

# Conservation of Momentum

- When objects collide, the laws of physics allows us to predict where they will go after the collision.
- The principle of conservation of momentum can be used to predict the motion of objects after collision.
  - Just as energy is conserved, linear momentum is also conserved.

- If a stationary object explodes, the total momentum of all the fragments even if they are moving must add up to zero because the object had zero momentum at start.

What is the principle of conservation of momentum?

## Law of Cons. of linear momentum.

For any Isolated System, the total linear momentum is constant.

An isolated system is a group of objects on which there is no external influence of force.

Mathematically, Conservation of momentum is

Total Momentum before = Total Momentum After

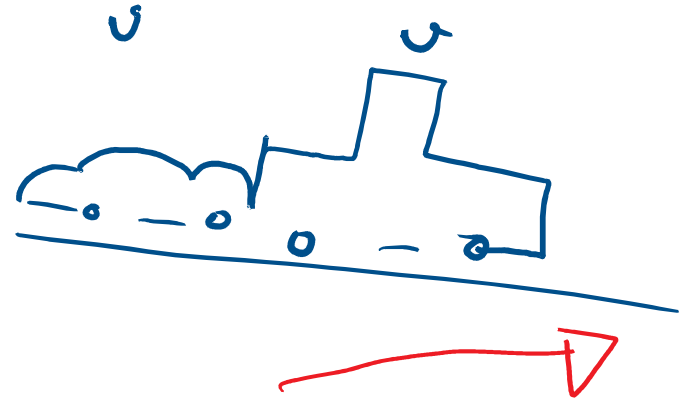
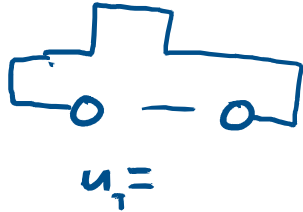
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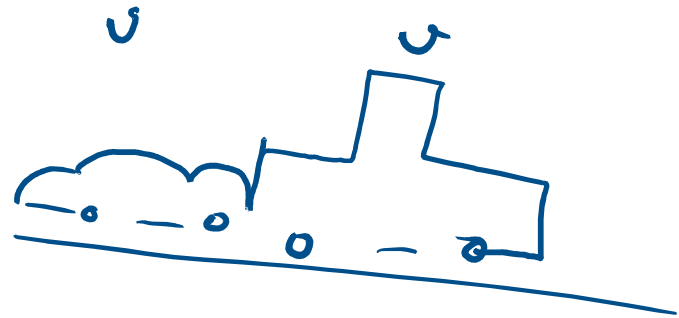
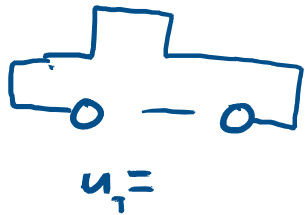
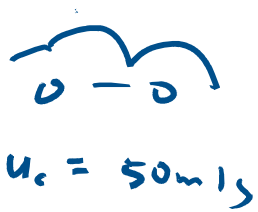
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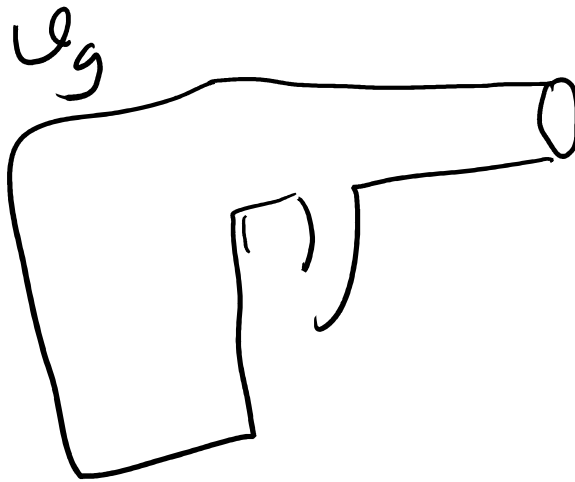
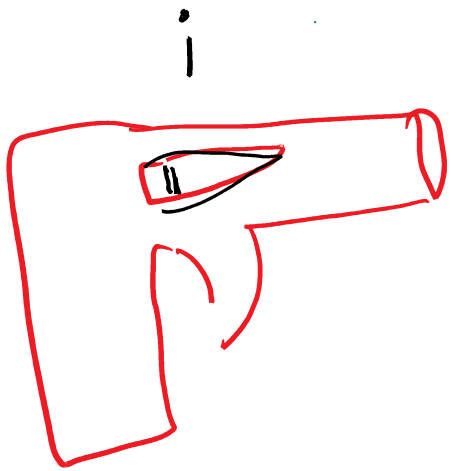
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$$\begin{aligned}
 \sum P_i &= \sum P_f \\
 m_c u_c + m_T u_T &= m_c u + m_T u = u [m_c + m_T] \\
 1000 \times 50 + 0 &= u (1000 + 5000) \quad \therefore \quad u = \frac{50000}{6000} \text{ m/s}
 \end{aligned}$$

## Recoil Velocity

- The backward velocity when a bullet leaves a gun
- Consider a gun of mass  $M_g$  and a bullet of mass  $m_b$ .
- The gun shoots the bullet and leaves the nozzle at velocity  $U_b$
- Determine the velocity of the gun  $U_g$



$$\Sigma P_i = \Sigma P_f$$

$$m_b u_b + m_g u_g = m_b U_b + m_g U_g$$

0 + 0 = m\_b U\_b + m\_g U\_g

$$0 = m_b U_b + m_g U_g$$

$$U_g = - \frac{m_b}{m_g} U_b$$

$U_g$  is  
-ve  $\Rightarrow$   
backward  
 $\Downarrow$   
recoil

## Elastic and Inelastic Collisions

- In many collisions, kinetic energy is lost. This is evidenced when two objects remain motionless.
- In this case KE is converted to work done in mangling the objects.
- This kind of collision where KE is lost is called an **Inelastic collision**.  
'An Inelastic collision is one during which KE is lost'

- Sometimes the two objects involved in collision may stick together.
- In this case, this is a perfectly inelastic collision.

→

- When no KE is lost, we call the collision elastic collision.

- Collisions involving hard balls, like pool balls are nearly elastic.

Therefore:

An elastic collision is one during which KE is conserved.

Elastic Collision

$$\sum K E_{\text{before}} = \sum K E_{\text{after}}$$

## In summary

1. Inelastic Collision

$$\sum P_i = \sum P_f .$$

2. Elastic Collision

$$\sum P_i = \sum P_f$$

$$\sum KE_i = \sum KE_f .$$

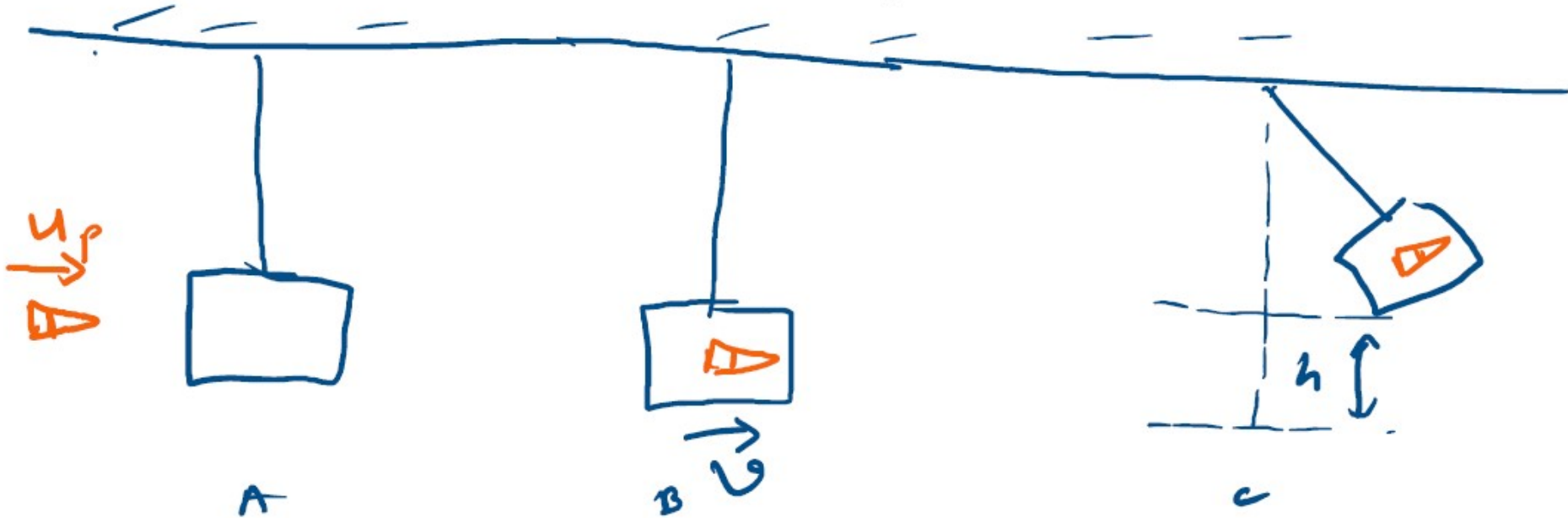
Ex: Ballistic pendulum: - Can be used to determine the velocity of a bullet.

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A 10g pellet of unknown speed is shot into a 2.00 kg block of wood suspended from a ceiling by a cord. The pellet hits the block and gets embedded into the block. After collision, the block & pellet swing to a height 30cm above the original position. What was the speed of the pellet before collision?

Solution:

- This is an example of a perfectly inelastic collision because the block & pellet stuck together. They thus move with a common velocity  $v$ .



KE at **B** (of the block + pellet) is converted  
to PE of the block at C

$$KE = PE$$

$$\frac{1}{2} \cancel{m} v^2 = \cancel{m} g h$$

$$v = \sqrt{2gh} = \sqrt{2(9.8)(0.3)}$$

$$= 2.4 \text{ m/s}$$

This is the velocity of the (block + pellet)  
after collision, just before it rises.

Use Cons. of mom.

$$\sum P_i = \sum P_f$$

momentum (pellet) + momentum (block) = momentum (pellet + block)

$$m_p u_p + m_b u_b = (m_p + m_b) v$$

$$(0.01) u_p + 0 = (2.000 + 0.01) 2.4$$

$$\underline{u_p = 490 \text{ m/s}} \quad \text{velocity of the pellet.}$$

## Conservation of Momentum in 2/3 D.

- In 1D the possible motion of colliding objects is limited.
- When collisions are no longer restricted to lie along a line as when billiard (pool) balls collide on a pool table, the vector of the mathematical equations becomes important.

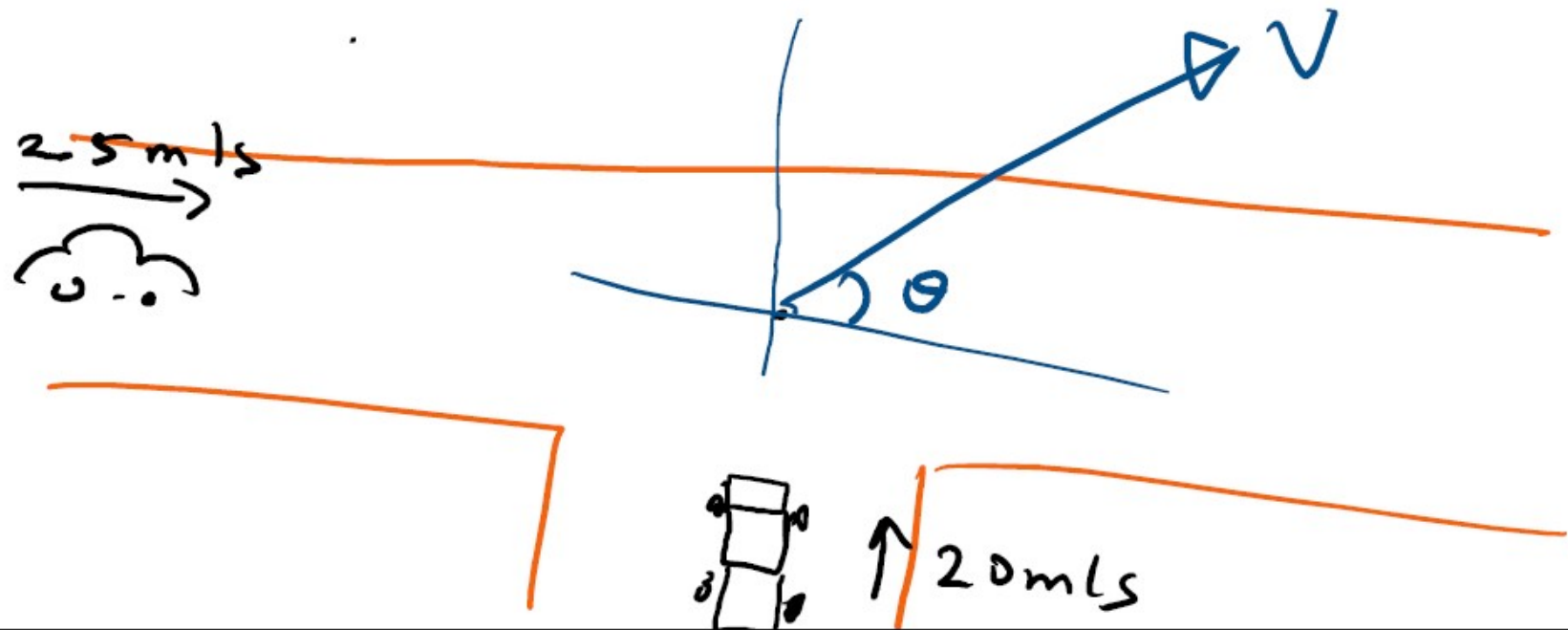
You can apply the Conservation of momentum in 2-D & 3-D as well

$$\begin{array}{l} \sum P_{xi} = \sum P_{xf} \\ \sum P_{yi} = \sum P_{yf} \\ \sum P_{zi} = \sum P_{zf} \end{array} \quad \left| \begin{array}{l} 2D \\ 3D \end{array} \right.$$

Ex. A 1500 kg car travelling east with a speed of 25.0 m/s collides at an intersection with a 2500 kg van travelling north at a speed of 20.0 m/s as shown.



Assume when they collide they move with  $v$



Conservation of Momentum in the X-dir

$$\sum P_{ix} = \sum P_{fx}$$

$$m_c u_{cx} + m_v u_{vx} = (m_c + m_v) v_x$$

$$(1200 \times 25) + 0 = 4000 v_x$$

$$v_x = 7.5 \text{ m/s}$$

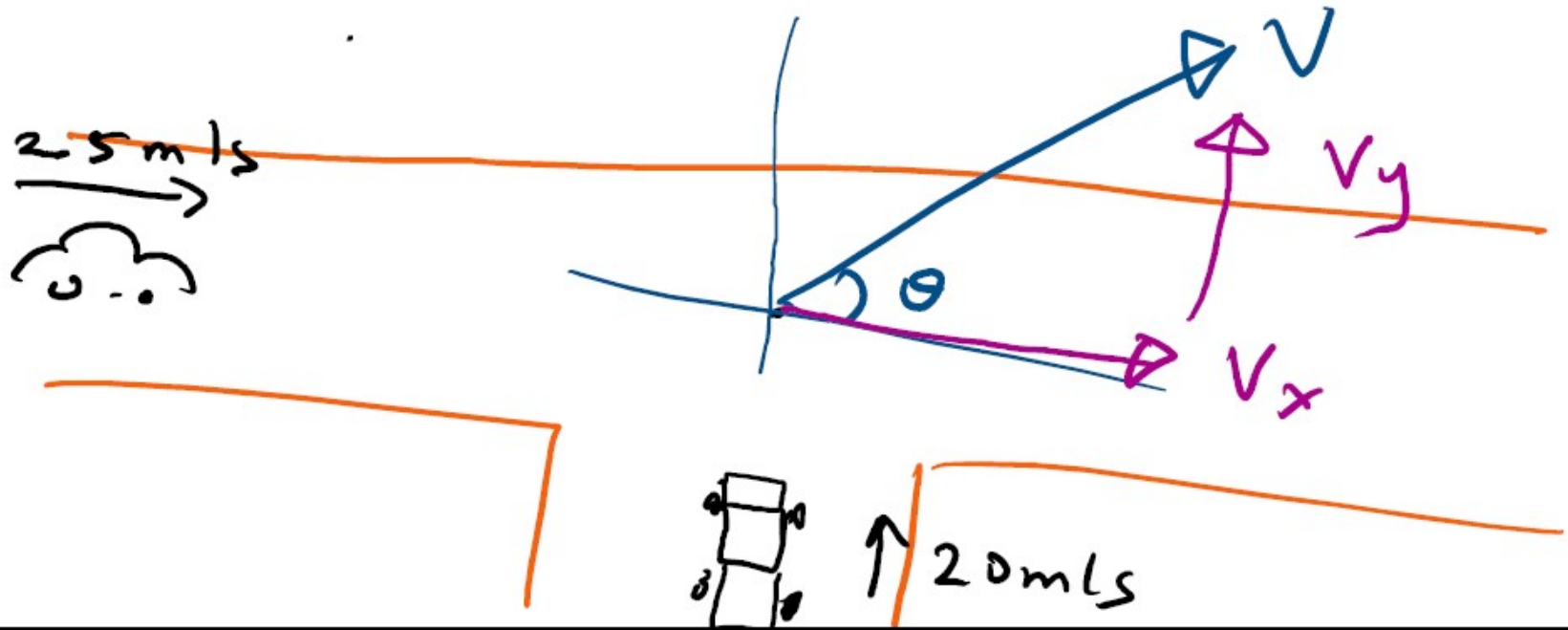
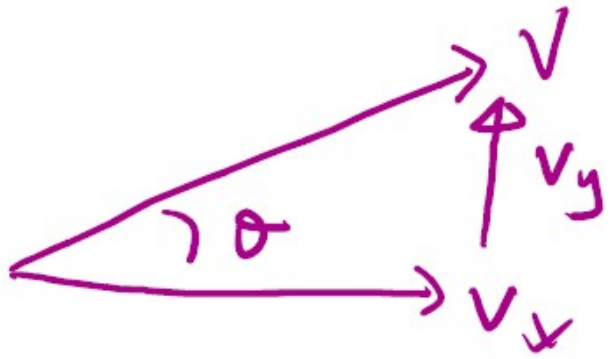
Conservation in the y dir

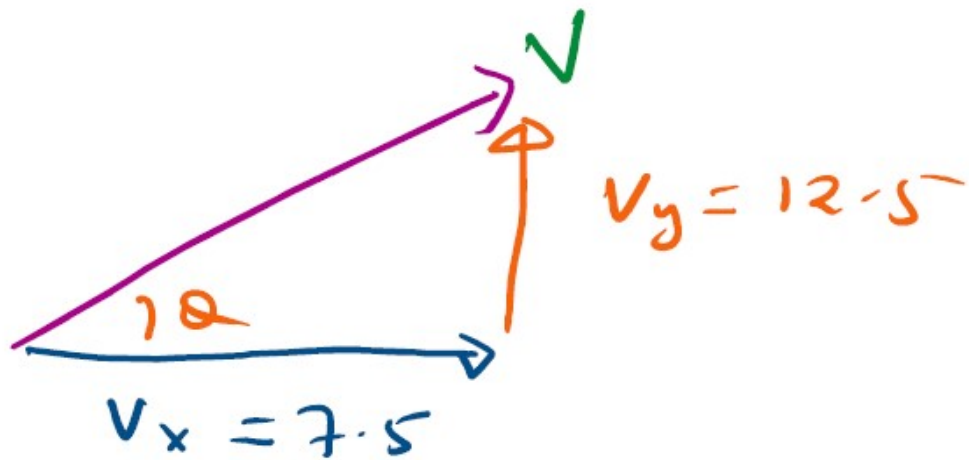
$$\sum P_{iy} = \sum P_{fy}$$

$$m_c u_{cy} + m_v u_{vy} = (m_c + m_v) v_y$$

$$0 + 2500(20) = 4000 v_y$$

$$v_y = 12.5 \text{ m/s}$$





$$\begin{aligned} V &= \sqrt{V_x^2 + V_y^2} &= \sqrt{7.5^2 + 12.5^2} \\ &= 15.6 \text{ m/s} \end{aligned}$$

$$\tan \theta = \frac{V_y}{V_x} = \frac{12.5}{7.5} ; \theta = 53.1^\circ$$

We are now able to predict  
that the wreckage will  
drift at an angle of  $53.1^\circ$   
at  $15.6 \text{ m/s}$ .

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## Court case — Investigation

Your friend was driving her 1265-kg car north at UNZA main entrance when she was hit by a 925-kg compact car going west on along Great East Road. The cars stuck together and slid 23.1 m at  $42^\circ$  north of west. The speed limit on both streets is 22 m/s (50 mph). Assume that momentum was conserved during the collision and that acceleration was constant during the skid. The coefficient of kinetic friction between the tires and the pavement is 0.65.

1. Your friend claims that she wasn't speeding, but that the driver of other car was. How fast was your friend driving before the crash?
2. How fast was the other car moving before the crash? Can you support your friend's case in court?

