ATOMIC ENERGY CENTRAL SCHOOL,ANUPURAM

CH-6 Work Power and Energy(module5/6)

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Elastic Collision

Introduction:

A collision occurs when two objects come in direct contact with each other. It is the event in which two or more bodies exert forces on each other in about a relatively short time. There are two types of collisions namely :

Elastic Collision

An elastic collision is one where there is no net loss in kinetic energy in the system as the result of the collision.

Inelastic Collision

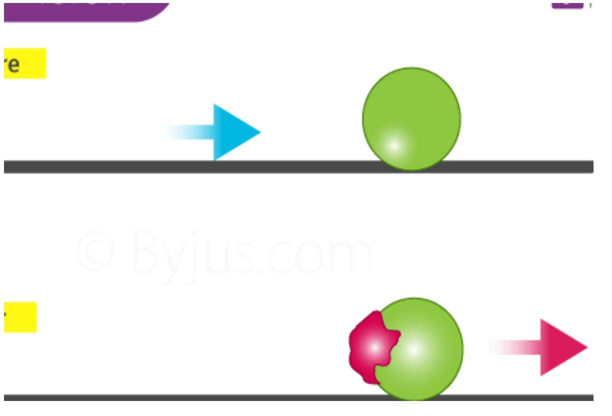
An inelastic collision is a type of collision where this is a loss of kinetic energy. The lost kinetic energy is transformed into thermal energy, sound energy, and material deformation.

- What is an Elastic Collision?
- When two bodies collide but there is no loss in the overall kinetic energy, it is called a **perfectly elastic collision**. It can be defined as:
- An elastic collision is an encounter between two bodies in which the total kinetic energy of the two bodies remains the same.
- Basically, in the case of collision, the kinetic energy before the collision and after the collision remains the same and is not converted to any other form of energy.
- *It can be either one-dimensional or two-dimensional. In the real world, perfectly elastic collision is not possible because there is bound to be some conversion of energy, however small.*
- However, though there is no change in the linear momentum of the whole system, there is a change in the individual momenta of the involved components, which are equal and opposite in magnitude and cancel each other out and the initial energy is conserved.

- **The collision of billiard balls is nearly elastic because the kinetic energy is conserved before and after the collision**
- Examples of Elastic Collision
- When a ball at a billiard table hits another ball, it is an example of elastic collision.
- When you throw a ball on the ground and it bounces back to your hand, there is no net change in the kinetic energy and hence, it is an elastic collision.

Inelastic Collision

- In physics, an inelastic collision occurs, when the maximum amount of kinetic energy of a colliding objects/system is lost. The colliding particles stick together in a perfectly inelastic collision. In such cases, kinetic energy lost is used in bonding the two bodies together. Problems involving collisions are usually solved using the conservation of momentum and energy.



- *The above schematic diagram illustrate a perfectly inelastic collision.*What is a collision? A collision is an event in which two or more objects exert forces on each other for a short interval of time. It is categorised into two types:
- Inelastic collision
- Elastic collision
- inelastic Collision Definition
- An inelastic collision is such a type of collision that takes place between two objects in which some energy is lost. In the case of inelastic collision, **momentum is conserved but the kinetic energy is not conserved**. Most of the collisions in daily life are inelastic in nature.Example:A dropped ball of clay doesn't rebound
- Perfectly Inelastic Collision
- The special case of inelastic collision is known as a perfectly inelastic collision. Here, after collision two objects stick together. Example: when wet mudball is thrown against a wall mudball stick to the wall.

- **Inelastic Collision Examples**
- Most of the collision we see in our day to day life falls under inelastic collision. Some of them are listed below.
- **Real World Examples Of Inelastic Collision**
- The ball is dropped from a certain height and it is unable to rise to its original height.
- When soft mudball is thrown against the wall, will stick to the wall.
- The accident of two vehicles
- A car hitting a tree.

Coefficient of Restitution or Coefficient of Resilience

Coefficient of restitution is defined as the ratio of relative velocity of separation after collision to the relative velocity of approach before collision.

It is represented by 'e'.

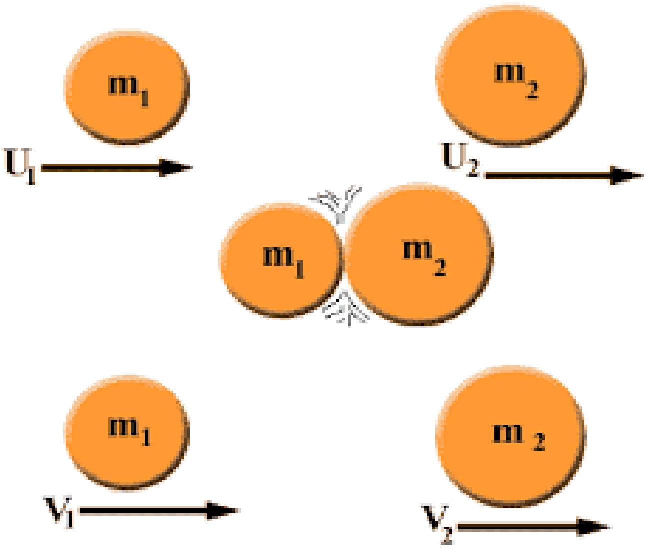
$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

Elastic Collision in one dimension

- Consider two particles whose masses are m_1 and m_2 respectively and they collide each other with velocity $\mathbf{u}_1$ and $\mathbf{u}_2$ and after collision their velocities become $\mathbf{v}_1$ and $\mathbf{v}_2$ respectively.

- Collision between these two particles is head on elastic collision. From law of conservation of momentum we have
  $m_1\mathbf{u}_1 + m_2\mathbf{u}_2 = m_1\mathbf{v}_1 + m_2\mathbf{v}_2$ (1)
  and from law of conservation of kinetic energy for elastic collision we have
  $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$ (2)

- rearranging equation 1 and 2 we get
  $m_1(\mathbf{u}_1-\mathbf{v}_1)= m_2(\mathbf{v}_2-\mathbf{u}_2)$ (3)
  and
  $m_1(\mathbf{u}_1^2 -\mathbf{v}_1^2)= m_2(\mathbf{v}_2^2-\mathbf{u}_2^2)$ (4)
  dividing equation 4 by 3 we get
  $\mathbf{u}_1 + \mathbf{v}_1 = \mathbf{u}_2 + \mathbf{v}_2$
  $\mathbf{u}_2 - \mathbf{u}_1 = -(\mathbf{v}_2 - \mathbf{v}_1)$ (5)



- where $(\mathbf{u}_2 - \mathbf{u}_1)$ is the Relative Velocity of second particle w.r.t. first particle before collision and $(\mathbf{v}_2 - \mathbf{v}_1)$ is the relative velocity of second particle w.r.t. first after collision.

- From equation 5 we come to know that in a perfectly elastic collision the magnitude of relative velocity remain unchanged but its direction is reversed. With the help of above equations we can find the values of $\mathbf{v}_2$ and $\mathbf{v}_1$, so from equation 5

  $$\mathbf{v}_1 = \mathbf{v}_2 - \mathbf{u}_1 + \mathbf{u}_2 \qquad (6)$$

  $$\mathbf{v}_2 = \mathbf{v}_1 + \mathbf{u}_1 - \mathbf{u}_2 \qquad (7)$$

  Now putting the value of $\mathbf{v}_1$ from equation 6 in equation 3 we get

  $$m_1(\mathbf{u}_1 - \mathbf{v}_2 + \mathbf{u}_1 - \mathbf{u}_2) = m_2(\mathbf{v}_2 - \mathbf{u}_2)$$

  On solving the above equation we get value of $\mathbf{v}_2$ as

$$\mathbf{v}_2 = \left(\frac{2m_1}{m_1 + m_2}\right)\mathbf{u}_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)\mathbf{u}_2 \qquad (8)$$

Similarly putting the value of $\mathbf{v}_2$ from equation 7 in equation 3 we get

$$\mathbf{v}_1 = \left(\frac{2m_2}{m_1 + m_2}\right)\mathbf{u}_2 + \left(\frac{m_1 - m_2}{m_1 + m_2}\right)\mathbf{u}_1 \qquad (9)$$

Total kinetic energy of particles before collision is

$$KE_i = \frac{1}{2} m_1 \mathbf{u}_1^2 + \frac{1}{2} m_2 \mathbf{u}_2^2$$

and total K.E. of particles after collision is

$$KE_f = \frac{1}{2} m_1 \mathbf{v}_1^2 + \frac{1}{2} m_2 \mathbf{v}_2^2$$

Ratio of initial and final K.E. is

$$\frac{KE_i}{KE_f} = \frac{\frac{1}{2} m_1 \mathbf{u}_1^2 + \frac{1}{2} m_2 \mathbf{u}_2^2}{\frac{1}{2} m_1 \mathbf{v}_1^2 + \frac{1}{2} m_2 \mathbf{v}_2^2} = 1$$

Special cases

- **Case I:** When the mass of both the particles are equal i.e., $m_1 = m_2$ then from equation 8 and 9 , $\mathbf{v}_2 = \mathbf{u}_1$ and $\mathbf{v}_1 = \mathbf{u}_2$. Thus if two bodies of equal masses suffer head on elastic collision then the particles will exchange their velocities. Exchange of momentum between two particles suffering head on elastic collision is maximum when mass of both the particles is same.
- **Case II:** when the target particle is at rest i,e $u_2=0$
  From equation (8) and (9)
- $$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right) u_1 \qquad \text{---(10)}$$

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 \qquad \text{---(11)}$$

Hence some part of the KE which is transformed into second particle would be

$$\frac{\frac{1}{2}m_2 v_2^2}{\frac{1}{2}m_1 u_1^2} = \frac{\frac{1}{2}m_2\left(\frac{2m_1u_1}{m_1+m_2}\right)^2}{\frac{1}{2}m_1 u_1^2}$$

$$= \frac{4\mathrm{m}_1\mathrm{m}_2}{(\mathrm{m}_1+\mathrm{m}_2)^2} = \frac{4\frac{\mathrm{m}_2}{\mathrm{m}_1}}{(1+\frac{\mathrm{m}_2}{\mathrm{m}_1})^2} \qquad \text{--(12)}$$

- when $m_1=m_2$,then in this condition $v_0=0$ and $v_2=u_1$ and part of the KE transferred would be
  =1Therefore after collisom first particle moving with initial velocity u_1 would come to rest and the second particle which was at rest would start moving with the velocity of first particle.Hence in this case when $m_1=m_2$ transfer of energy is 100%.if $m_1 > m_2$ or $m_1 < m_2$,then energy transformation is not 100%
- **Case III:**
  if $m_2 >>>> m_1$ and $u_2=0$ then from equation (10) and (11)
  $v_1 \cong -u_1$ and $v_2=0$ (13)
  For example when a ball thrown upwards collide with earth
- **Case IV:**
  if $m_1 >>>> m_2$ and $u_2=0$ then from equation (10) and (11)
  $v_1 \cong u_1$ and $v_2=2u_1$ (14)
- Therefore when a heavy particle collide with a very light particle at rest ,then the heavy particle keeps on moving with the same velocity and the light particle come in motion with a velocity double that of heavy particle