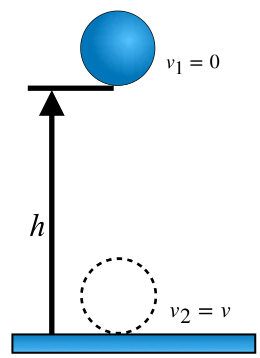
Calculate Impact force for on an object dropped on different surface

Introduction

If an object of mass "m" is moving with velocity "v" then the product mass × velocity is known as momentum (p). When this object of mass "m" is dropped from a height "h" it gains in velocity "v". As soon as this object hits the ground the object is stopped, meaning its velocity instantly becomes zero (for simplicity lets not consider the rebound). This change in momentum will cause an impact force known as Impulse "J". If "F" is the impact force then Impulse "J" is given by,



$$J = F\Delta t \qquad (1)$$

where Δt is the duration time of impact.

Hence to reduce the force on impact we need to increase the duration time of impact. Thus, by putting a cushion material in packaging we will be increasing the duration time to impact and lower the impact force just in case if a package is dropped.

Theory

From Newton's second law of motion, the net force "F" acting on a body of mass "m" is given by

$$F = ma \qquad (2)$$

where a is an acceleration. Also acceleration is defined as change in velocity, $(v_2 - v_1)$, over time interval, $(t_2 - t_1)$. Hence equation (1) can be rewritten as,

$$F = m\frac{v_2 - v_1}{t_2 - t_1}$$

$$m(v_2 - v_1) = F\Delta t \qquad (3)$$

where $\Delta t = (t_2 - t_1)$. v_1 is the initial velocity and v_2 is the final velocity.

$$mv_2 - mv_1 = F\Delta t \qquad (4)$$

where $mv = p$ is known as the momentum of an object.

$$p_2 - p_1 = F\Delta t \qquad (5)$$

This change in momentum is known as the impulse acting on an object.

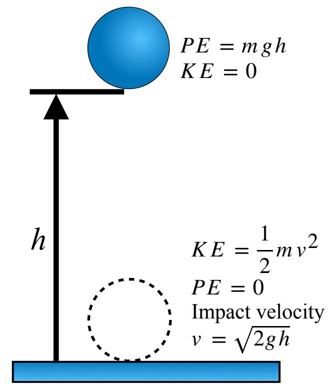
Therefore, the impulse on an object is also a measure of force and duration of force acting on it. For same impulse (change in momentum), the force "F" acting on an object could be small if the duration of impact "Δt" is large and vice versa.

$$J = F\Delta t \qquad (6)$$

where $J = m\Delta v$ is known as impulse.

F is the impact force, this force is responsible for damage during a collision

- **Calculate Impact force**



When an object of mass "m" is resting at height "h", it has a potential energy,

$$PE = mgh$$

Since the object is at rest if has no kinetic energy since velocity $v = 0$,

$$KE = \frac{1}{2}mv^2 = 0$$

The total energy of this mass system is,
Total Energy = Potential Energy + Kinetic Energy

$$E = PE + KE$$

At height "h", the total energy of the system is,

$$E = mgh + 0$$

$$E = mgh \tag{7}$$

When is mass is released and hit the ground, $h = 0$, with final velocity "v" just before impact,

$$PE = 0$$

and kinetic energy,

$$KE = \frac{1}{2}mv^2$$

Total energy,

$$E = 0 + \frac{1}{2}mv^2$$

$$E = \frac{1}{2}mv^2 \tag{8}$$

Equation (7) and (8) are both total energy, hence,

$$\frac{1}{2}mv^2 = mgh$$

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

Multiply both sides by 2, we get,

$$2 \times \frac{1}{2}v^2 = 2 \times gh$$

$$\cancel{2} \times \frac{1}{\cancel{2}}v^2 = 2gh$$

$$v^2 = 2gh$$

$$v = \sqrt{2gh} \tag{9}$$

For an object dropped for height "h",

$$F\Delta t = mv_{final} - mv_{initial}$$

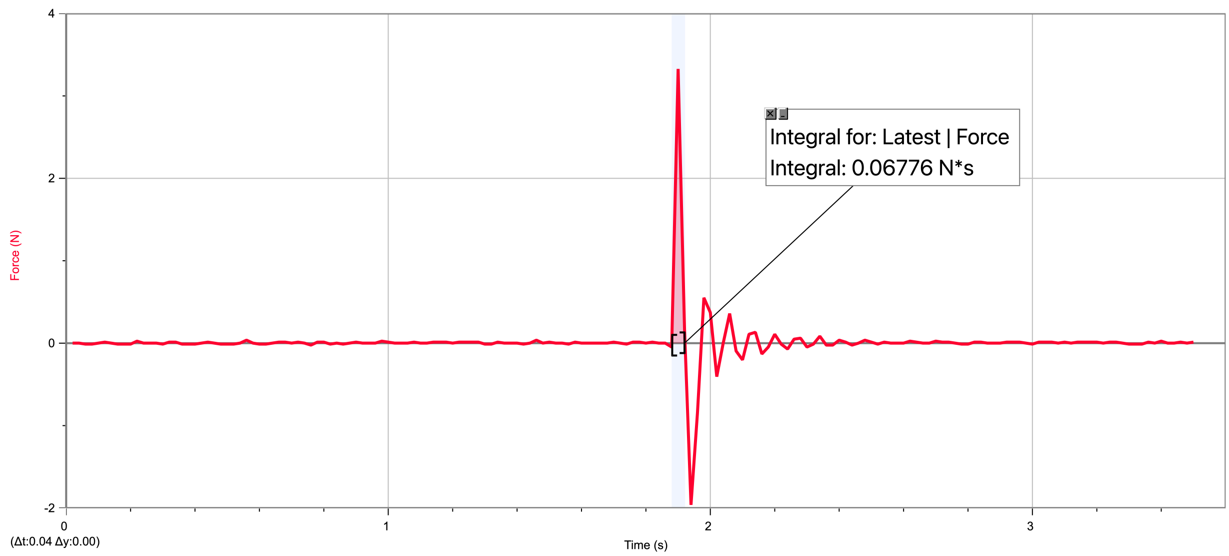
since $v_{initial} = 0$

$$F\Delta t = mv_{final}$$

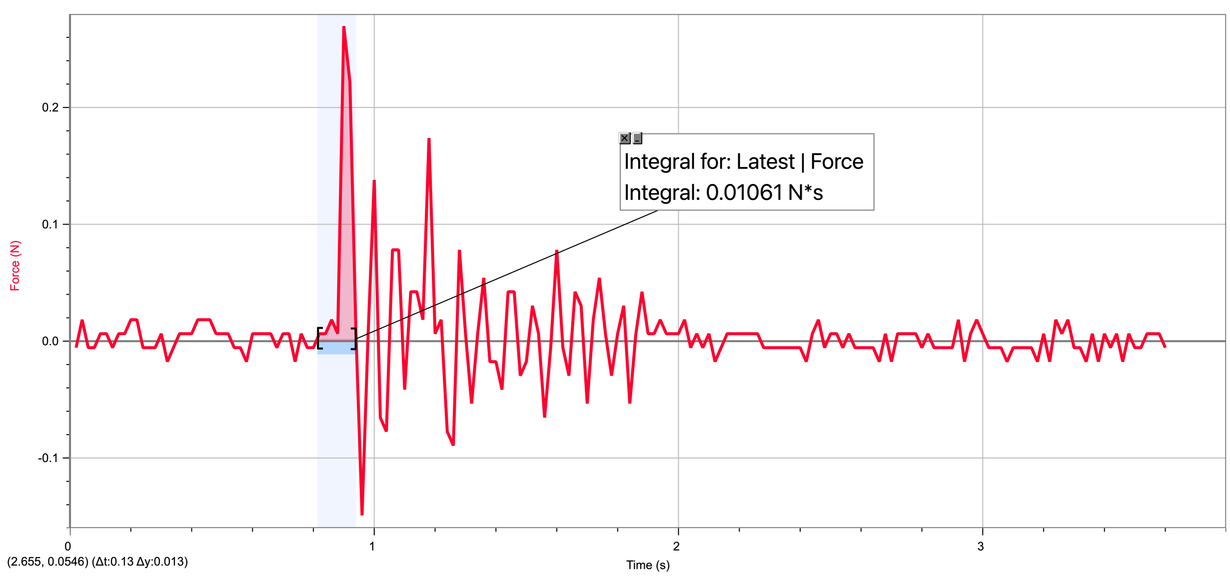
$$F\Delta t = m \times \sqrt{2gh} \tag{10}$$

Right hand side of the equation is constant, so product $F \times \Delta t$ is a constant. If somehow we increase time of impact "Δt", force F will be lowered.
This time of impact Δt can be increased by adding cushion layer on surface and hence impact force can be lowered and have less injury or damage.

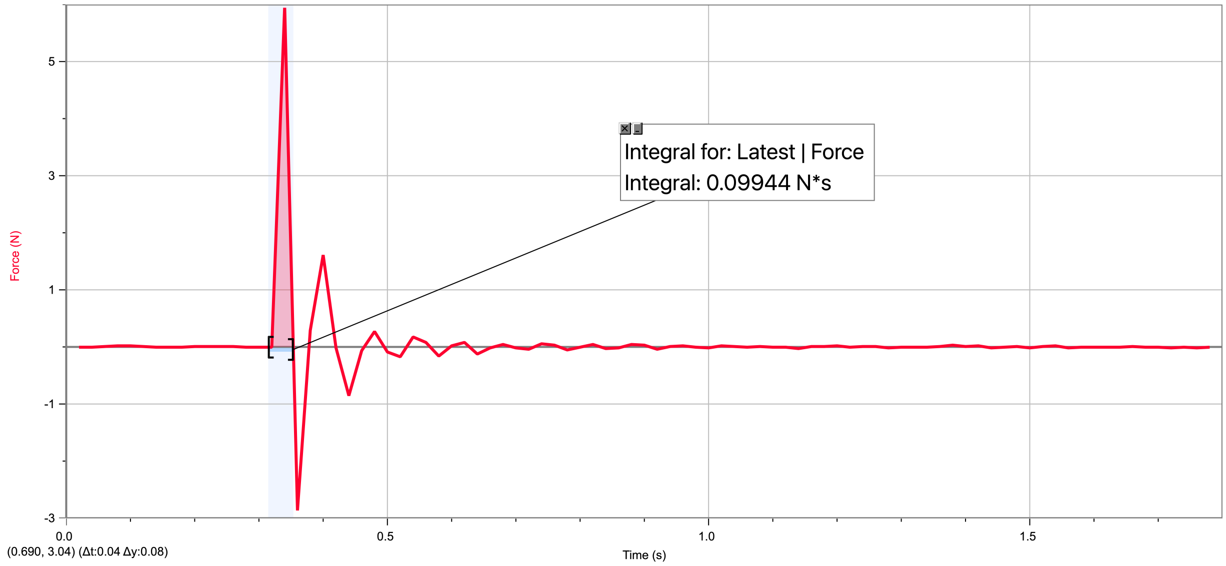
Following is the an example of dropping spoon from certain height on hard surface.



dropping spoon from same height with air ziplock bag.



Following is the an example of dropping spoon from certain height on hard surface.



dropping spoon from same height with air ziplock bag.