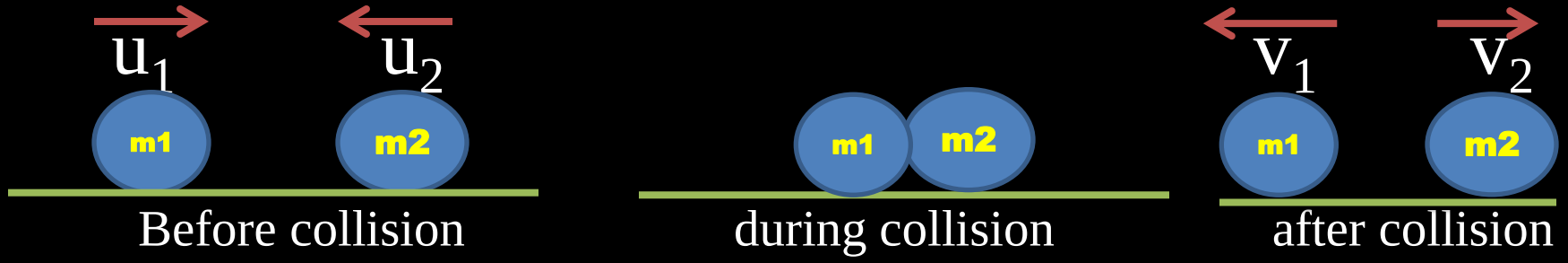
$$e = -\frac{v_2 - v_1}{u_2 - u_1}$$

- ✓ where v1 and v2 are final velocities of two interacting bodies after impact and u1 and u2 are initial velocity after impact.

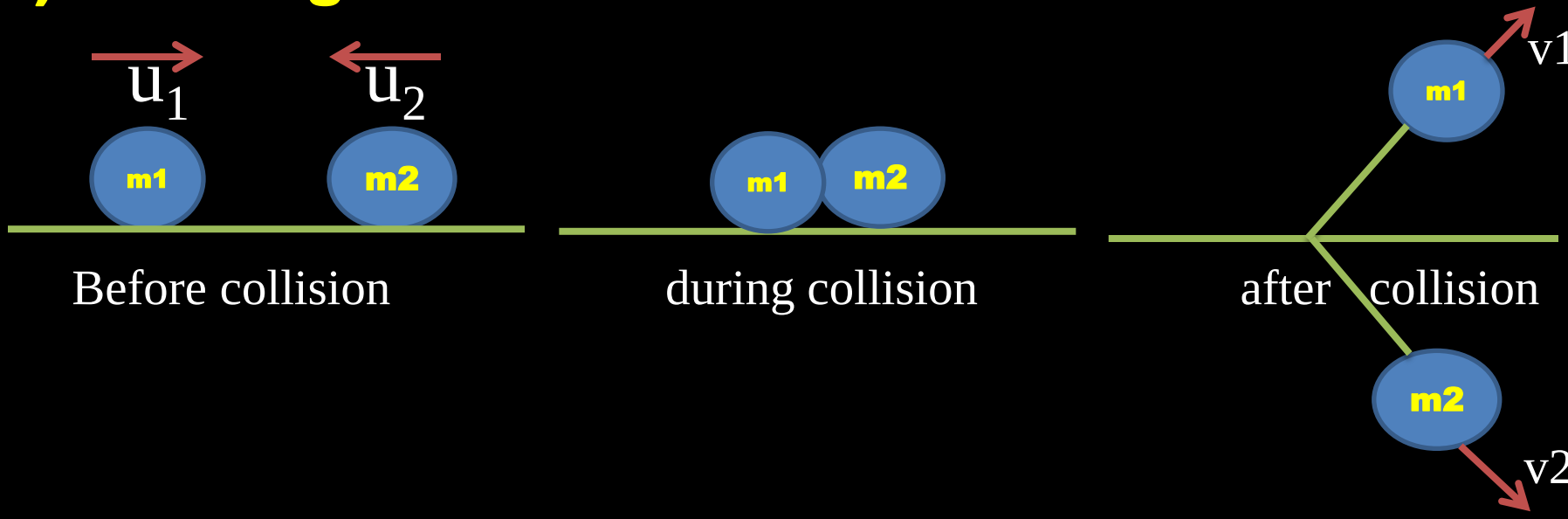
e	<1	0	1	>1
Type	inelastic	Perfectly inelastic	Elastic	Perfectly elastic

B) Based on dimension

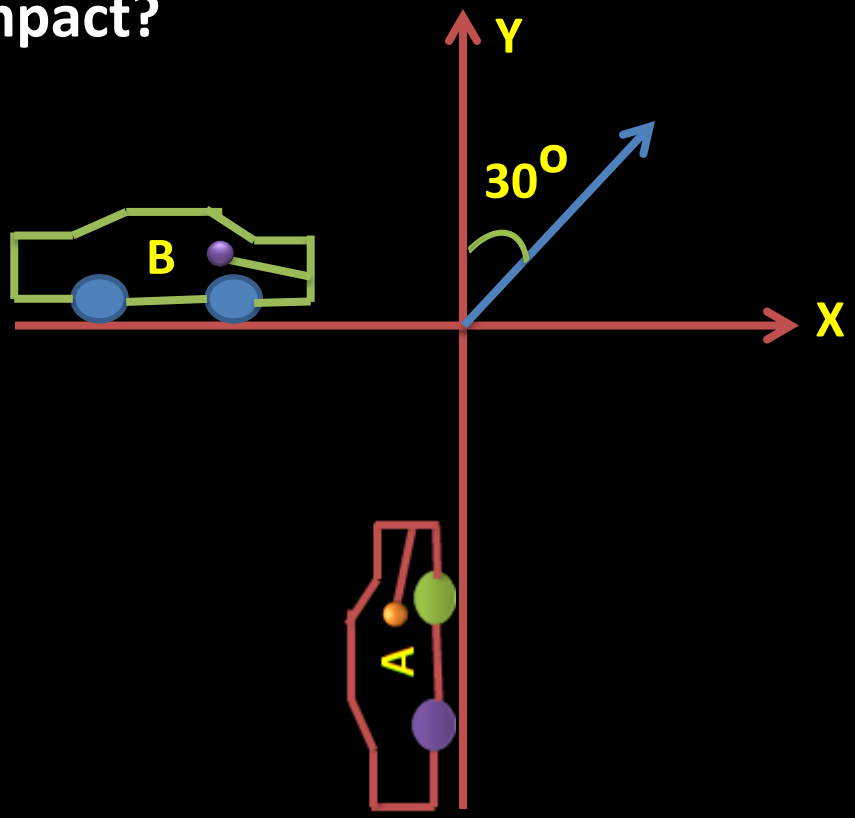
1) Head on collision: is a collision in one dimension



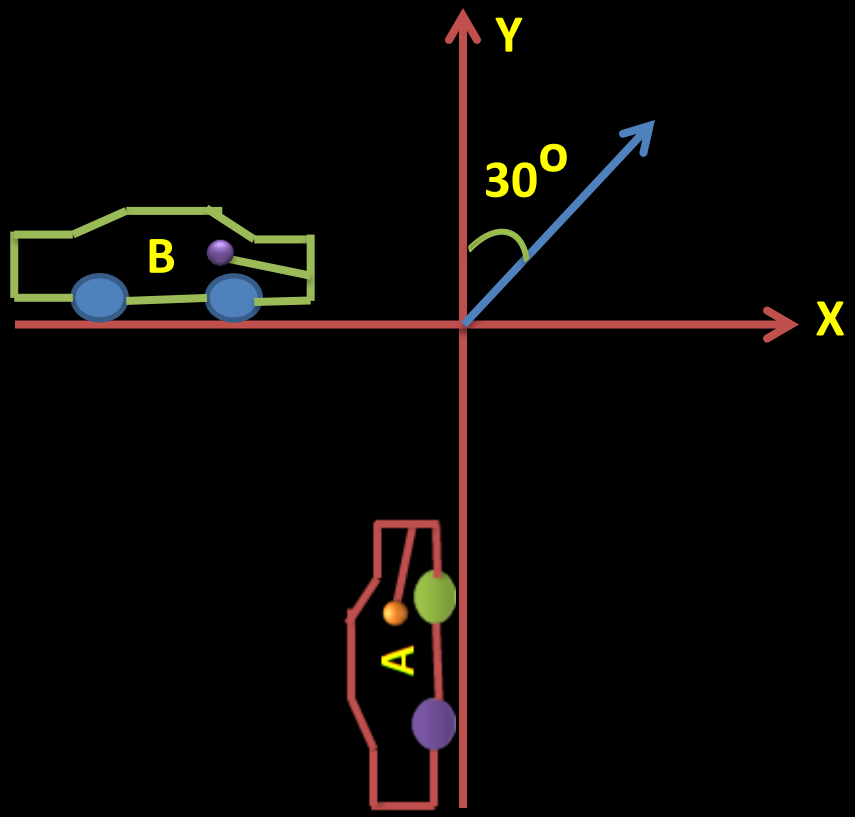
2) Glancing collision: is a collision in two dimension



Example: Two cars collide at right angles in the intersection. Car A was mass of 1200kg, car B has mass of 1600kg. The car move with common velocity after impact. If car A was moving at 50km/h , what was the velocity of car B before impact?



Example: Two cars collide at right angles in the intersection. Car A was mass of 1200kg, car B has mass of 1600kg. The car move with common velocity after impact. If car A was moving at 50km/h , car B before impact?



Example: A 3.5g bullet is fired on to two block resting on smooth surface. If the bullet passes through the first block and giving it a 0.63 m/s and then embedded itself in the second block and move with 1.4 m/s together with it. What was?

a) the speed of the bullet immediately after it emerges from the block

b) the initial speed of the bullet



Example: A 3.5g bullet is fired on to two block resting on smooth surface. If the bullet passes through the first block and giving it a 0.63 m/s and then embedded itself in the second block and move with 1.4 m/s together with it. What was?

a) the speed of the bullet immediately after it emerges from the block

b) the initial speed of the bullet



Example: A 3.5g bullet is fired on to two block resting on smooth surface. If the bullet passes through the first block and giving it a 0.63 m/s and then embedded itself in the second block and move with 1.4 m/s together with it. What was?

a) the speed of the bullet immediately after it emerges from the block

b) the initial speed of the bullet



Examples from text book

Worked example 4.7

Two roads are perpendicular and meet at a junction.

Car A of mass 1000 kg travels along one road at 20 m/s due North.

Car B of mass 1300 kg, travels due West along the other road at 16 m/s.

At the junction the cars collide and move together.

a) Write down the initial velocities of the cars before collision in vector form.

b) Find the velocity of the cars after collision.

First draw a diagram of the cars before collision (Figure 4.17).

a) Assume North and West to be positive in our frame of reference. The initial velocities are:

car A: $\begin{bmatrix} 0 \\ 20 \end{bmatrix}$ m/s

car B: $\begin{bmatrix} 16 \\ 0 \end{bmatrix}$ m/s

b) momentum before collision $= 1000 \begin{bmatrix} 0 \\ 20 \end{bmatrix}$ kg m/s

$+ 1300 \begin{bmatrix} 16 \\ 0 \end{bmatrix}$ kg m/s

$= \begin{bmatrix} 20\,800 \\ 20\,000 \end{bmatrix}$ kg m/s

momentum after collision $= (1000 + 1300)\,\mathbf{v}$ kg m/s

$= 2300\mathbf{v}$ kg m/s

So $\mathbf{v} = \begin{bmatrix} 20\,800/2300 \\ 20\,000/2300 \end{bmatrix}$ m/s

$= \begin{bmatrix} 9.04 \\ 8.70 \end{bmatrix}$ m/s

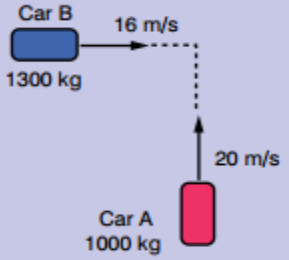


Figure 4.19

Examples from text book

Worked example 4.8

A ball of mass 500 g and velocity $\begin{bmatrix}5\\2\end{bmatrix}$ m/s bounces off a vertical wall.

a) What is the impulse of the ball?

b) The ball changes direction in 0.1 s. What is the force exerted by the wall on the ball?

a) First draw a diagram showing the known variable (Figure 4.20).

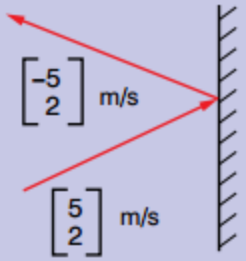


Figure 4.20

Assume the frame of reference to be Cartesian coordinates, that is positive x-direction is to the right and positive y-direction is upwards.

Use the equation $p = mv$ to find the momentum before and after collision, and then $I = m\Delta v$ to find the impulse.

Momentum before collision $= 0.5 \times \begin{bmatrix}5\\2\end{bmatrix} = \begin{bmatrix}2.5\\1.0\end{bmatrix}$ kg m/s

Momentum after collision $= 0.5 \times \begin{bmatrix}-5\\2\end{bmatrix} = \begin{bmatrix}-2.5\\1.0\end{bmatrix}$ kg m/s

Impulse = change in momentum $= \begin{bmatrix}2.5\\1.0\end{bmatrix} - \begin{bmatrix}-2.5\\1.0\end{bmatrix}$ kg m/s

$= \begin{bmatrix}5\\0\end{bmatrix}$ kg m/s

b) Use the equation $I = F\Delta t$ and rearrange it to find the force exerted by the wall.

$F = I/\Delta t$

Force exerted by wall $= \begin{bmatrix}5\\0\end{bmatrix} / 0.1 = \begin{bmatrix}50\\0\end{bmatrix}$ N

Examples from text book

Worked example 4.9

The cue ball in a pool game is travelling at $\begin{bmatrix} 3 \\ -2 \end{bmatrix}$ m/s. It collides with a pool ball which is stationary. After the collision, the pool ball moves with a velocity of $\begin{bmatrix} 2 \\ 0.5 \end{bmatrix}$ m/s.

What is the velocity of the cue ball after the collision?

The cue ball has a mass of 90 g, and the pool ball has a mass of 100 g.

First draw a diagram showing the known variables and the unknown one (Figure 4.24).

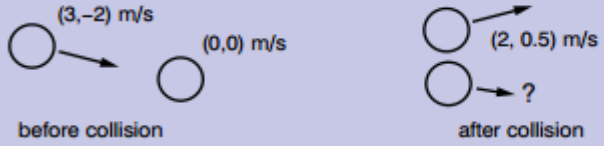


Figure 4.24

Momentum before collision = $0.09 \times \begin{bmatrix} 3 \\ -2 \end{bmatrix} = \begin{bmatrix} 0.27 \\ -0.18 \end{bmatrix}$ kg m/s

Momentum after collision = $0.1 \times \begin{bmatrix} 2 \\ 0.5 \end{bmatrix} + 0.09 \times \begin{bmatrix} x \\ y \end{bmatrix}$ kg m/s

$= \begin{bmatrix} 0.2 \\ 0.05 \end{bmatrix} + \begin{bmatrix} 0.09x \\ 0.09y \end{bmatrix}$ kg m/s

As momentum after collision = momentum before collision

$$\begin{bmatrix} 0.2 \\ 0.05 \end{bmatrix} + \begin{bmatrix} 0.09x \\ 0.09y \end{bmatrix} = \begin{bmatrix} 0.27 \\ -0.18 \end{bmatrix}$$

$$\begin{bmatrix} 0.09x \\ 0.09y \end{bmatrix} = \begin{bmatrix} 0.27 - 0.2 \\ -0.18 - 0.05 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0.07/0.09 \\ -0.23/0.09 \end{bmatrix} = \begin{bmatrix} 0.78 \\ -2.56 \end{bmatrix} \text{ m/s}$$

So the velocity of the cue ball is $\begin{bmatrix} 0.78 \\ -2.56 \end{bmatrix}$ m/s

Examples from text book

Worked example 4.10

Car A collides with car B, which is stationary and then both cars move together.

Before the collision, car A had a velocity of 5 m/s. The masses of car A and car B are 1250 kg and 1500 kg, respectively.

What is the speed of the two cars after the collision?

First draw a diagram to show all the known variables and the unknown.

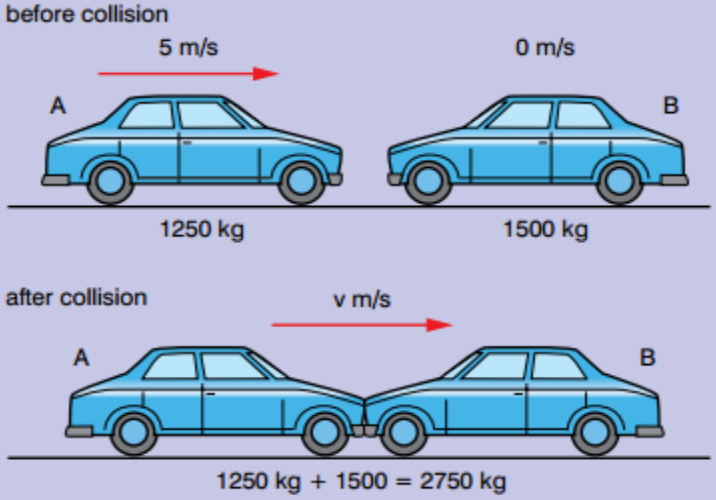


Figure 4.25

Use the law of conservation of momentum and the equation $p = mv$

$m_A v_A + m_B v_B = (m_A + m_B)v$

As $v_B = 0$, this term in the equation is zero. Rearrange the equation to find v_{AB}:

$v_{AB} = m_A v_A/(m_A + m_B)$

Substituting in the values:

$v_{AB} = (1250\ \text{kg} \times 5\ \text{m/s})/(1250\ \text{kg} + 1500\ \text{kg})$

$= 6250\ \text{kg m/s} \div 2750\ \text{kg} = 2.3\ \text{m/s}$

Thank You