A.2

Impulse

IB PHYSICS - MOTION

IB Physics Data Booklet

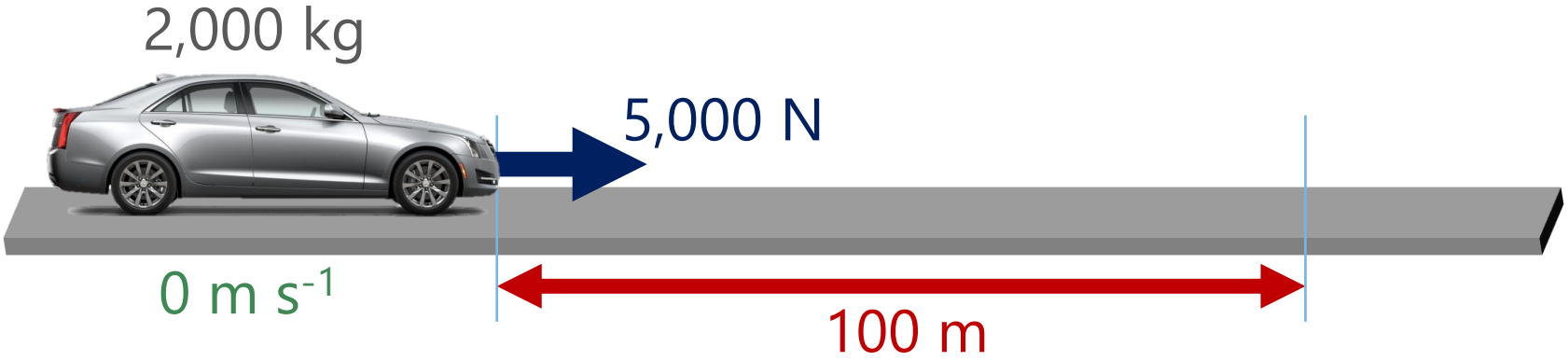
A.2

A.2 Forces and momentum	
	$F_f \leq \mu_s F_N$
	$F_f = \mu_d F_N$
	$F_H = -kx$
	$F_d = 6\pi\eta rv$
	$F_b = \rho Vg$
	$F_g = mg$
	$p = mv$
	$J = F\Delta t$
	$F = ma = \frac{\Delta p}{\Delta t}$
	$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$
	$v = \frac{2\pi r}{T} = \omega r$

Introducing Impulse

A.2

Impulse = Force × Time 8.94 s



Initial Momentum = 0 kg m s^{-1}

Impulse = (5,000 N)(8.94 s) = 44,700 N s

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A.2

A.2 Forces and momentum	
	$F_f \leq \mu_s F_N$
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Impulse

A.2

Impulse → Change in Momentum

$$J = F\,\Delta t = \Delta p$$

What about Units? $[N] = [kg][m\ s^{-2}]$

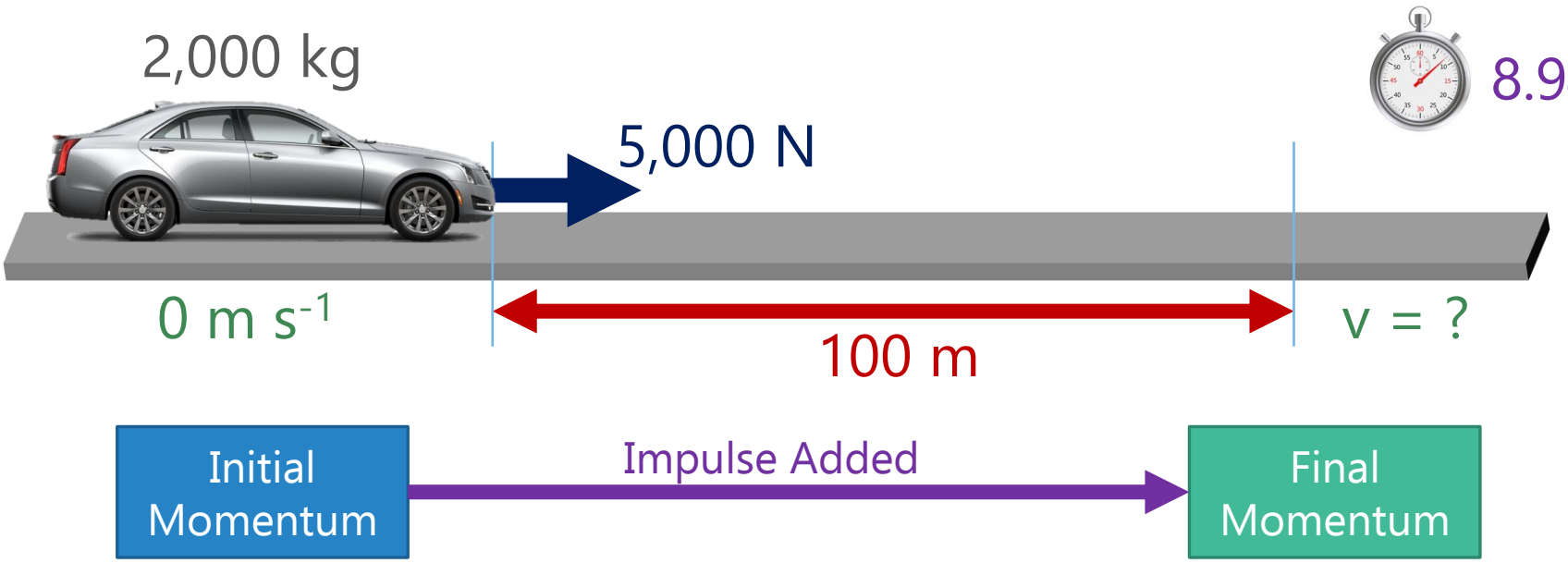
Impulse = F × t = $[N][s] = [kg][m\ s^{-2}][s]$

Impulse = **[N s]** or **[kg m s^{-1}]***

*same unit as momentum

Using Impulse

A.2



Initial Momentum = 0 kg m s^{-1}

Impulse = (5,000 N)(8.94 s) = 44,700 kg m s^{-1} ← Momentum added to system

Final Momentum = 44,700 kg m s^{-1} = mv = (2,000 kg)v

Final Velocity = v = 22.35 m s^{-1}

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A.2

A.2 Forces and momentum

$$J = F\,\Delta t = \Delta p$$

$$F_f \le \mu_s F_N$$

$$F_f = \mu_d F_N$$

$$F_H = -kx$$

$$F_d = 6\pi\eta r v$$

$$F_b = \rho V g$$

$$F_g = mg$$

$$p = mv$$

$$J = F\Delta t$$

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

Same idea

$$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$$

$$v = \frac{2\pi r}{T} = \omega r$$

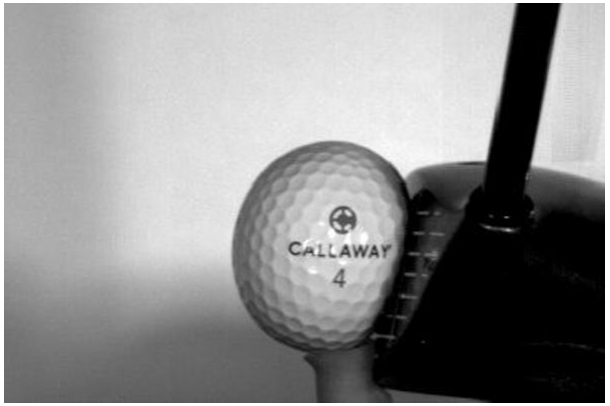
A.2

Impulse and Momentum

Impulse can act to increase or decrease an object's momentum

Final Velocity
$0\ m/s$

Initial Velocity
$0\ m/s$



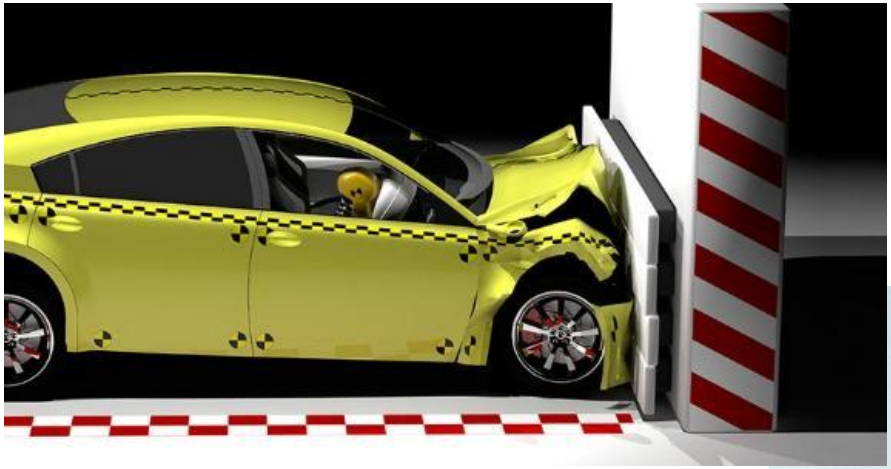
Initial Velocity
$0\ m/s$

How are these the same? different?

A.2

Impulse → Slowing Down

A.2



How can we decrease the force acting on an object?

Impulse and Momentum

A.2

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

Same Mass

Same Momentum

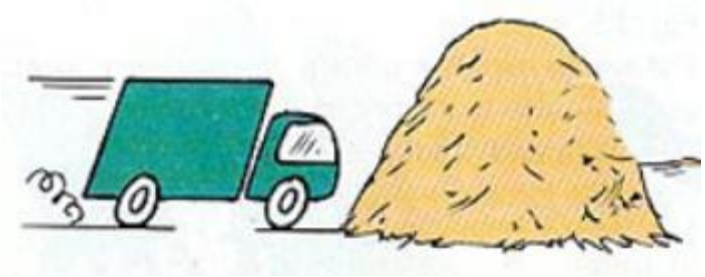
Short Time

Large Force

$F \times \Delta t$

$$F \times \Delta t = F \times \Delta t$$

Same Impulse



Long Time

Small Force

Impulse to Speed Up

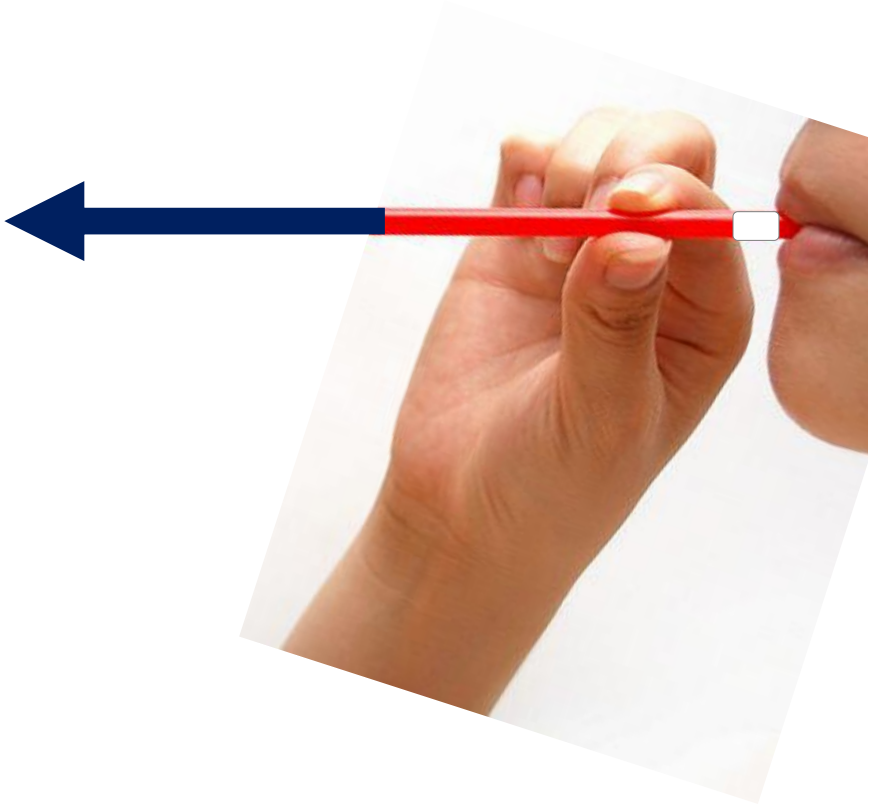
A.2

Should a cannon have a long or short barrel to produce to largest final velocity? Why?

Both designs will experience the same force but the long barrel experiences that force for more time and creates a larger impulse / change in momentum

Marshmallow Shooter

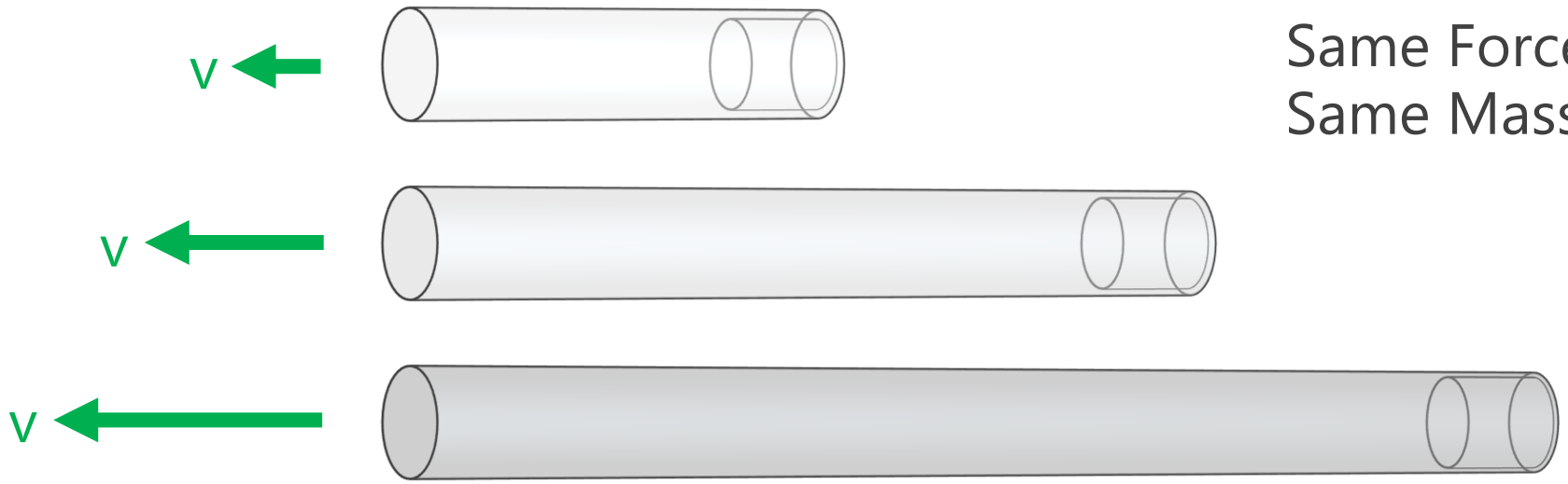
A.2



Marshmallow Shooter

A.2

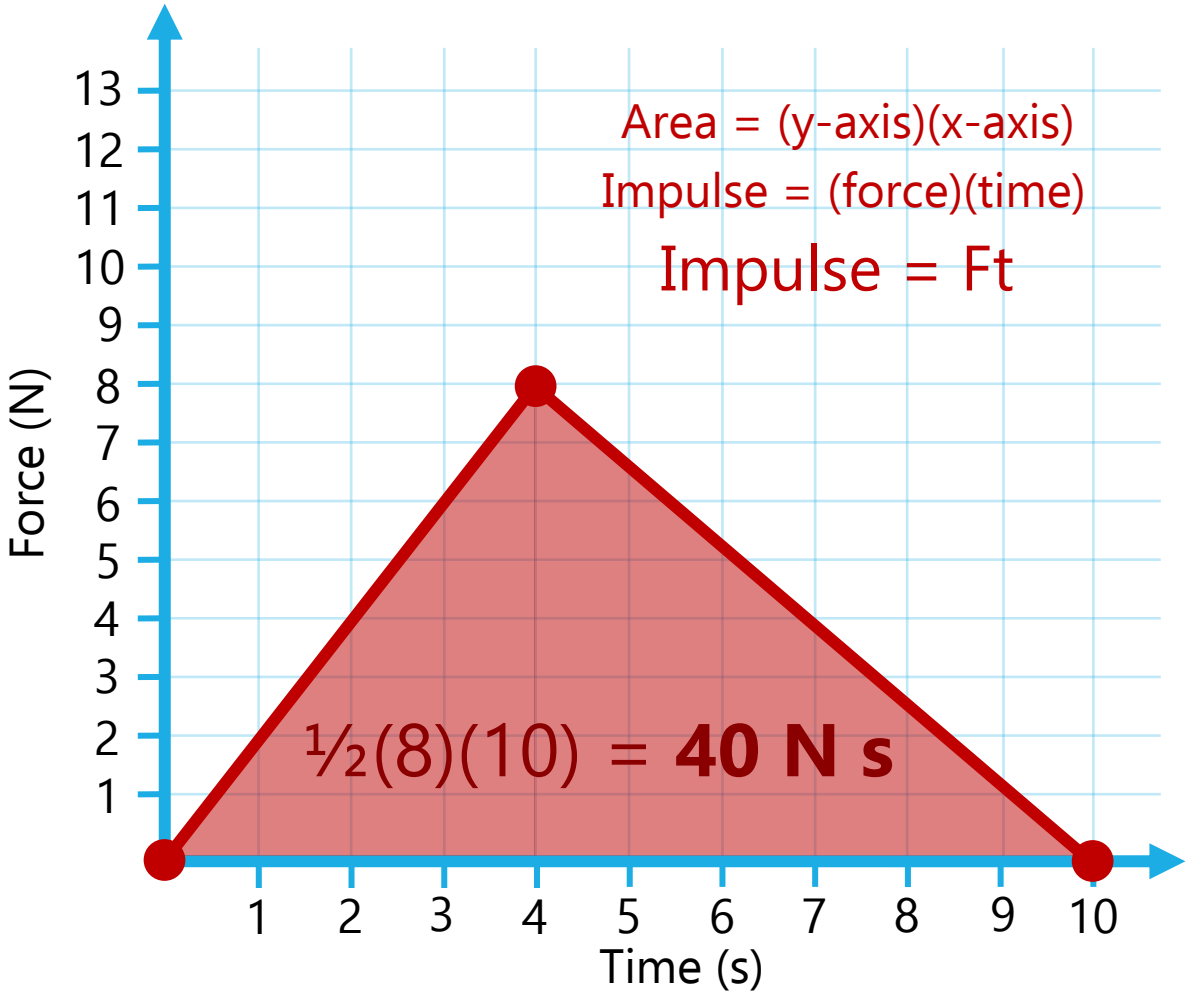
$$J = F\Delta t = \Delta p = m\Delta v$$



Same Force
Same Mass

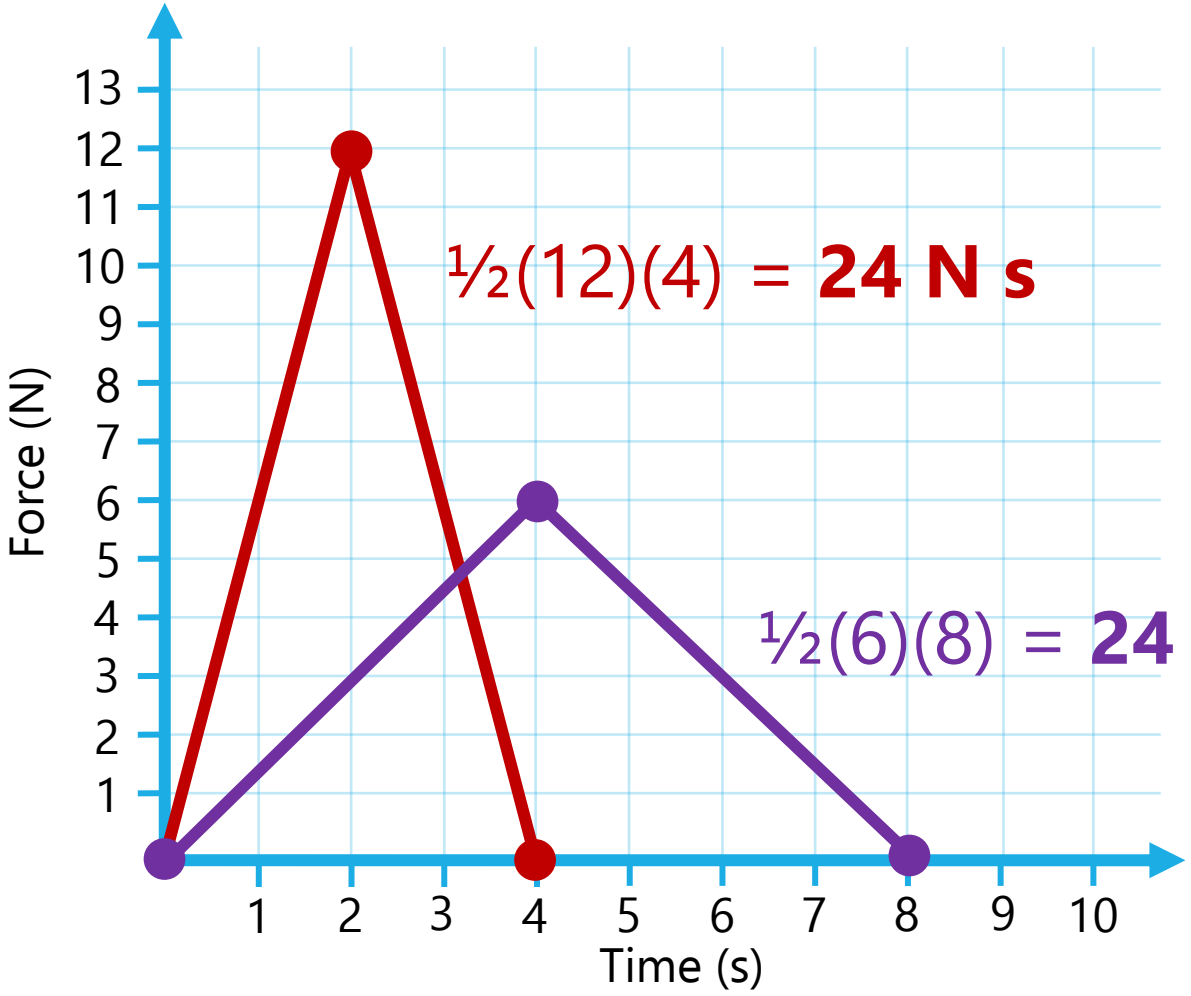
More Time → More Velocity

What if the force isn't constant?



Which impulse is larger?

A.2



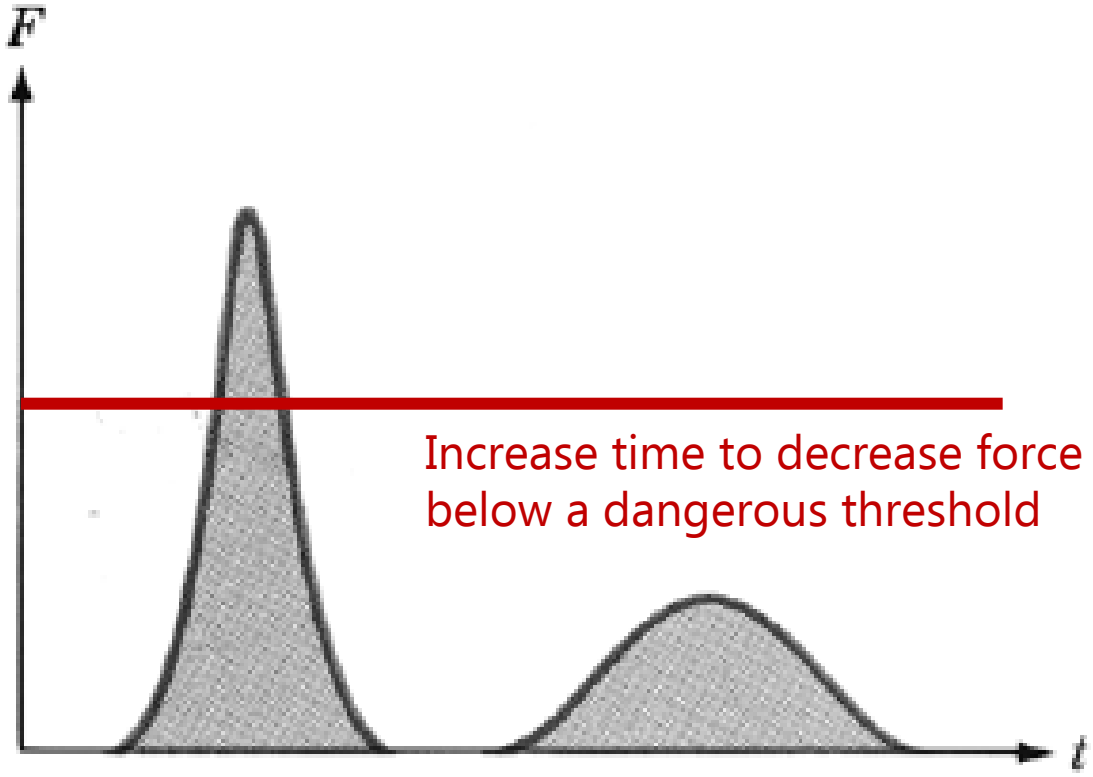
Same

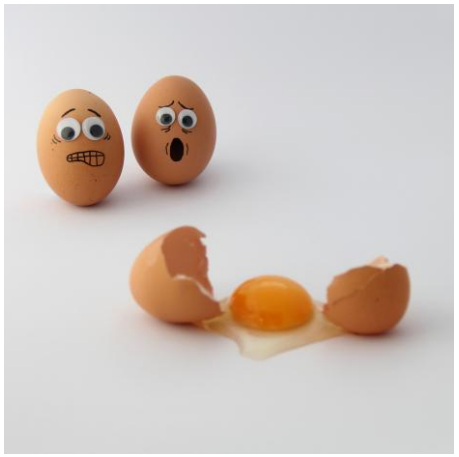
Twice the time

Half the force

The force matters!

A.2





A.2

Slapshot!

A hockey puck has a mass of 0.115 kg. A player takes a slap shot which exerts a force of 31.0 N for 0.15 sec. How fast will the puck be moving?

Initial Momentum = 0 kg m s^{-1}

Impulse = FΔt = (31 N)(0.15 s) = 4.65 kg m s^{-1}

Final Momentum = 4.65 kg m s^{-1} = mv = (0.115 kg)v

Final Velocity = v = **40.4 m s^{-1}**

Impulse and Momentum

A.2

The 440 newton Liquid Apogee Motor (LAM) of India's Mars Orbiter Spacecraft, was successfully fired for a duration of 3.968 seconds on September 22, 2014. This operation of the spacecraft's main liquid engine was also used for the spacecraft's trajectory correction and changed its velocity by 2.18 m s^{-1}. What was the mass of the spacecraft at the time of this engine firing?

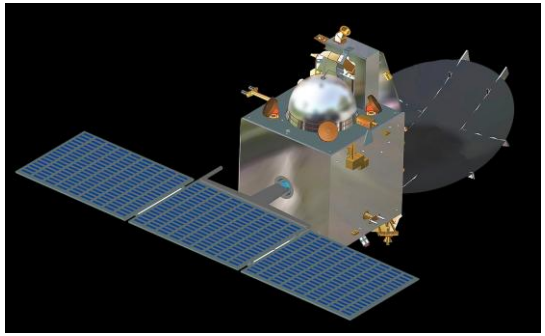
$$J = F\Delta t = \Delta p$$

Impulse = $F\Delta t$ = (440 N)(3.968 s) = 1746 kg m s^{-1}

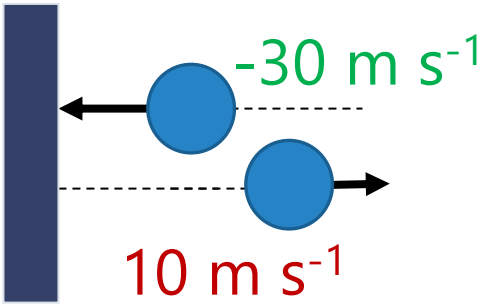
Change in Momentum = 1746 kg m s^{-1} = (m)(Δv)

1746 kg m s^{-1} = (m)(2.18)

m = 801 kg



Direction Matters



Initial speed = 30 m/s (left)
Final speed = 10 m/s (right)

What is the change in velocity?

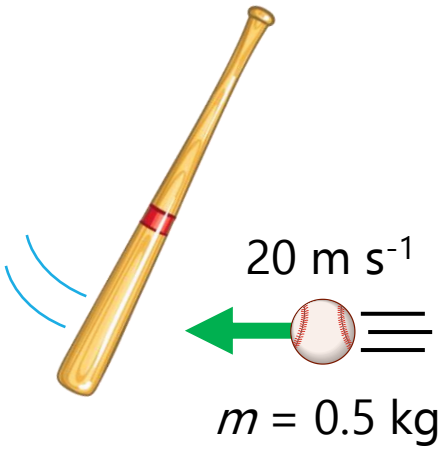
Change in Velocity = 40 m s^{-1}

A.2

Try This…

A.2

A **500 g** baseball moves to the left at **20 m s^{-1}** striking a bat. The bat is in contact with the ball for **0.002 s**, and it leaves in the opposite direction at **40 m s^{-1}**. What was average force on ball?



Initial Momentum → Final Momentum

Impulse Added

p = (0.5)(-20)

-10 kg m s^{-1}

Δp

30 kg m s^{-1}

p = (0.5)(40)

20 kg m s^{-1}

Impulse = FΔt = Δp

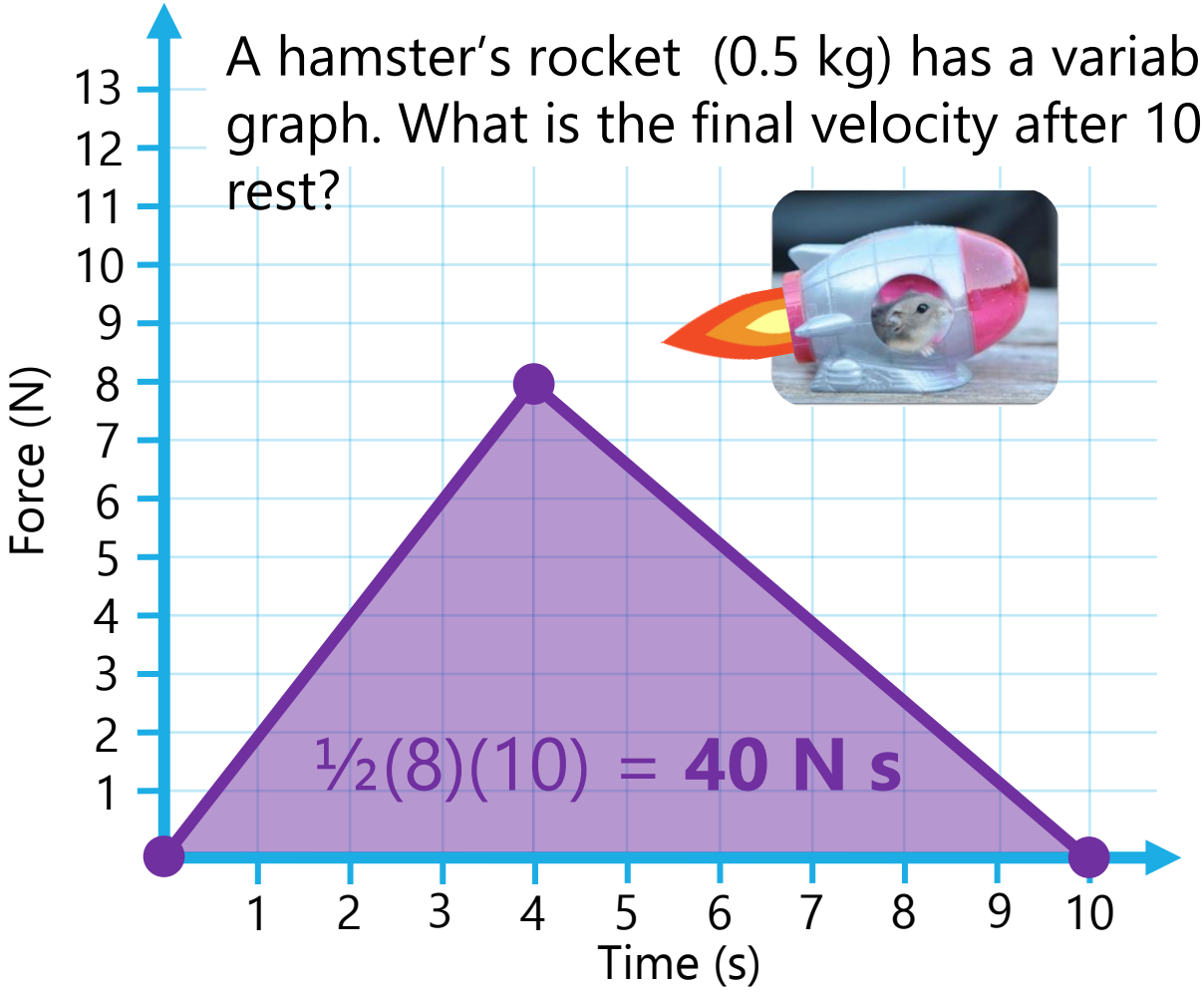
Impulse = F(0.002 s) = 30 kg m s^{-1}

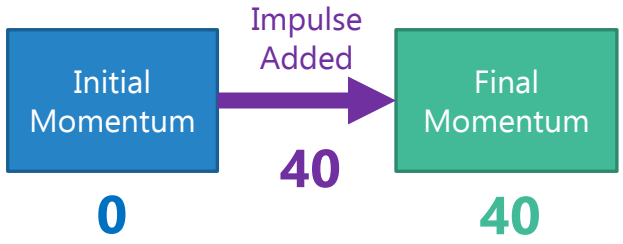
F = 15,000 N

Impulse from a Graph

A.2

A hamster's rocket (0.5 kg) has a variable force as shown in the graph. What is the final velocity after 10 seconds if it starts from rest?





$p = mv$

$40 = (0.5)v$

$v = 80$ m/s

Try This…

A.2

Kara Less was applying her makeup when she drove into South's busy parking lot last Friday morning. Unaware that Lisa Ford was stopped in her lane, Kara rear-ended Lisa's rental car. Kara's 1300-kg car was moving at 5 m s^{-1} and stopped in 0.4 seconds. What was the force?

Initial Momentum = mv = (1,300)(5) = 6,500 kg m s^{-1}

Final Momentum = 0 kg m s^{-1}

Impulse = 6,500 kg m s^{-1} = (F)(0.4 s)

Force = F = **16,250 N**

Lesson Takeaways

A.2

- ❑ I can describe the meaning of impulse and how it is related to momentum change
- ❑ I can conceptually describe how to decrease the force experienced in a collision
- ❑ I can determine the impulse of a collision from a force vs time graph