IMPULSE

- When an object accelerates, its velocity changes and therefore its momentum changes. A **change in momentum** is also called **impulse**

$$\text{impulse} = \overset{\swarrow \text{means "change in"}}{\Delta p} = p_f - p_i$$

- When a net force acts on an object for a period of time, the object accelerates/decelerates according to Newton's 2nd Law. This means the momentum of the object also changes (ie. the object experiences an impulse)

  * $F_{net} = ma$ Newton's 2nd Law

  but acceleration can also be defined as $a = \frac{\Delta v}{t}$

  substitute the acceleration equation into Newton's 2nd law to get $F = \frac{m\Delta v}{t}$

  therefore another equation to use for impulse is

  on data sheet $\boxed{Ft = m\Delta v}$ $\rightsquigarrow$ $\therefore \Delta p = Ft$ or $\Delta p = m\Delta v$

  where F is force (N)
  t is time (s)
  m is mass (kg)
  Δv is ***change*** in velocity (m/s) $\Delta v = v_f - v_i$

* - Impulse has the same units as momentum (kg·m/s or N·s) and is a vector quantity
  - If an object is accelerating, the impulse will be in the same direction as the initial velocity
  - If an object is decelerating, the impulse will be in the opposite direction of the initial velocity

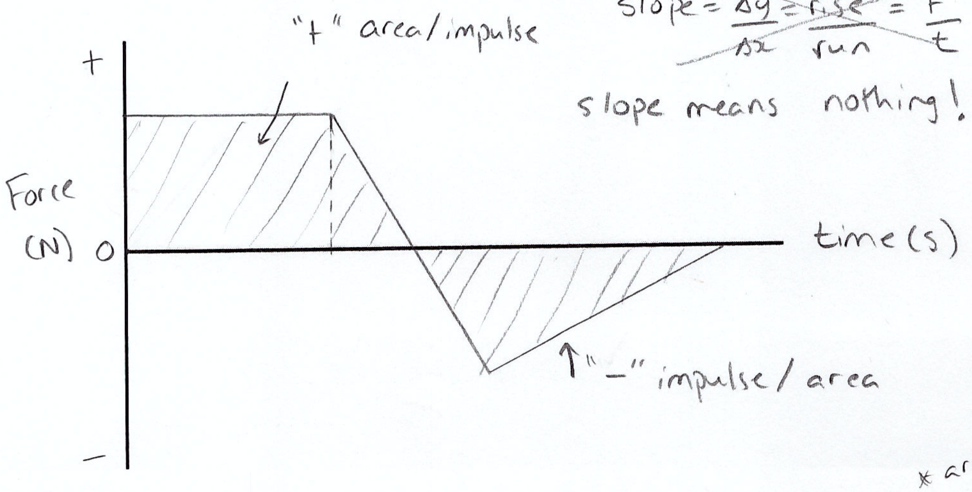
- Impulse may be determined from a graph of net force and time

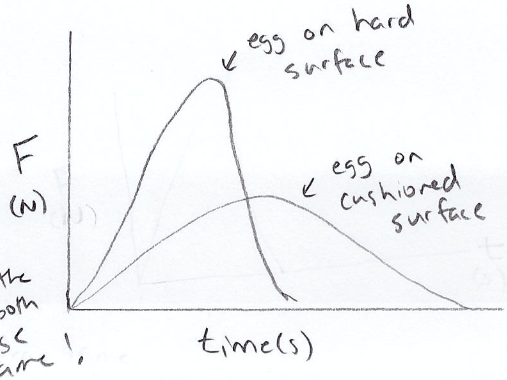
$\cancel{\text{slope} = \frac{\Delta y}{\Delta x} = \frac{\text{rise}}{\text{run}} = \frac{F}{t}}$

slope means nothing!

area = lw or $\frac{bh}{2} = Ft$

area = impulse!



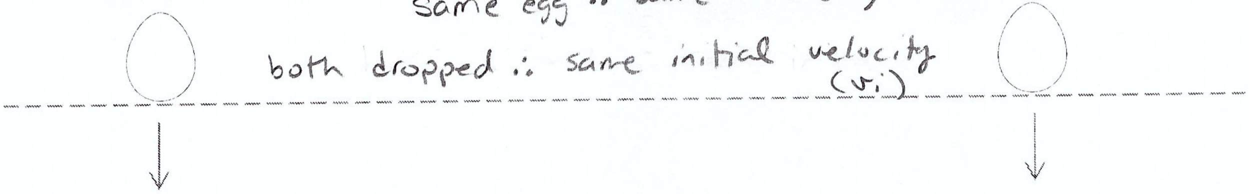


* area is the same for both b/c impulse ∴ the same!

- Consider the physics principles that explain why when identical eggs dropped from the same heights, one egg will break when it hits a hard surface and the other egg will remain un-cracked when it hits a foam surface

HARD SURFACE **FOAM SURFACE**

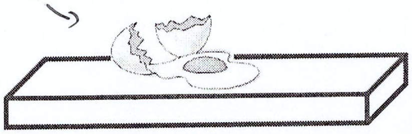
same egg ∴ same mass (m)



both dropped ∴ same initial velocity (v_i)

same height ∴ same final velocity (v_f)

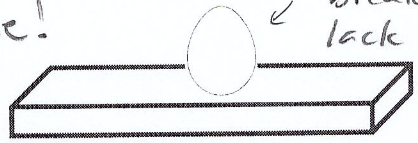
egg breaks b/c of force



∴ each egg experiences the same impulse!

($\Delta p = m\Delta v$)

egg doesn't break b/c a lack of force



$$\underbrace{m\Delta v}_{\text{equal for both eggs}} = F\,{\scriptstyle\Delta t}$$

← egg comes to a stop very quickly

large force experienced by egg ∴ it breaks

$$\underbrace{m\Delta v}_{\text{equal for both eggs}} = {\scriptstyle F}\,\Delta t$$

← egg comes to a stop more slowly (more gradually)

less force experienced by egg ∴ it doesn't break

$$m\Delta v = F\Delta t$$

$$\therefore \frac{1}{\Delta t} \propto F$$

force & time period are inversely related

  - This is the same theory used in the development of air bags in vehicles to reduce the extend of human injury

EXAMPLES

1. A satellite has a mass of 172 kg and is initially traveling at $2.35\text{x}10^3$m/s. To correct its orbit, a thruster is fired for 2.27s, which changes the speed of the satellite to $2.89\text{x}10^3$ m/s. Calculate the magnitude of the force generated by the thrusters.

$m = 172\text{ kg}$

$v_i = 2.35\times10^3\text{ m/s}$

$t = 2.27\text{ s}$

$v_f = 2.89\times10^3\text{ m/s}$

$F = ?$

$$Ft = m\Delta v$$

$$F = \frac{m(v_f - v_i)}{t}$$

$$F = \frac{(172\text{ kg})(2.89\times10^3\text{ m/s} - 2.35\times10^3\text{ m/s})}{2.27\text{ s}}$$

$$F = 40916.299\ldots\text{ N}$$

$$\boxed{F = 4.09\times10^4\text{ N}}$$

2. A 1.00 kg ball hits the floor with a velocity of 2.00 m/s. If the ball bounces upward off the floor with a velocity of 1.6 m/s, what is the ball's change in momentum?

↳ impulse $= \Delta p$

$m = 1.00\text{ kg}$

$v_i = -2.00\text{ m/s}$

$v_f = +1.6\text{ m/s}$

$\Delta p = ?$

$$\Delta p = m\Delta v$$

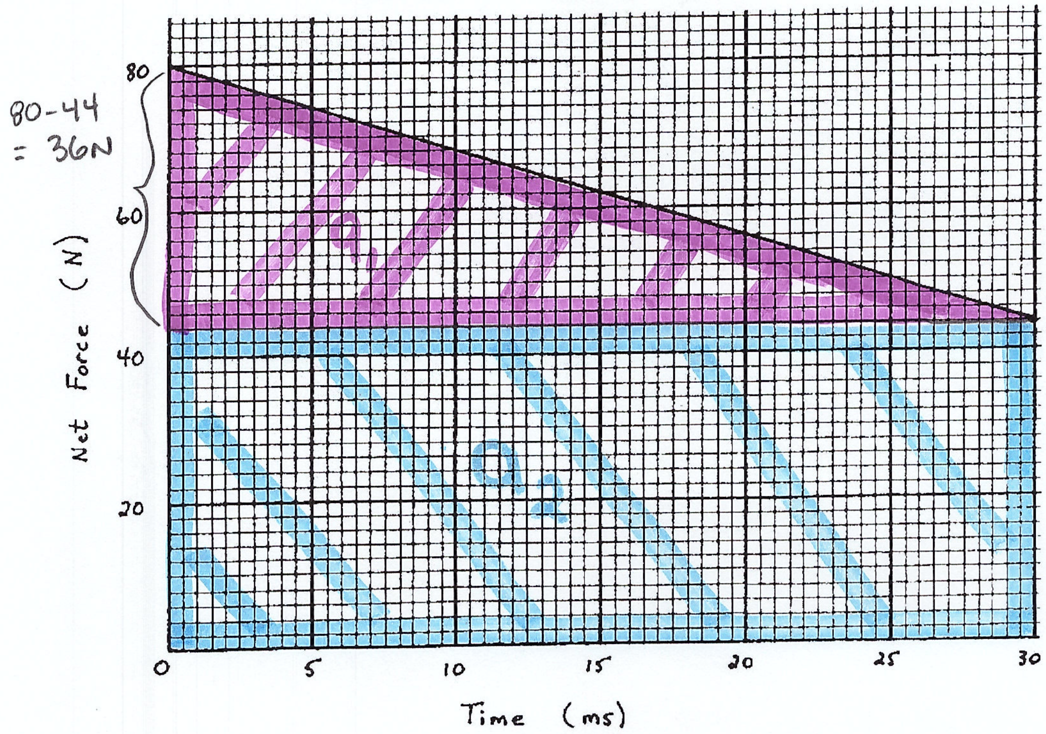
$$\Delta p = m(v_f - v_i)$$

$$\Delta p = (1.00\text{ kg})(1.6\text{ m/s} - [-2.00\text{ m/s}])$$

$$\Delta p = +3.6\text{ kg}\cdot\text{m/s}$$

$$\boxed{\Delta p = 3.6\text{ kg}\cdot\text{m/s, up}}$$

3. Calculate the magnitude of the impulse provided to an arrow shot from a bow given the following graph.


Magnitude of Net Force vs Interaction Time for an Arrow Shot with a Bow

watch units!

$1 ms = 10^{-3} s$

$30 \cancel{ms} \times \left(\frac{10^{-3} s}{1 \cancel{ms}} \right)$

$= 3.0 \times 10^{-2} s$

area = Ft = impulse!

area = $a_1 + a_2$

area = $\frac{lw}{2} + lw$

area = $\frac{(36N)(3.0 \times 10^{-2} s)}{2} + (44N)(3.0 \times 10^{-2} s)$

area = 1.9 N·s

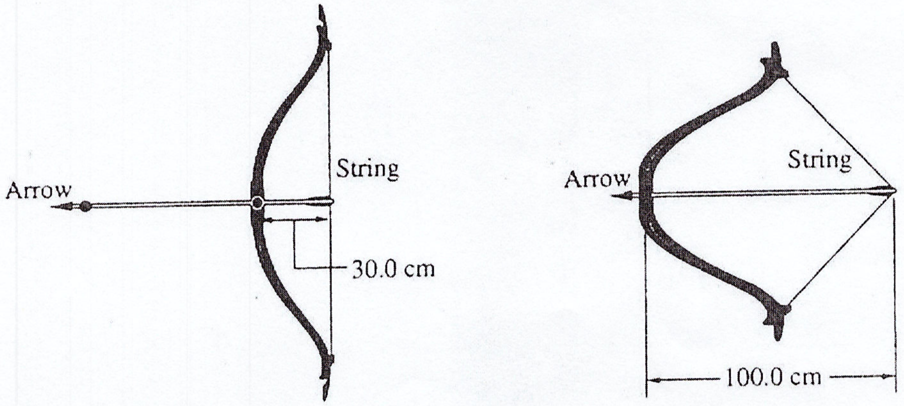
$\boxed{\Delta p = \text{impulse} = 1.9 N \cdot s}$

*****Now try pg. 44 #2, 3, 6, 8, 11, 14 (acceptable), 4, 9, 10, 13, 15 (intermediate), 16 (excellence)*****

Impulse Review Question

Use the following information to answer the next question.

A "full draw" is the maximum distance that an archer can pull back an arrow. Using the "recurve bow" shown below, a particular archer requires an average force of 130N to pull a full draw of 70.0cm.



1. Calculate the maximum speed reached by a 20.6g arrow after leaving this bow from a full draw.

Principles Used

1 - accelerated motion

m = 0.0206 kg

F_{net} = 130N

d = 0.70m

v_i = 0.0m/s

v_f = ?

$$v_f^2 = \overset{0}{\cancel{v_i}}^2 + 2ad \quad ②$$

↓

$$F_{net} = ma \quad ①$$

① $a = \frac{F_{net}}{m} = \frac{130N}{0.0206kg} = 6310.67... m/s^2$

② $v_f = \sqrt{2ad} = \sqrt{2(6310.67... m/s^2)(0.70m)}$

$v_f = 93.99... m/s$

$\boxed{v_f = 94.0 \ m/s}$

2. When the archer releases the arrow from a full draw, calculate the impulse that the arrow received from the bow.

$\Delta p = m\Delta v = m(v_f - \overset{0}{\cancel{v_i}})$

$\Delta p = (0.0206kg)(93.99... m/s - 0.0m/s)$

$\boxed{\Delta p = 1.94 \ kg \cdot m/s, \text{ left}}$