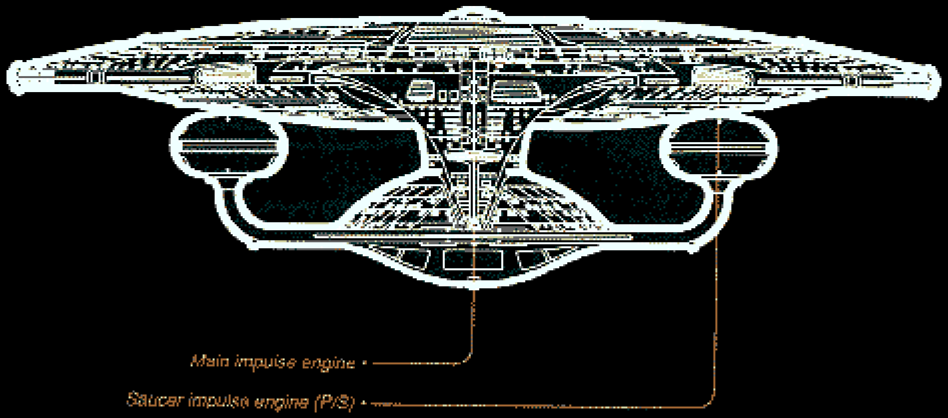
Impulse – A Change in Momentum



Lesson 2

POS Checklist:

☐ define change in momentum as impulse ($mt = Ft$) and relate impulse to acceleration and Newton's second law of motion ($p/t = ma$), and apply the concept of impulse to explain the functioning of a variety of safety devices.

Review

$$\vec{F} = \frac{\Delta \vec{p}}{\Delta t}$$

- **Recall that Newton wrote his Second Law in terms of momentum. This could be arranged as:**

$$\Delta \vec{p} = \vec{F} \Delta t$$

From this, we can see that the product of force and time is momentum. Let's apply this to a real-life situation.

Assume we have an egg with mass m and initial velocity $\vec{v}_i$, dropped onto two different floors: one concrete floor and one with padding on it.

- **The $\vec{p}_i$ in each trial is the same as the mass and velocity of each egg is equal.**

- **The $\vec{p}_f$ are both 0 as the egg comes to a stop.**

- **This means the change in momentum is the same in each trial.**

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

Now, just because the momentums are the same does not mean the force and time are the same:

eg) $\Delta p = F\Delta t$

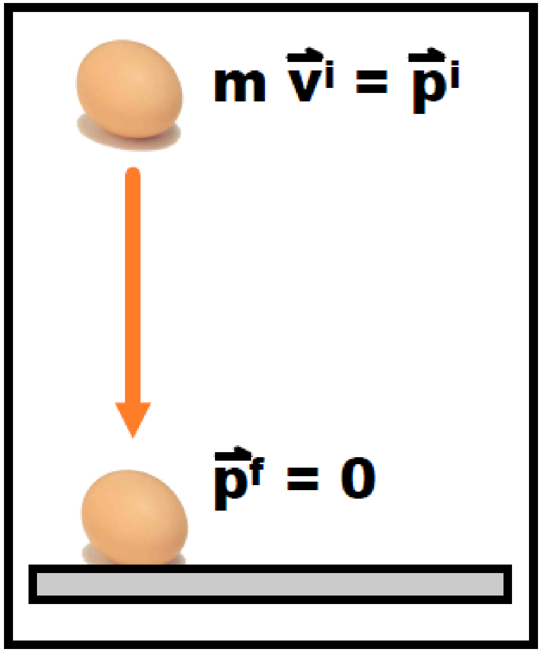
$12\ \text{Ns} = (1\ \text{N})(12\ \text{s})$

$12\ \text{Ns} = (2\ \text{N})(6\ \text{s})$

$12\ \text{Ns} = (3\ \text{N})(4\ \text{s})$

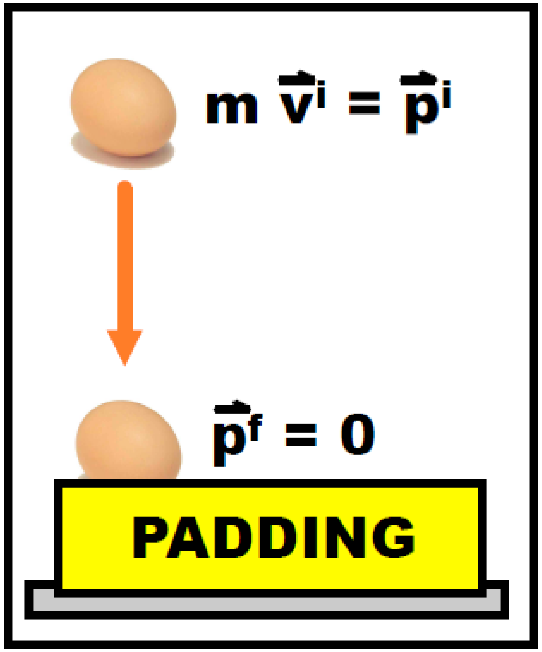
$12\ \text{Ns} = (4\ \text{N})(3\ \text{s})$ ...etc...

*Force and time can vary, but as one goes up, the other goes down if momentum must be the same.



In the first trial, the time the egg takes to stop is very fast. It hits the concrete and stops immediately. This means we have a small time and a large force to make up the momentum.

$$\Delta p = \underset{\text{large force}}{\vec{F}}\ \underset{\text{small time}}{\Delta t}$$



In the second trial, the egg stops over a longer period of time. This allows the same momentum change, but with a smaller force acting.

$$\Delta p = \vec{F}\Delta t$$

small force

large time

In each of these trials, the change in momentum is the same. We call the change in momentum of an object the impulse.

$$\vec{F}\Delta t = m\Delta\vec{v}$$

Impulse is defined as the product of a force and the time interval that force acts over. It is the change in momentum an object experiences.

Impulse is a vector quantity.

Impulse does not receive a symbol (other than $\Delta\vec{p}$), but it does receive the units of Ns or kgm/s

ex) A force of 14.0 N acts on a 6.00 kg __________ for 1.00 ms. What is the change in velocity of this object?

ex) A 5.00 kg _________ accelerates uniformly from rest to a velocity of 15.0 m/s East. What is the impulse on the object?

ex) A 1.0 kg ball hits the floor with a velocity of 2.0 m/s. If this ball bounces up with a velocity of 1.6 m/s, what is the ball's impulse?

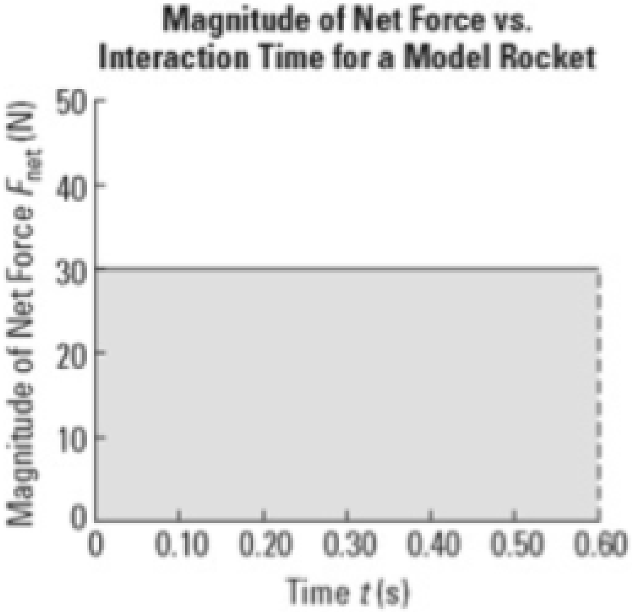
Applications of Impulse

There are a number of applications of impulse in everyday life. Be familiar with these for your diploma!

- car crashes: old rigid cars vs. new crumpling cars
- bullets fired from guns with long barrels vs short barrels
- "following through" on a throw, shot, swing
- "rolling with a punch" in boxing
- safety equipment in cars like air bags, new dashboards, steering columns
- helmets
- breaking a board with your fist!
- etc...

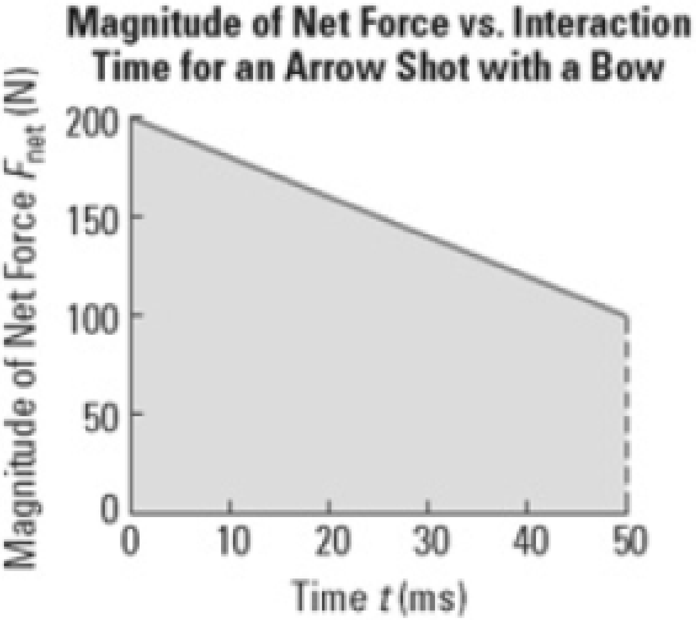
Graphs of F vs t

- Another way of calculating impulse is from a force vs time graph.
- The area under a graph of F vs t will give impulse:



▲ **Figure 9.16** Magnitude of net force as a function of interaction time for a model rocket. The area under the graph is equal to the magnitude of the impulse provided to the rocket.

- **This is a particularly good method to use when the force is not constant.**



◀ **Figure 9.17** Magnitude of net force as a function of interaction time for an arrow shot with a bow.

Example

- a) From the graph, what is the magnitude of the impulse on the 48 g tennis ball?
- b) What is the velocity of the ball when it leaves the racquet?