Impulse

Level 3 Physics

January 2013

Recall from Last Time

Momentum

$$p = m * v$$

Note that p is the symbol for momentum.

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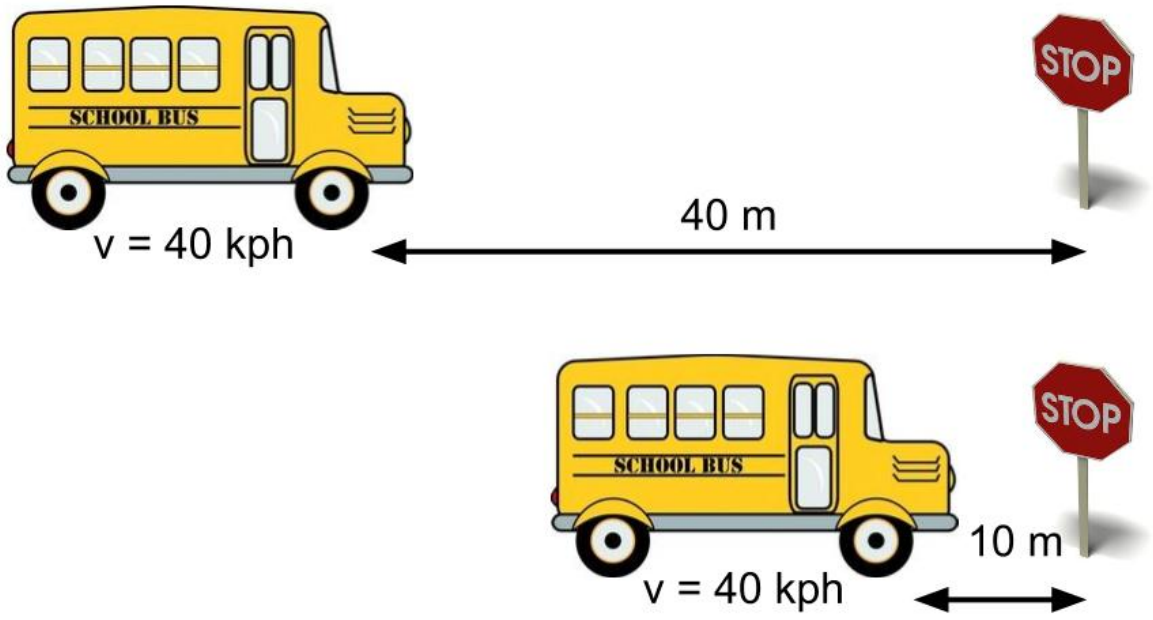
Conservation of Momentum

The net momentum of a system remains constant when there is no net force on the system.

Relating Momentum and Force

Consider these two situations of a school bus making a stop.



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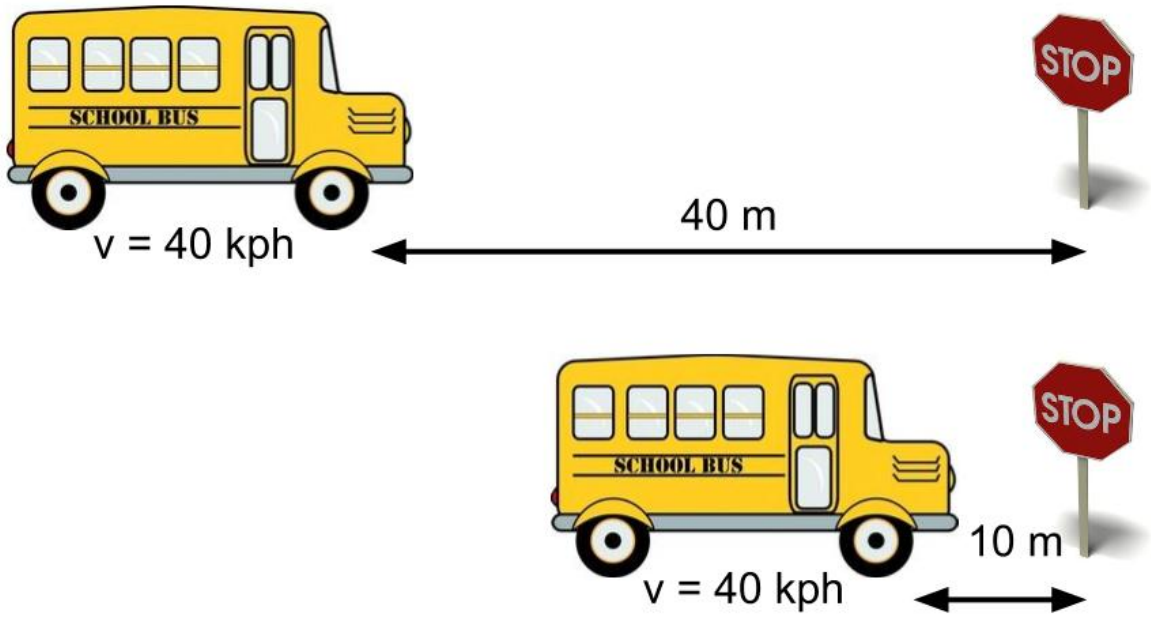


It appears that given constant change in momentum, force and time are inversely related.

Relating Momentum and Force

Make the assumption that mass and acceleration (and therefore force) are constant.

$$F = m * a$$

$$F = m * \frac{\Delta v}{\Delta t}$$

$$F = \frac{\Delta (m * v)}{\Delta t}$$

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

$$\Rightarrow \Delta p = F * \Delta t$$

Impulse

Definition

Impulse is the change in momentum. It is given by the formula

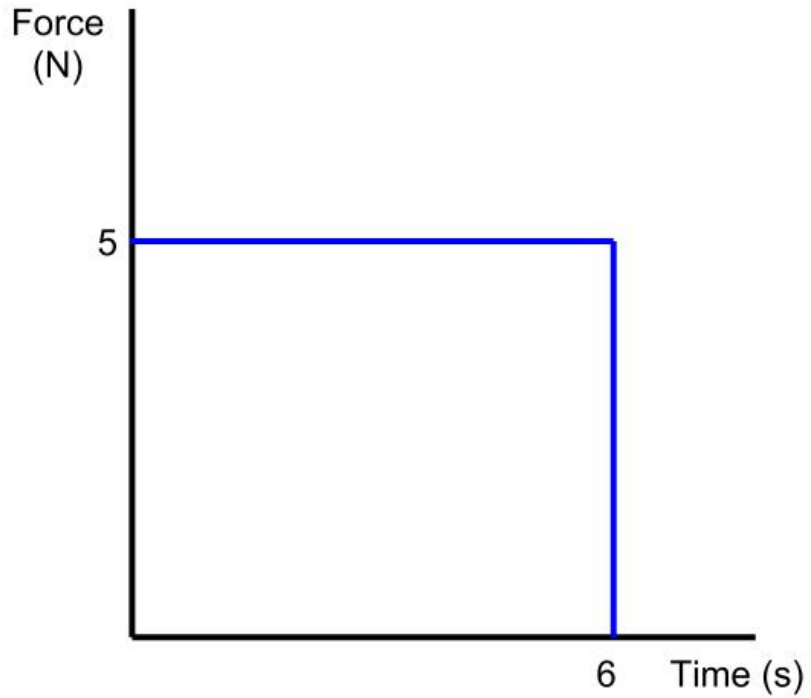
$$J = F * \Delta t = p_f - p_i$$

where force is constant.

Note that J is the symbol for impulse.

Reading Graphs

What is the impulse of a system undergoing change described by this graph?



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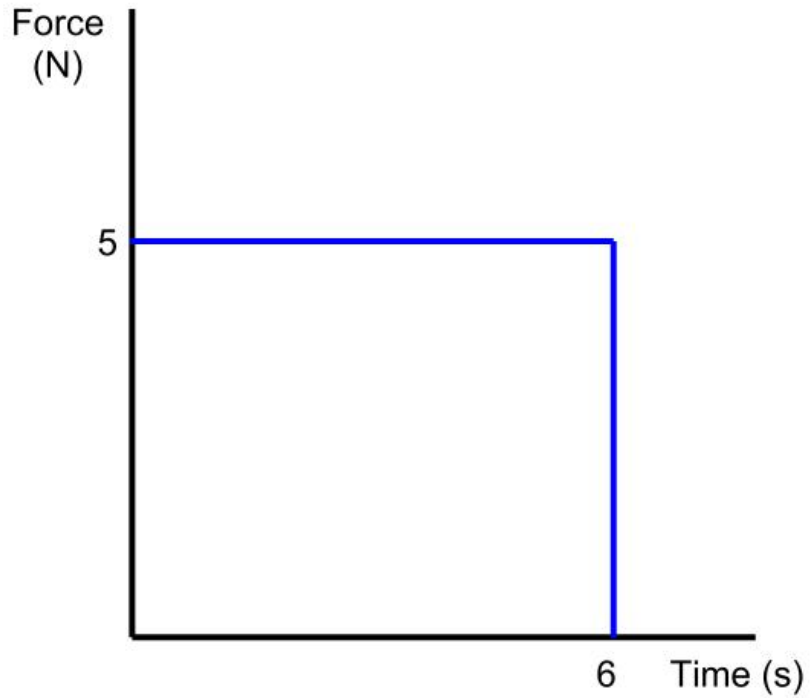

$$J = F * \Delta t$$
$$= 5 * 6$$
$$= 30N * s$$

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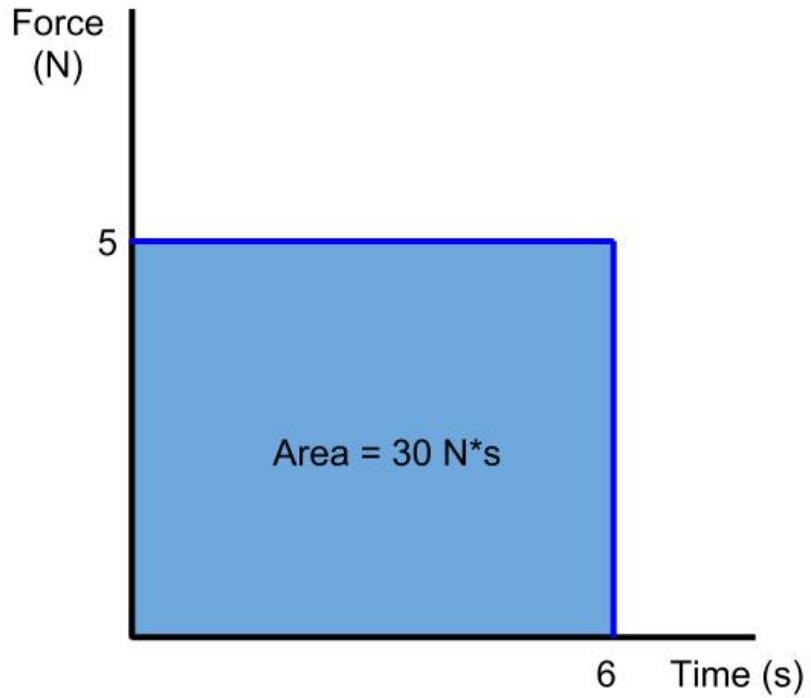

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More Complicated Graph

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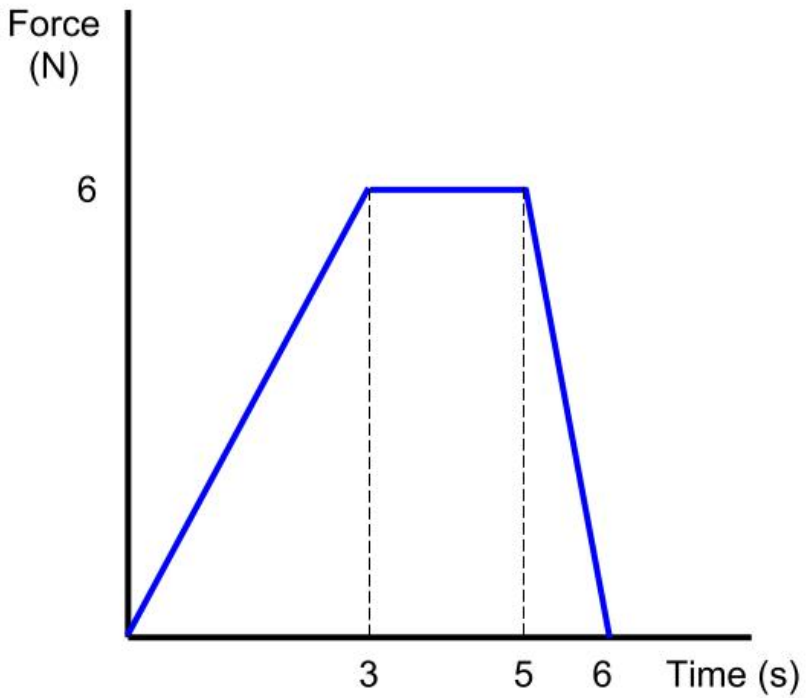

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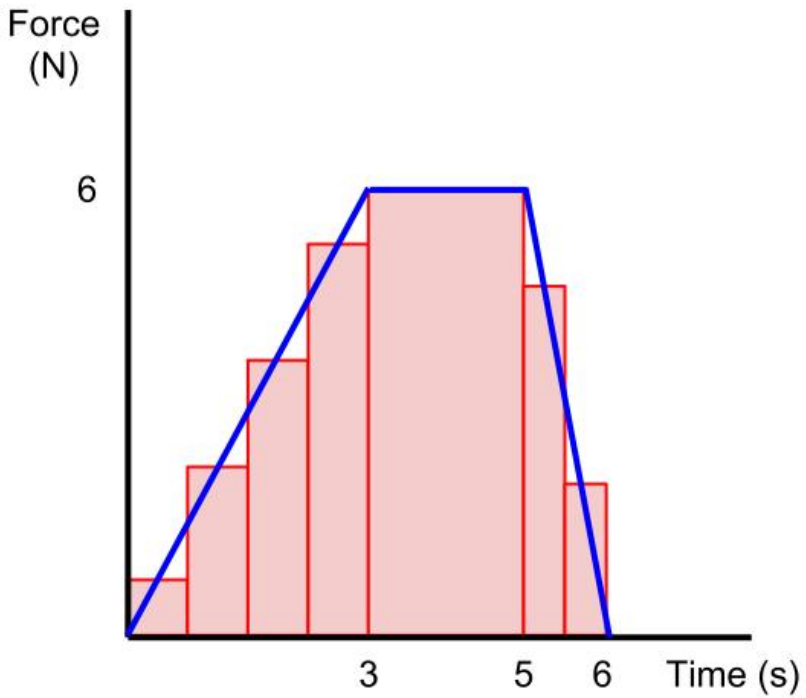

Approximate the graph using segments of constant force

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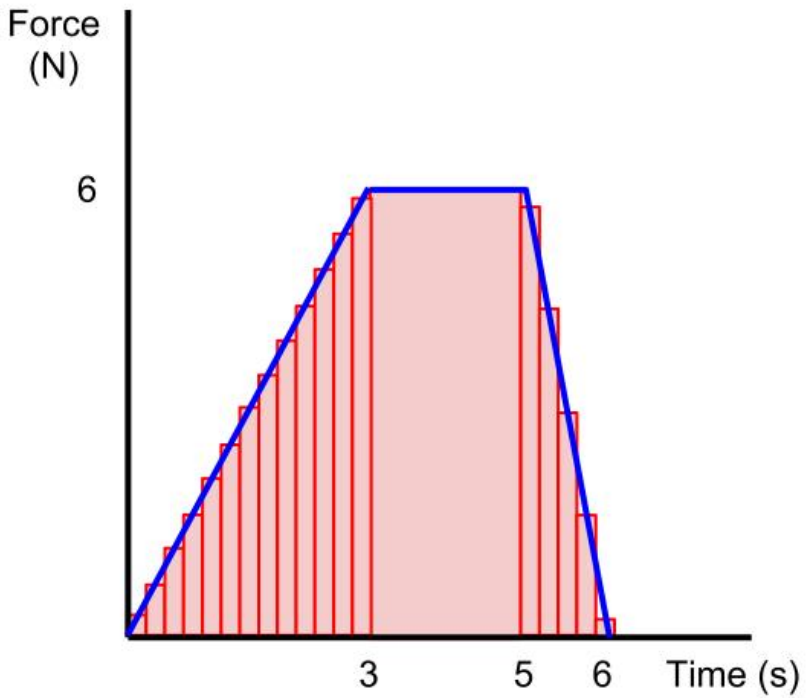

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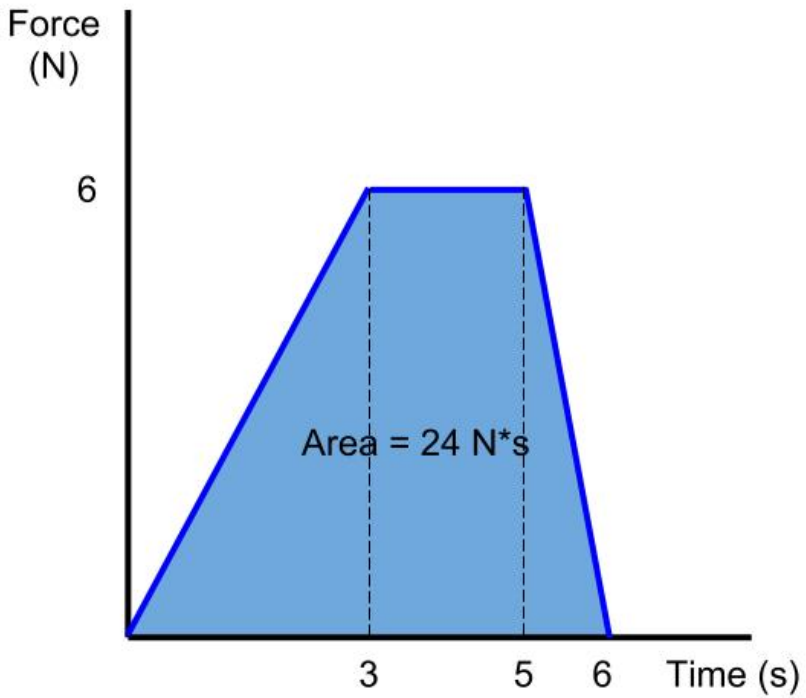


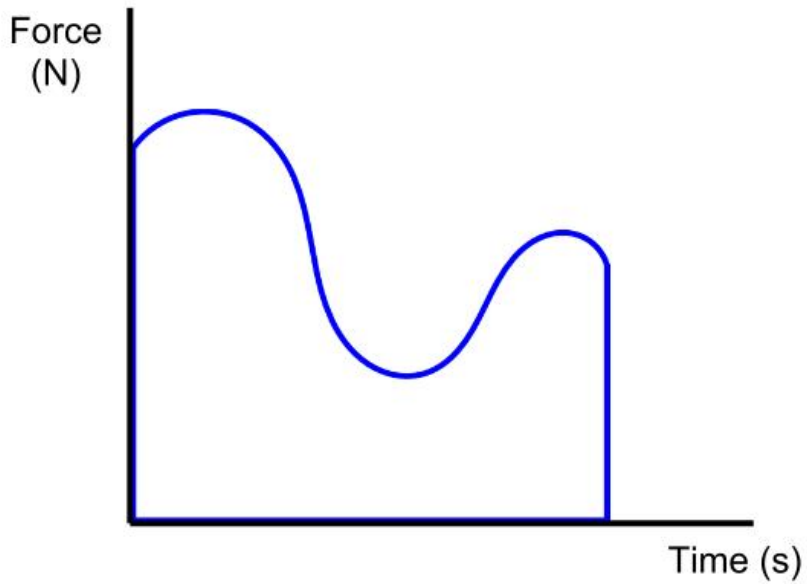
Approximate the graph using segments of constant force

Impulse is the area under a force-time graph

$$J = \sum F * \Delta t$$
$$= 0.5(6)(3) + 6(2) + 0.5(6)(1)$$
$$= 9 + 12 + 3$$
$$= 24N * s$$

Simplification

Suppose there is a system that undergoes the change described by the graph below.



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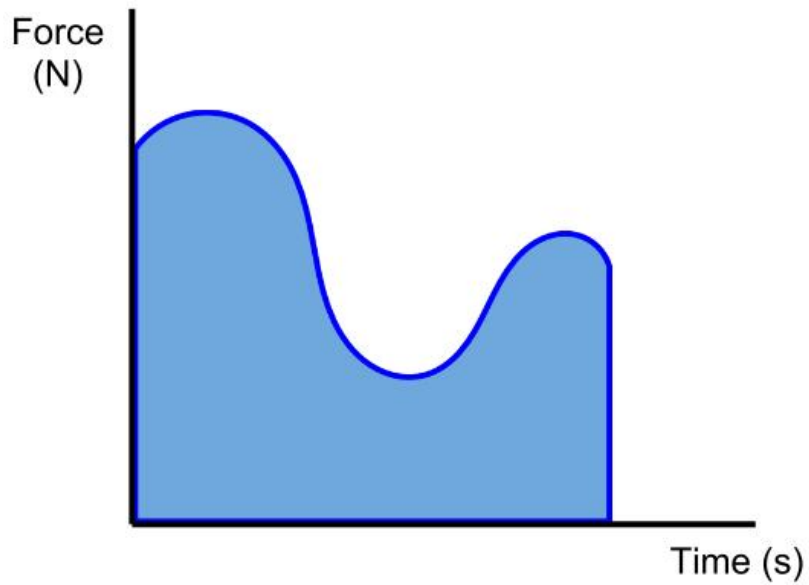

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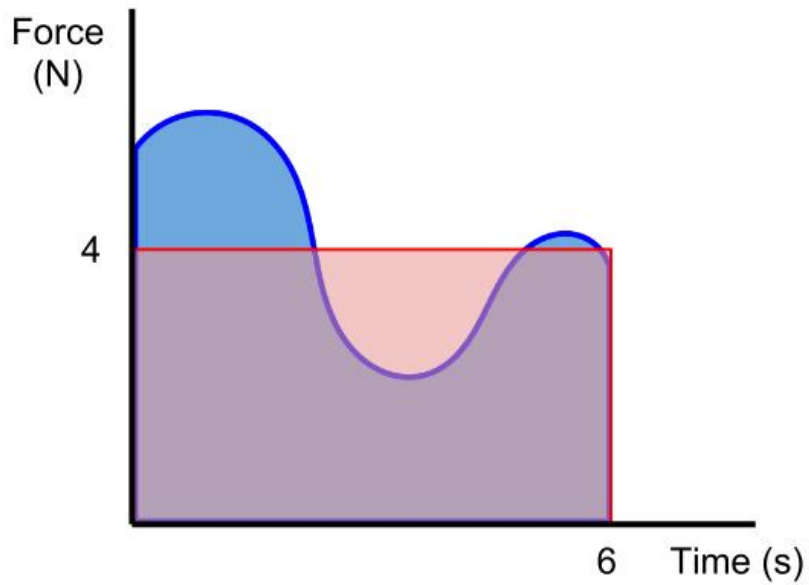

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Suppose a horizontal line is drawn such that the area of the blue and pink regions are equal. What does the horizontal line represent?

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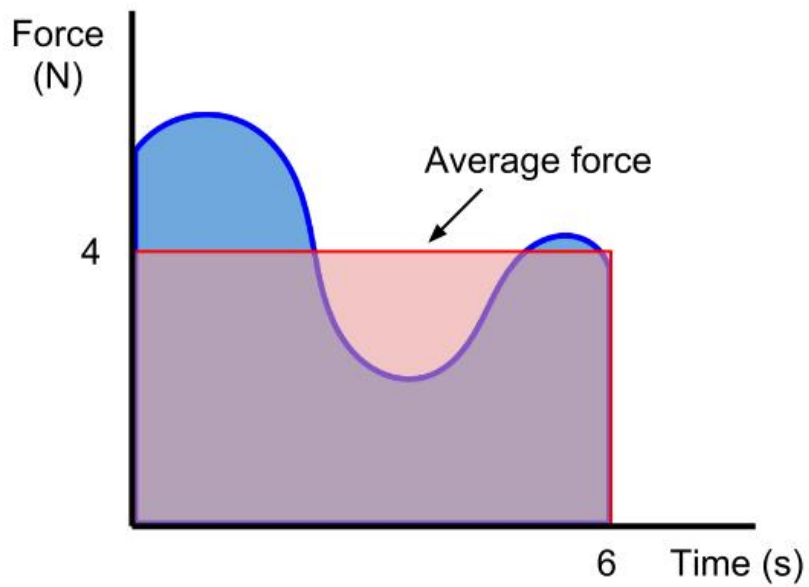

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Suppose a horizontal line is drawn such that the area of the blue and pink regions are equal. What does the horizontal line represent? **Average force**

Finding Averages

Why does finding a horizontal line that produces the same area give the average force?

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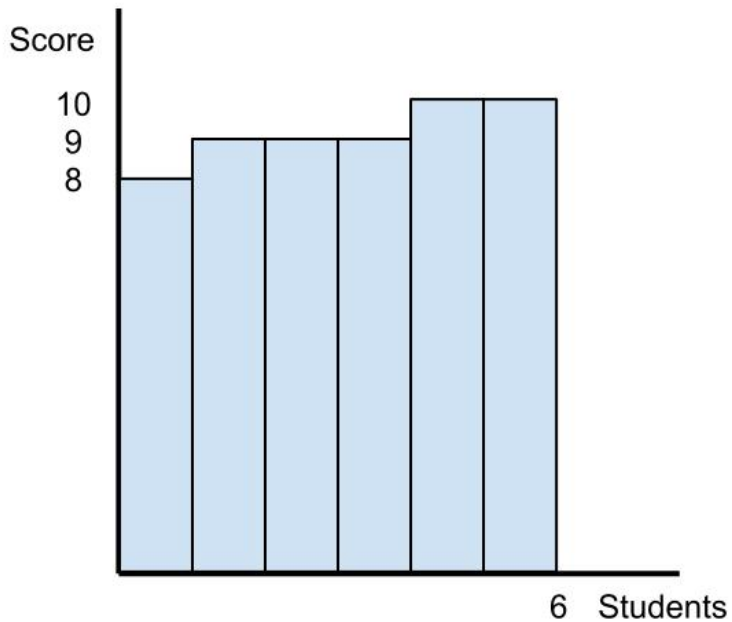
Let's consider a similar problem of finding the average of students' test scores.
Suppose 1 student gets 8/10, 3 students get 9/10, and 2 students get 10/10.

$$\begin{aligned}\text{avg. score} &= \frac{1(8)+3(9)+2(10)}{1+3+2}\\ &= \frac{55}{6}\\ &= 9.17\end{aligned}$$

Averages using Graphs

Now consider the test scores problem using a graph.



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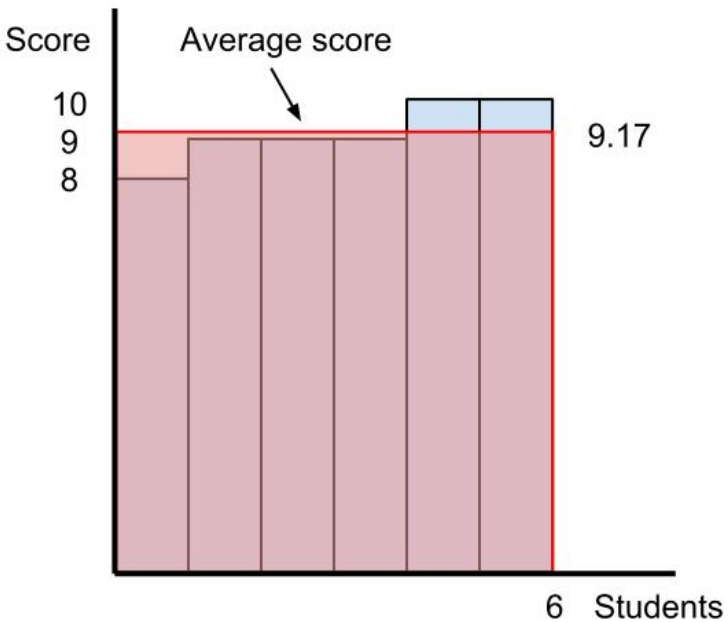


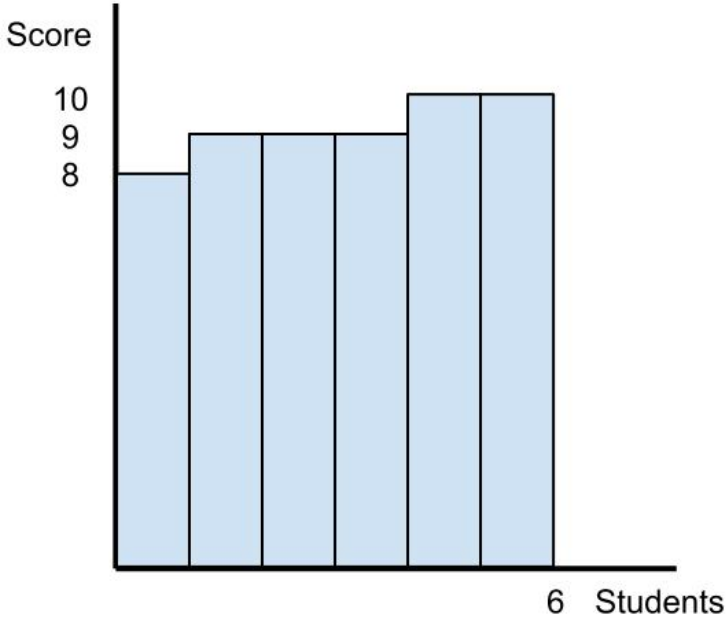
The calculation we did before is related to finding the area

$$\text{avg. score} = \frac{1(8) + 3(9) + 2(10)}{1 + 3 + 2}$$

$$= \frac{\text{area of blue}}{\text{total students}}$$

Back to Average Force

Test Scores



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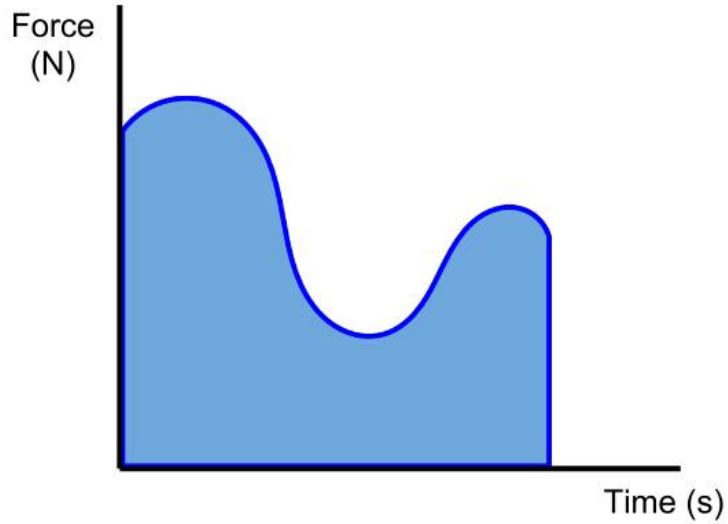

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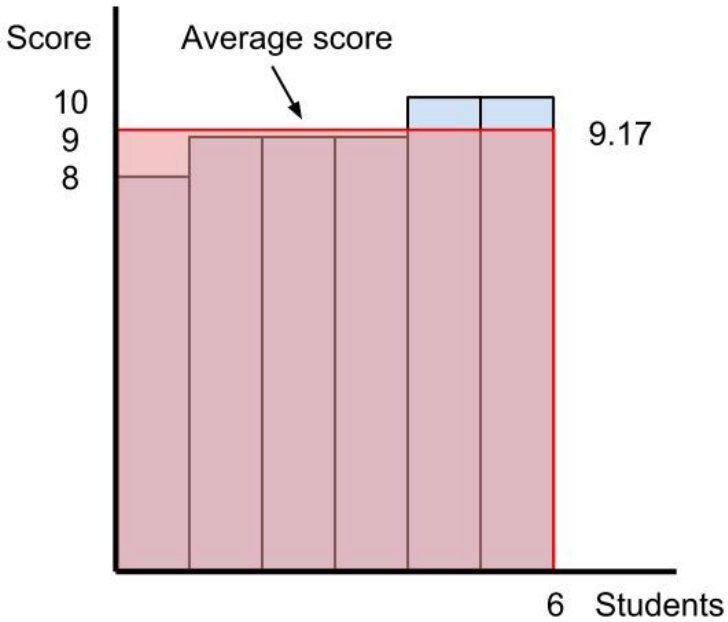

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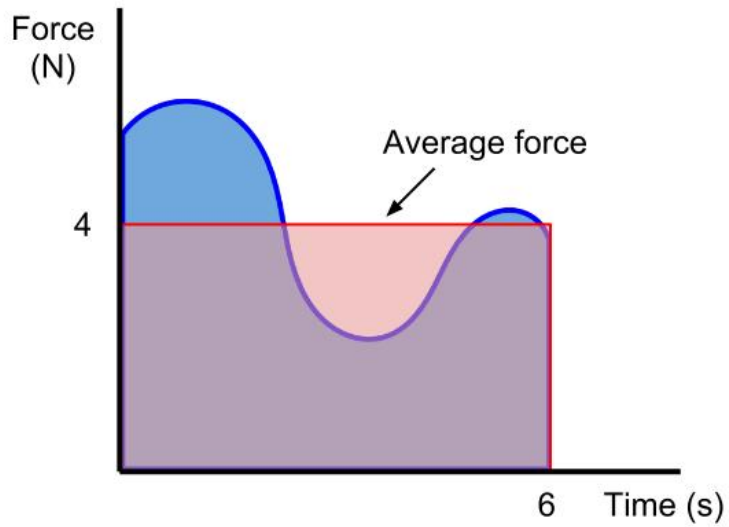
Impulse



$$\text{avg. force} = \frac{\text{blue area}}{\text{total time}}$$

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Average Force

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$$\text{average force} = \frac{J}{\Delta t} = \frac{p_f - p_i}{\Delta t}$$

Relevance

Why do we care about impulse and average force?

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Hint: Force and time are inversely related in the formula for average force.

Pole Vaulting

The landing mat increases the time of impact, decreasing the average force the pole vaulter experiences.

Boxing

Similarly, boxing gloves and helmets increase the time of impact, decreasing the average force experienced by the boxer.

Gymnastics

Gymnasts are taught to land with their knees bent. This increases the time of impact, reducing the force on their lower body.

Airbags

During car crashes, air bags inflate in order to increase the time of impact.

Units

What are the units of impulse?

1. N*s
2. kg*m/s
3. Both N*s and kg*m/s

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1. Magnitude
2. Direction
3. Magnitude and direction

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3. **Magnitude and direction**

(Note that the direction of the impulse also tells you the direction of the average force.)

Dough

A piece of dough with mass 0.5 kg is traveling downward at a speed of 1 $\frac{m}{s}$. It lands on the table and sticks. If the coordinate system is defined such that up is positive, what is the impulse?

1. 0 N*s
2. 0.5 N*s
3. -0.5 N*s

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Tennis ball

You throw a tennis ball with mass 0.05 kg at the ground at a speed of $2\frac{m}{s}$. It makes contact with the ground for 0.1 seconds, and then the tennis ball bounces up at a speed of $2\frac{m}{s}$. What is the magnitude and direction of the average force experienced by the tennis ball?

1. 2 N, upward
2. 2 N, downward
3. 1 N, upward
4. 1 N, downward

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