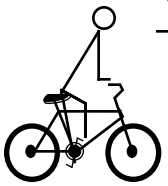
# Impulse & Momentum Worksheets

**A**



V= 5 m/s

$M_R$= 60 kg

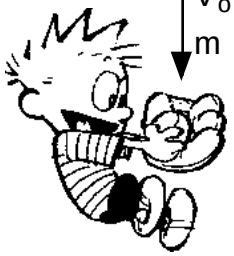
$M_B$= 20 kg

Impulse: _____

Momentum of the bike: _____

Momentum of the rider: _____

**B**



$V_o$ = 30 m/s

m = 0.150 kg

Calvin catches the ball

**C**

BEFORE

$V_o$ = 20 m/s

m = 0.150 kg

AFTER

V = 35 m/s

Line drive - straight back at the pitcher.

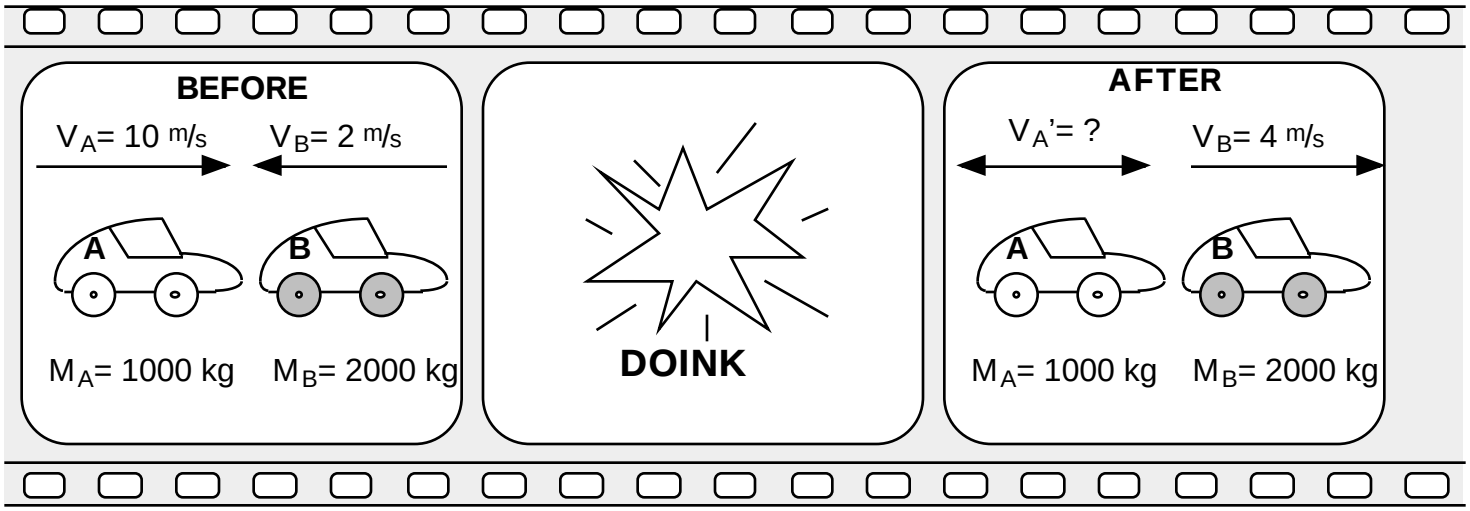
**D**

$V_o$ = 10 m/s

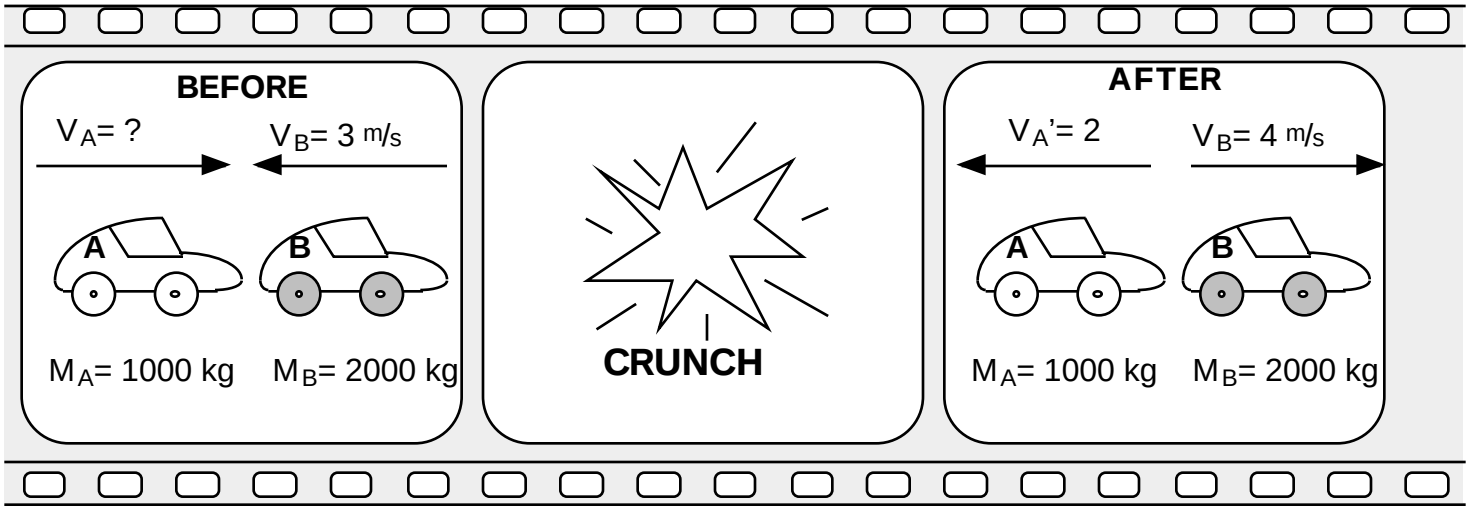
m = 0.1 kg

The snow ball hits Susie on the head and sticks there.

**E**


BEFORE
$V_A$= 10 m/s
$V_B$= 2 m/s
A
B
$M_A$= 1000 kg
$M_B$= 2000 kg
DOINK
AFTER
$V_A$'= ?
$V_B$= 4 m/s
A
B
$M_A$= 1000 kg
$M_B$= 2000 kg

**F**

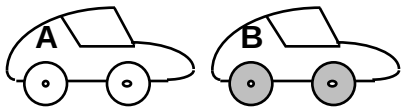

BEFORE
$V_A$= ?
$V_B$= 3 m/s
A
B
$M_A$= 1000 kg
$M_B$= 2000 kg
CRUNCH
AFTER
$V_A$'= 2
$V_B$= 4 m/s
A
B
$M_A$= 1000 kg
$M_B$= 2000 kg

**G**

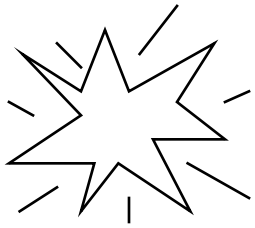
**BEFORE**

$V_A$= ?

$V_B$= 3 m/s



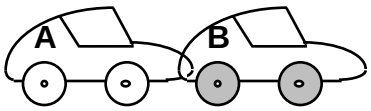

$M_A$= 2000 kg $M_B$= 4000 kg



**UMPH**

**AFTER**

$V_B$= 5 m/s



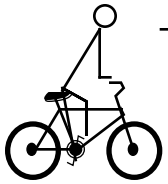

$M_A$= 2000 kg $M_B$= 4000 kg

STICK TOGETHER

**H**

**BEFORE**

V= 5 m/s



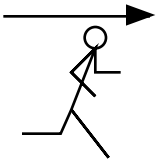
$M_R$= 60 kg

$M_B$= 20 kg

**Whoa !**

**AFTER**

$V_R$'= 2 m/s



$M_R$= 60 kg

$V_B$'= ? m/s

$M_B$= 20 kg

**I**

Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 11 $^{m}/_{s}$. Calvin is running in the same direction as Hobbes, away from Hobbes, at 8.33 $^{m}/_{s}$.

(a) If the two collide and stick together, what is their final velocity?

(b) What impulse is exerted on Hobbes by Calvin?

(c) What impulse is exerted on Calvin by Hobbes?

(d) If the collision occurred in 0.109 seconds, Then what force was exerted on Hobbes?

**J**

Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 7.22 $^{m}/_{s}$. Calvin is running at Hobbes.

(a) If the two collide, stick together, and are then at rest, what was Calvin's initial velocity?

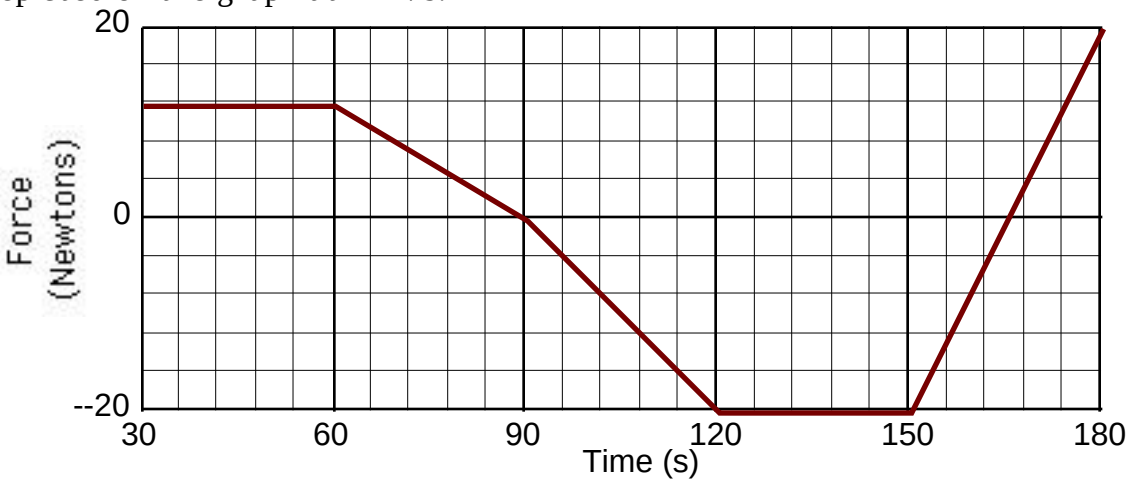
(b) What impulse is exerted on Hobbes by Calvin?

(c) What impulse is exerted on Calvin by Hobbes?

(d) If the collision occurred in 0.0600 seconds, Then what force was exerted on Hobbes?

**K**

Calvin & Hobbes, 45 kg, are sleigh riding down a hill. The hill they are on is irregular shaped, slopes up and down and has snow of varying depths and textures. Below is a force vs time graph of the force acting on their sled. The initial velocity when they hit the part of the hill depicted on the graph at 11 $^{m}/_{s}$.




(a) How do you find the impulse from 30 to 60 seconds?

(b) Which 30 seconds time interval contains a net negative impulse?

(c) What is the impulse from 30 to 60 seconds?

(d) What is the impulse from 90 to 120 seconds?

(e) What is the impulse from 150 to 180 seconds?

(f) Using the information from text above combined with the graph, calculate the final velocity **at the 60 second mark.**

(g) Calculate the final velocity **at the 120 second mark**.

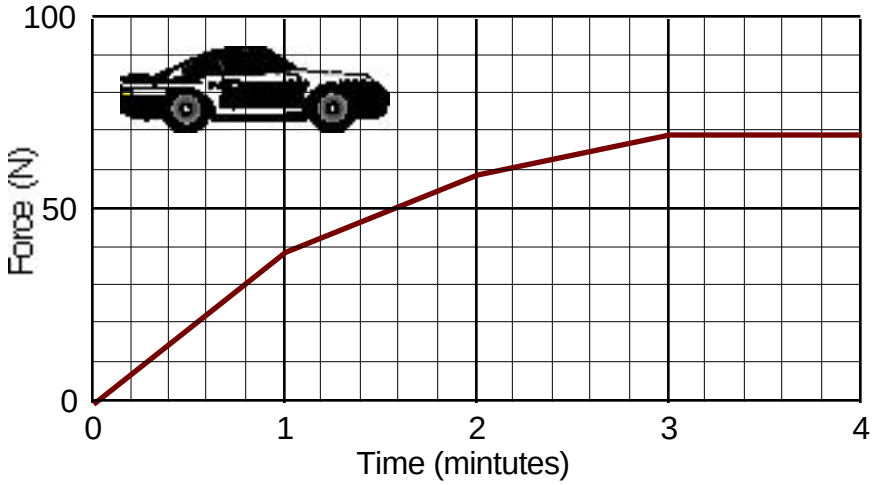
(h) Calculate the final velocity at the end of the ride?

(i) What was the average velocity for the entire ride?

(j) What is the (average) acceleration over the entire ride?

(k) What must the initial velocity be so that Calvin and Hobbes come to a rest at the end of the ride?

A toy car, 3.0 kg exerts the force shown on the graph.




**Express all answers in standard S.I. units.**

(a) What is the change in speed from 1 to 2 minutes?

(b) What is the change in speed from 2 to 3 minutes?

(c) If the final velocity at 3 minutes is 10 $^{m}/_{s}$, then what is the initial velocity at 2 minutes?

(d) If the initial velocity is of the car is 5 $^{m}/_{s}$ at 1 minute, then what is the velocity of the car at 2 minutes?

(e) If the car starts from rest at 0 minutes, then what is the velocity of the car after the first 4 minutes?

(f) What is the momentum of the car at 3 minutes if the car started from rest?

Momentum, **p**, is the product of **mv**. The mass and velocity must be put in standard SI units.

**1**. What is the momentum of a 70 kg runner traveling at 10 m/s?

**2**. What is the momentum of a 800 kg car traveling at 20 m/s?

**3**. What is the momentum of a 47 gram tennis ball that is traveling at 40 m/s?

**4**. What is the momentum of a 120 pound bicyclist that is traveling at 25 mph?

**5**. What is the momentum of a 1500 pound car that is traveling 5 mph?

**6**. What is the speed of a 0.050 kg bullet that is to have the same momentum as the car in problem #5?

**7**. What is the speed of a 60 kg runner that travels with the same momentum as the car in problem #5? (Answer in m/s and mph).

**8**. What is the momentum of a 453 gram football that is thrown with a speed of 30 m/s?

**9**. How fast must a 150 g baseball be traveling to have the same momentum as the football in problem #8? (Answer in m/s and mph)

**Changes in momentum**, $\Delta p$. $\Delta \mathbf{p} = \mathbf{mv_{final} - mv_{initial}}$.

**Direction counts! if the objects switches directions then the $\Delta$p is added.**

**10**. What is the change in momentum of a 950 kg car that travels from 40 m/s to 31 m/s?

**11**. What is the change in momentum of a 40 kg runner that travels from 5 m/s to 11 m/s?

**12**. A mud blob, 0.350 kg, is thrown at a wall at 10 m/s. The blob sticks to the wall. What is the change in momentum of the blob?

**13**. A 0.095 kg tennis ball is traveling 40 m/s when is bounces of a wall and travels in the opposite direction it came from. The bounced leaving the wall with a speed of 30 m/s. What is the change in momentum of the ball?

**14**. A baseball, 167 grams, is pitched at 50 m/s when is hit by the batter. The ball travels in the opposite direction it was thrown from with a speed of 70 m/s. What is the change in momentum of the baseball?

**15**. In a football game a 70 kg player is running at 10 m/s when he is hit by another player. When he is hit by the other player he bounces off in the opposite direction at 5 m/s. What is the players change in momentum?

---

## IMPULSE ($J = Ft = \Delta p$)

**16**. If the runner, in #10, took 30 seconds to change its speed, then what force caused the change?

**17**. If the car, in #11, took 2 minutes to change its speed, then what force caused the change?

**18**. How much time was taken to stop the blob in #12 if the mud blob was stopped by 400 N force?

**19**. Contact with the ball in #13 lasts for 0.05 seconds. What force caused the ball's change in speed?

**20**. The baseball in #14 is hit by a 1608 N force. How long is the ball in contact with the bat?

**21**. When the two players collide in #15, there contact took 0.05 seconds. What force was exerted by each player in the collision?

**22**. Baseball pitcher throws a fast ball with a 100 Ns impulse. If he applied the force in 0.15 seconds, What force did he apply.

**23**. A hockey puck is hit by a hockey player at the goalie. The puck is hit with a 1200 newton force. The stick made contact for 0.1 seconds. What impulse was given to the puck?

If a goalie stopped it with a force that acts for 0.65 seconds, then what force did he apply

**24**. In a lacrosse game a ball is thrown with a force of 2000 N. the throwing force acted for 0.8 seconds. Another player stopped the ball in 0.3 seconds with their helmet. What force did their helmet use to stop the ball?

**25**. A 1000 kg car crashed into a bearer. The car changed speed from 30 m/s to 20 m/s in 2 seconds. What force did the bearer apply to stop the car?

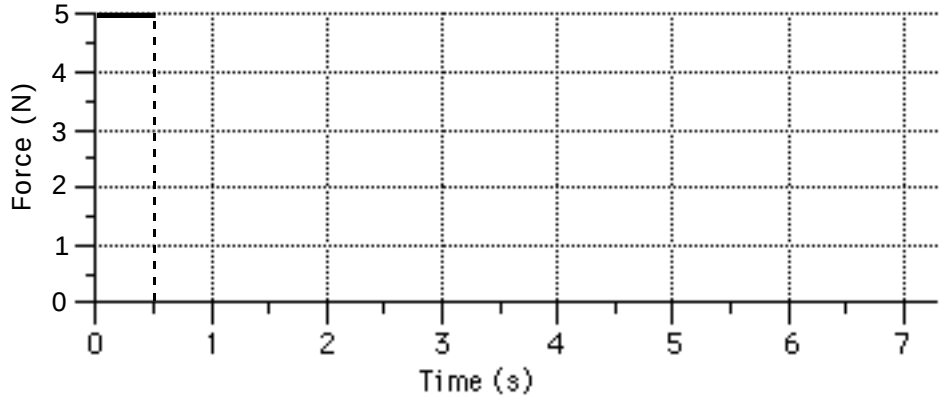
**26**. A 60 kg skateboarder accelerated from 5 m/s to 12 m/s. She applied a force of 4200 N. How quickly did she accelerate?

**27**. A outfielder stops a ball that is originally hit with an impulse of 2000 Ns. The balls mass is 0.25 kg. What was the ball's change in speed when the outfielder stopped it?

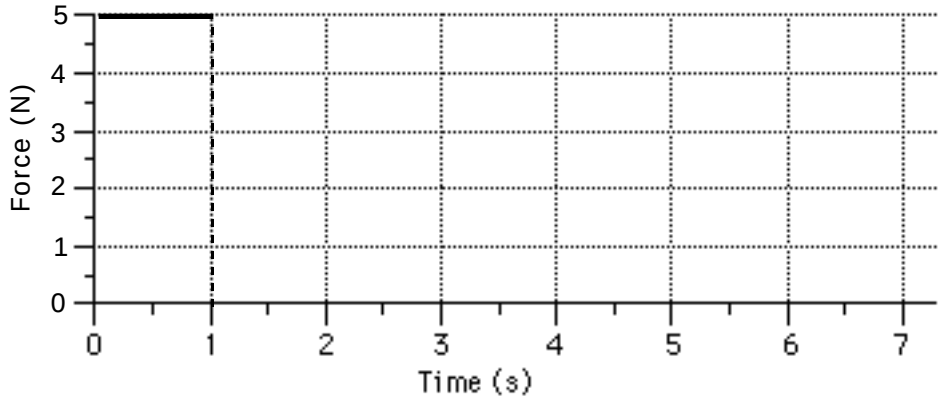
Model rocket engines are marked by the a letter, a number, hyphen, and another number. The first number is the thrust of the motor in newtons, the second is the time delay between when the motor burns out and the ejection charge is ignited. Figure out what the letters stand for.

**Calculate the impulse for each of the graphs that represent the rocket motors thrust time curve.**

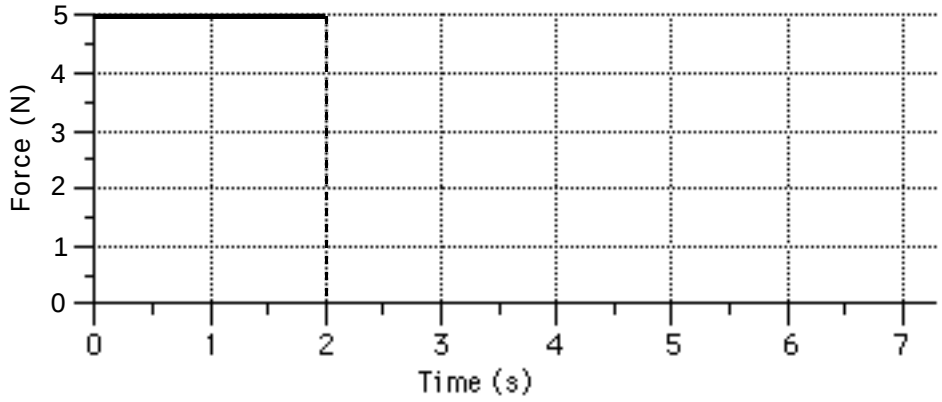
**28**. THE A5-3



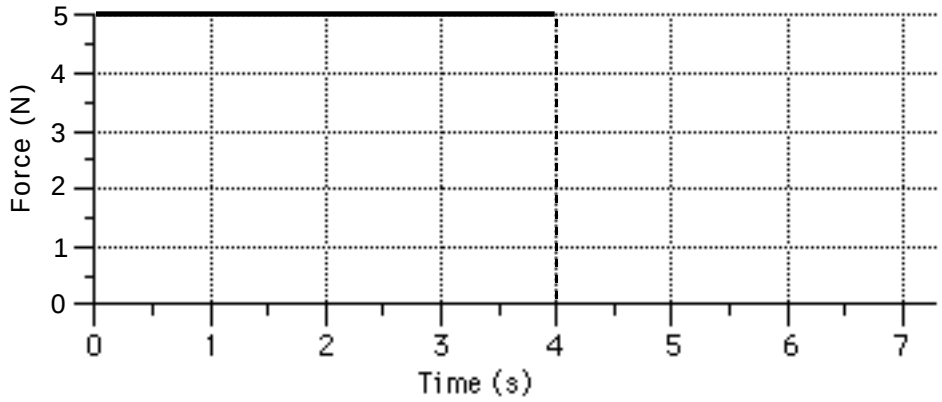

**29**. THE B5-3




**30**. THE C5-3

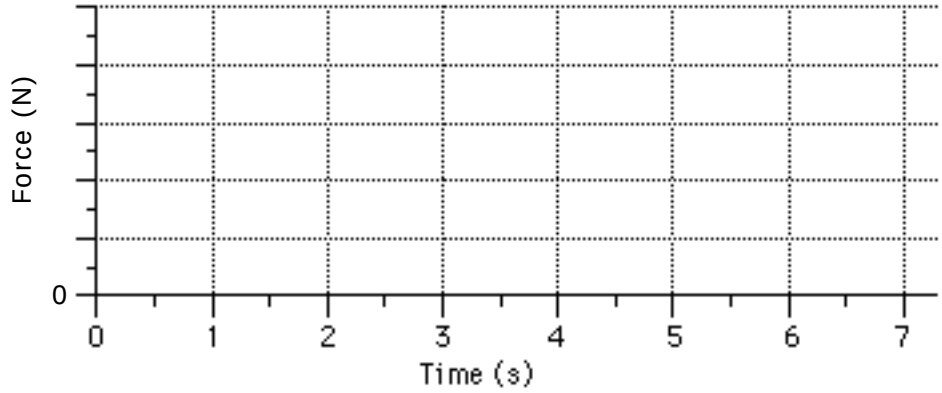


**31**. THE D5-3

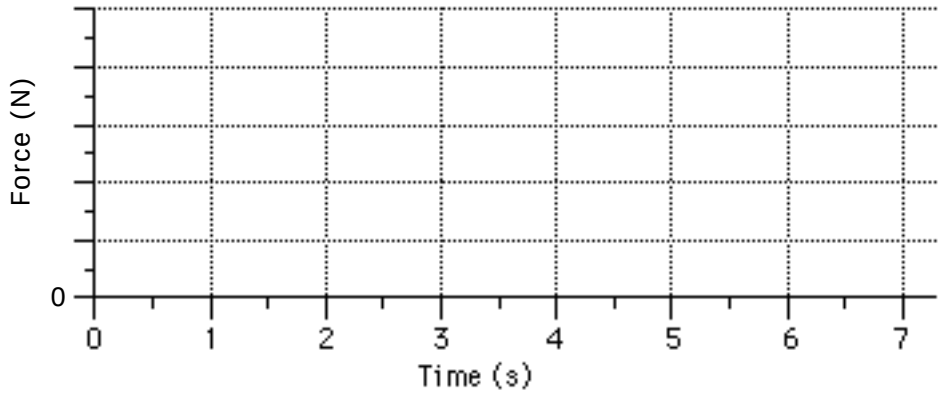



**DRAW AN FORCE VERSUS IMPULSE GRAPH FOR THE FOLLOWING ROCKET MOTORS**

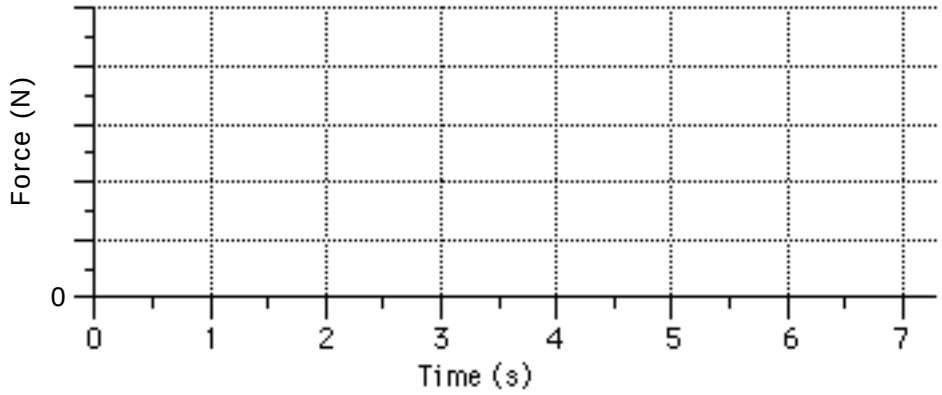
**32**. THE D12-3



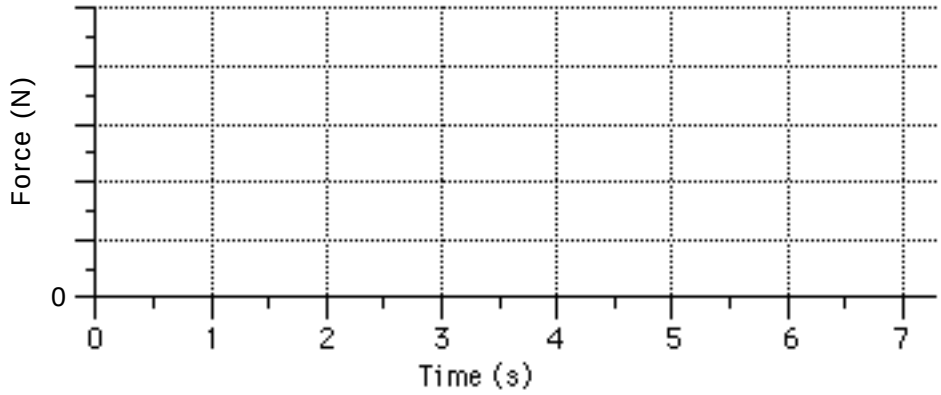

**33**. THE B6-5



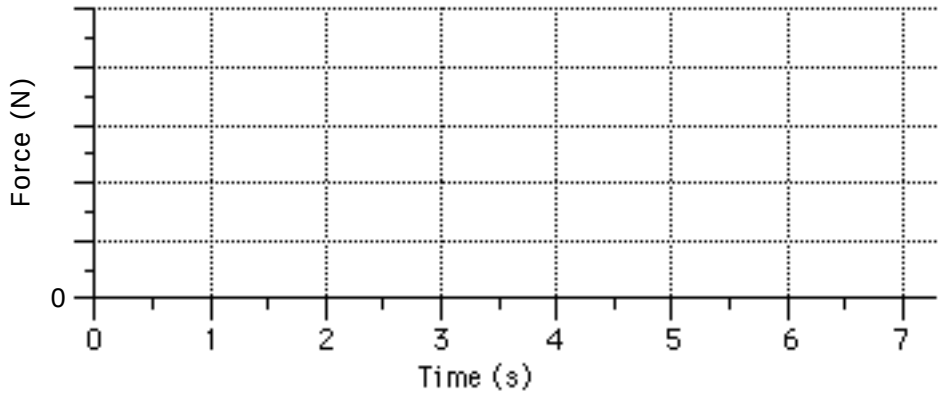
**34**. THE A8-3



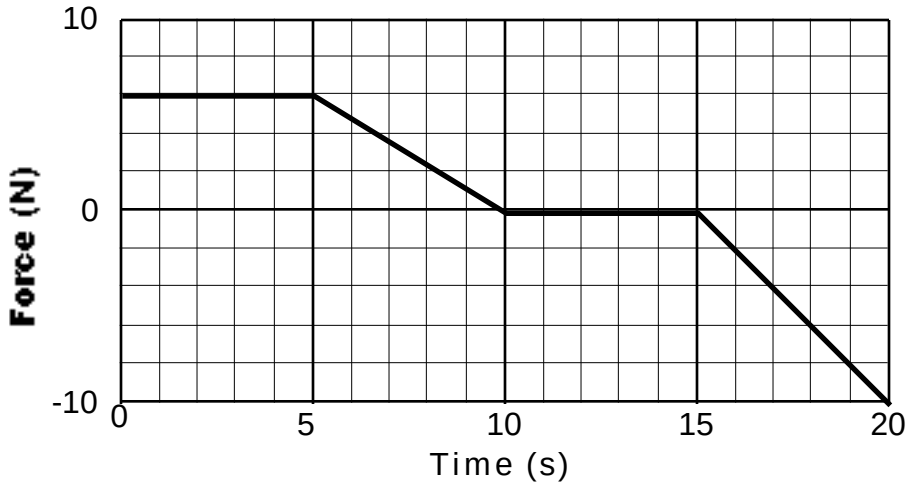

**35**. THE 1/2A3-4




**36**. THE B6-6



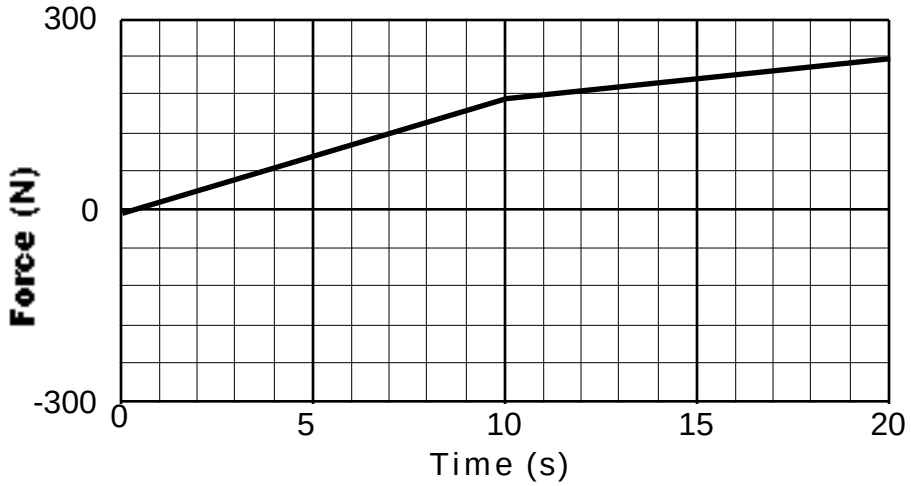
To the right is a force versus time graph for a child's toy car. The toy is malfunctioning and is producing the force shown,




**37** What is velocity of the toy car, 0.756 kg, after 20 seconds if it starts from rest?

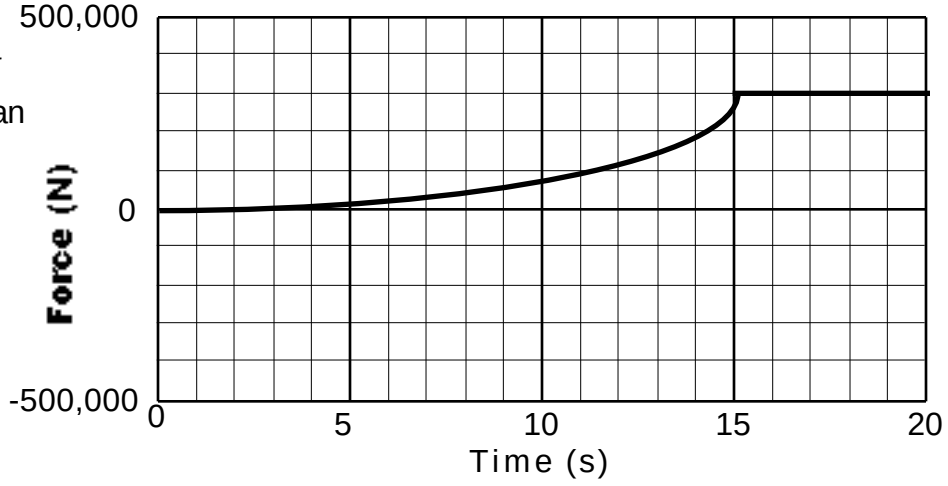
**38** What is velocity of the toy car, 0.756 kg, after 20 seconds if it starts from 10 m/s?

To the right is a force versus time graph for a child's toy dart gun. The toy is malfunctioning and is producing the force shown,




**38** What is the mass of the dart if the change in velocity is 2 m/s?

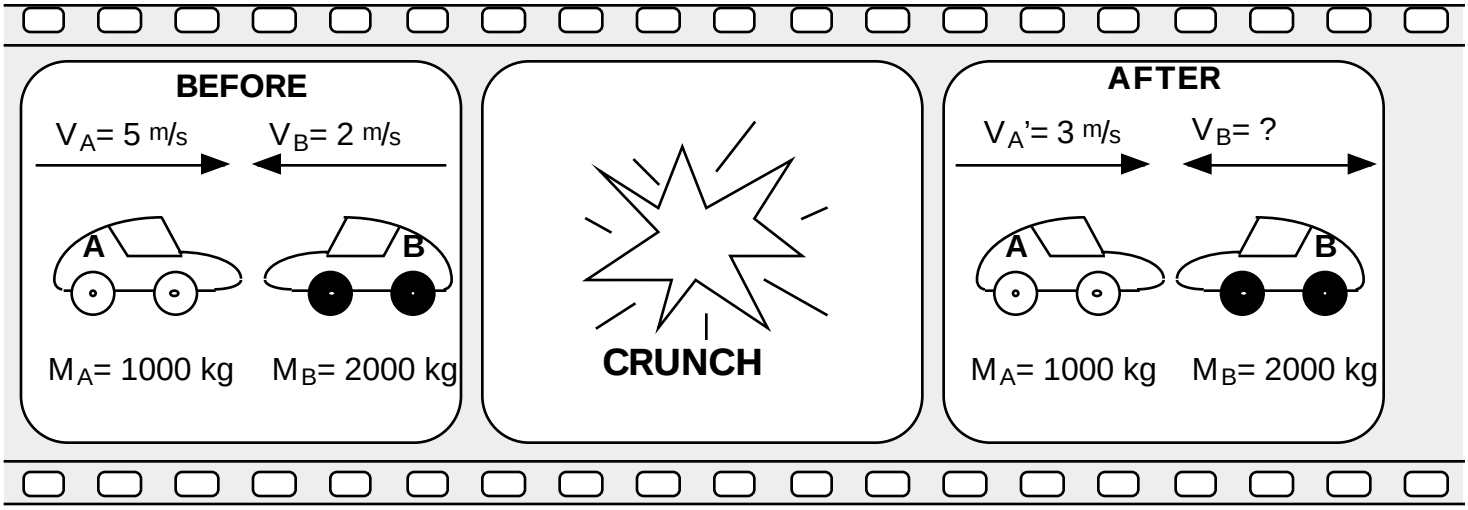
To the right is a force versus time graph for an automobile.



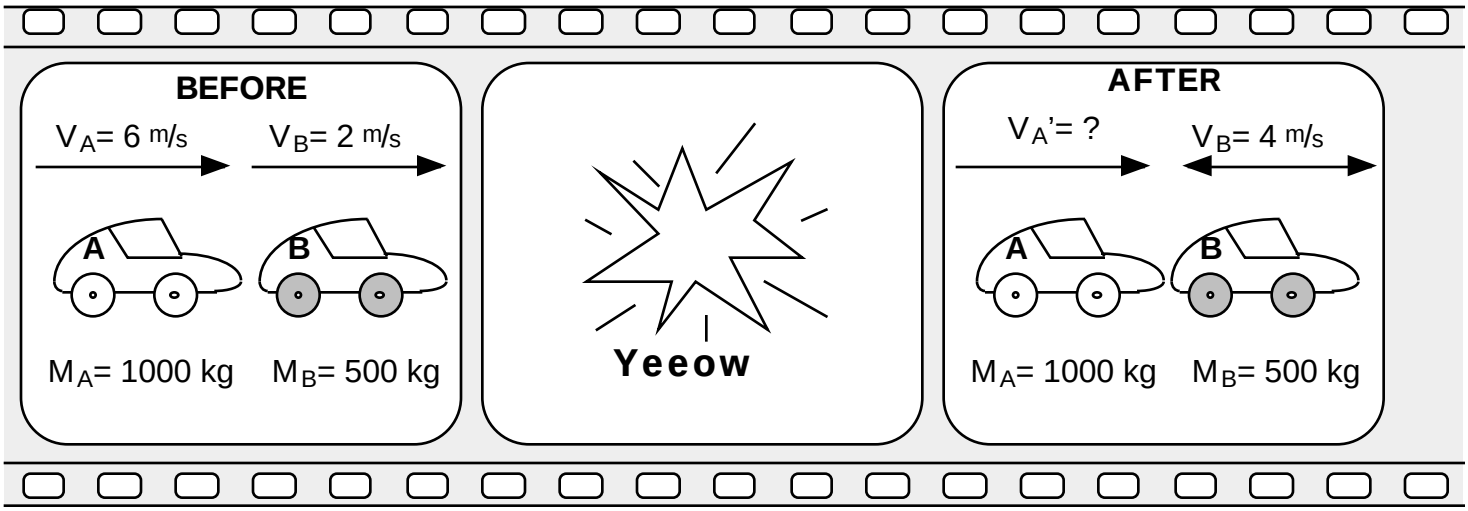

**39** If the car is traveling 20 m/s when the force was traveling 30 m/s after 15 seconds, then what is the mass of the car?

ELASTIC COLLISIONS

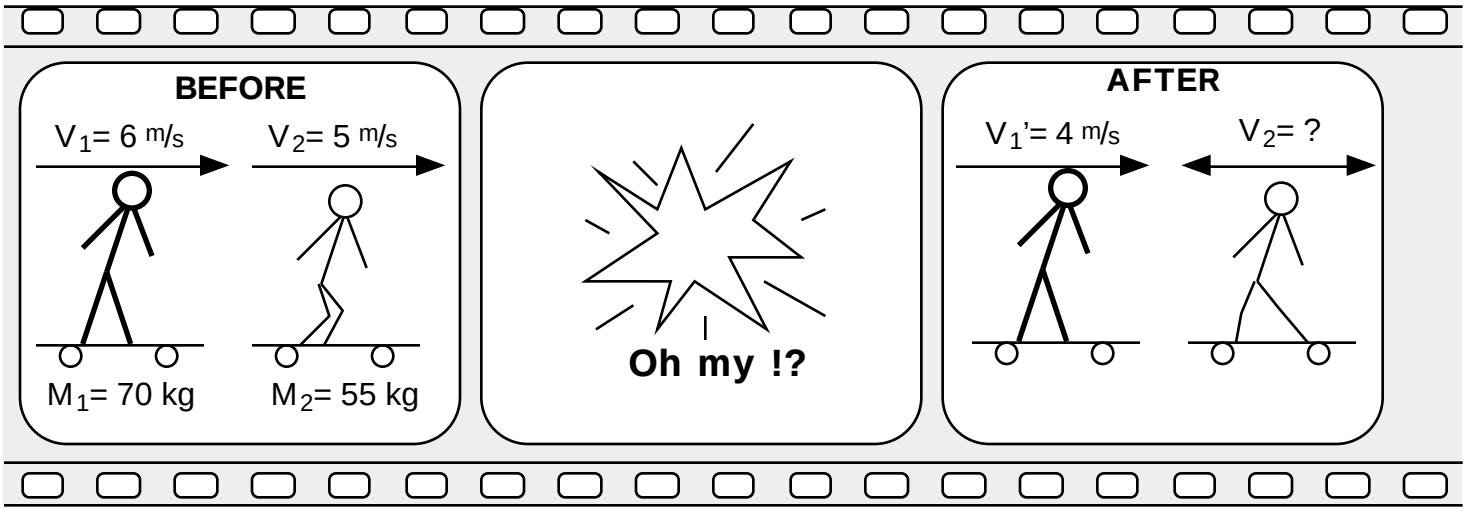
**37**. Two cars collide head on. Car **A** has a mass of 1000 kg car **B** has a mass of 2000 kg. What is the speed of car **B** after the collision?




**38**. Two cars bump going the same direction. Car A has a mass of 1000 kg car B has a mass of 500 kg. What is the speed of car A after the collision?



**39**. 2 skate boarders collide while traveling in the same direction. Skate boarder 1 has a mass of 70 kg and skate boarder 2 has a mass of 55 kg. What is the speed of skate boarder 2 after the collision?




**40**. Two football players collide head-on. The defensive player has a mass of 100 kg the offensive player has a mass of 90 kg. What is the speed of the offensive player after the collision?

| (defense) | (offense) | (defense) |
|---|---|---|
| 100 kg------> | <--------90 kg | 100 kg--> |
| 6 m/s | 2 m/s | 1 m/s |

## INELASTIC

**41**. A loaded train freight car (10 metric tons) rolls at 2 m/s towards a resting car (mass = 2 metric tons). Upon collision the two cars couple (lock together).
a. What is the speed of the two cars after the collision?
b. Calculate the impulse felt by each car.

**42**. A loaded train freight car (10 metric tons) rolls at 2 m/s towards another freight car. The seconds freight car is traveling towards the first at 3 m/s. Its mass is 15 metric tons. Upon collision the two cars couple (lock together).
a. What is the speed and direction of the two cars after the collision?
b. Calculate the impulse felt by each car.

**43**. In problem #2 above suppose the initial velocity of the 15 ton car was not known. After the collision the two cars came to a rest.
a. What was the speed of the seconds freight car before the collision?
b. What impulse was felt by each car?

**44**. Two cars collide in a head on collision. They lock together.

----------> <----------
1200 kg 1500 kg
28 m/s 20 m/s

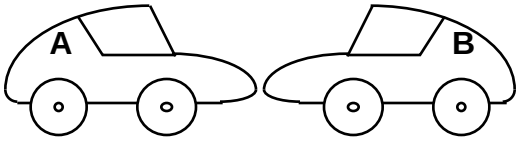
a. What is the speed and direction of the two cars after the collision?
b. Calculate the impulse felt by each car.
c. If the collision lasted 0.7 seconds, what force is felt by each car?

**45**. Two football players collide. The offensive player, mass = 100, was running at 8.00 m/s. A defensive player catches up to the offensive player from behind. The defensive player was traveling 11 m/s when he tackled the other player.
a. What was the speed of the two players after the collision?
b. What impulse is felt by each player?
c. If the collision lasted 0.05 seconds, then what was the force felt by each player?

**46**. Two football players collide head-on. The defensive player has a mass of 100 kg the offensive player has a mass of 90 kg. What is the speed of the two players after the collision if they don't separate?

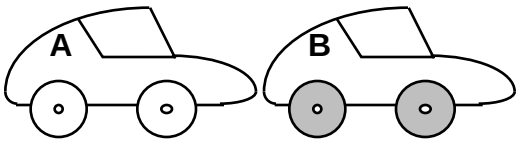
100 kg------> <--------90 kg
6 m/s 2 m/s

**47**. Two cars collide and then stick together in an accident. Car **A** has a mass of 1000 kg car **B** has a mass of 2000 kg. What is the speed of the cars after the collision?




1000kg ------> <------ 2000 kg
5 m/s 2 m/s

**48**. Two cars bump going the same direction and stick together. Car **A** has a mass of 1000 kg car **B** has a mass of 2000 kg. What is the speed of the cars after the collision?

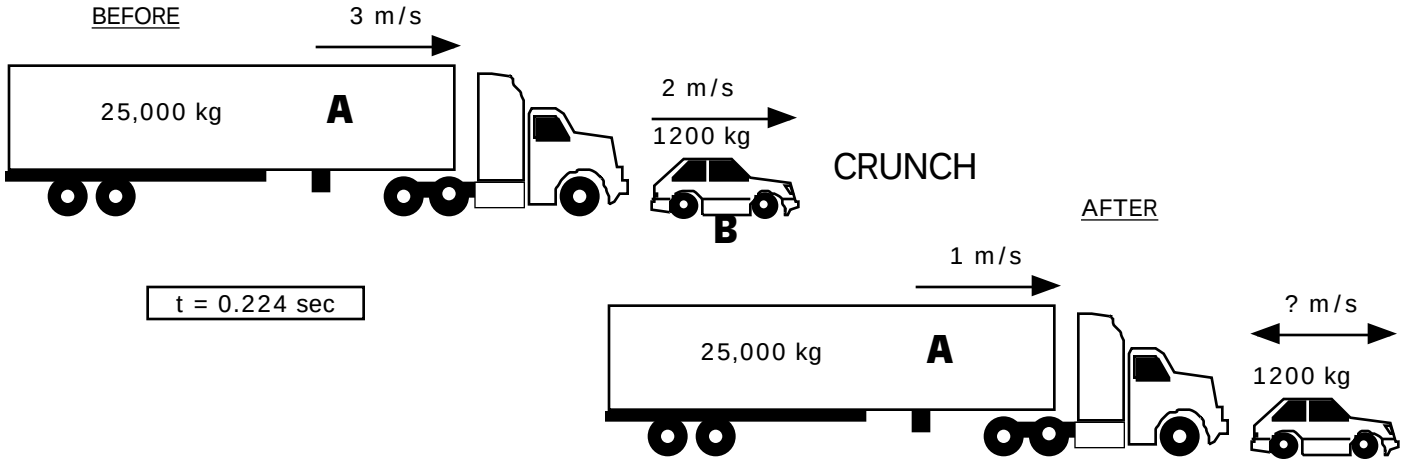



1000kg ------> 2000 kg --->
5 m/s 2 m/s

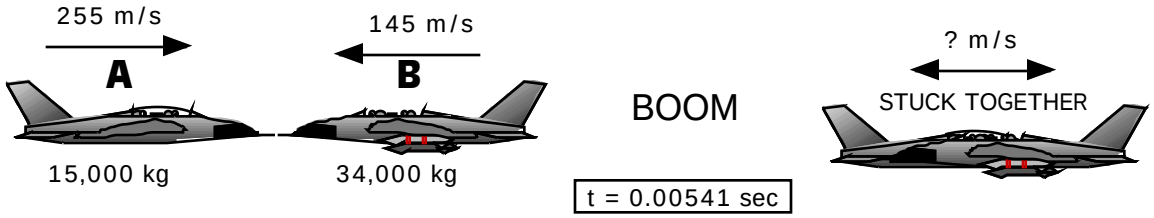
**49.** Two vehicles collide as shown below. For each collision calculate;

(a) ...the unknown velocity.
(b) ...the impulse on vehicle "A."
(c) ...the impulse on vehicle "B."
(d) ...the force of the collision given the times shown. -when shown.

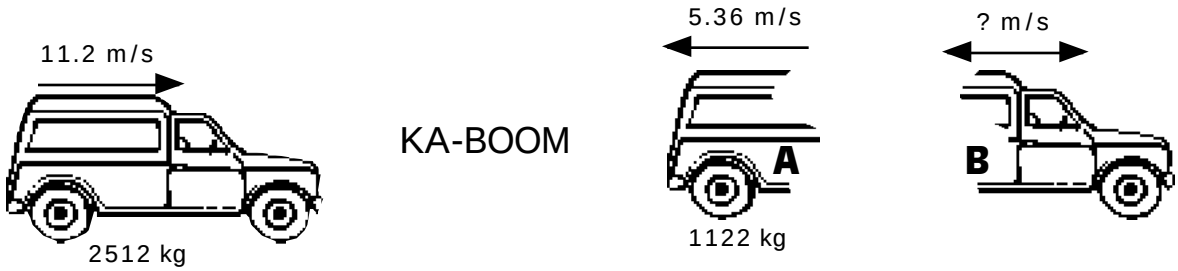
**[A]**



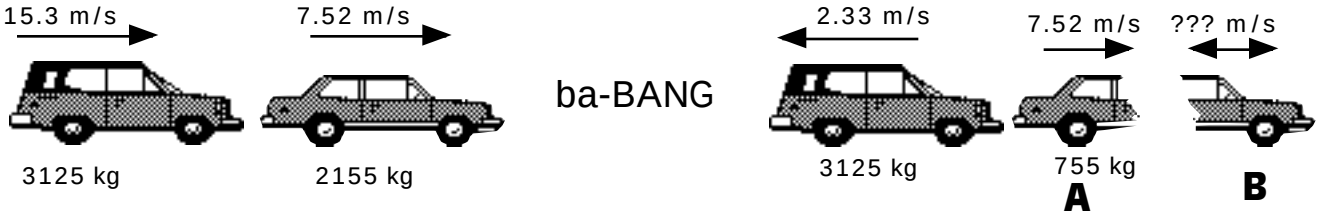

**[B]**




**[C]**

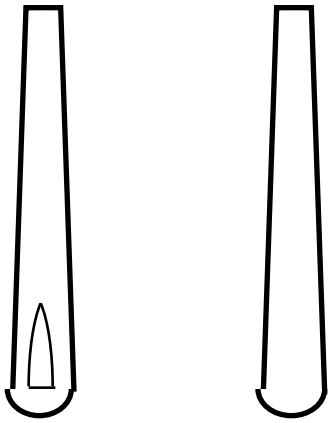


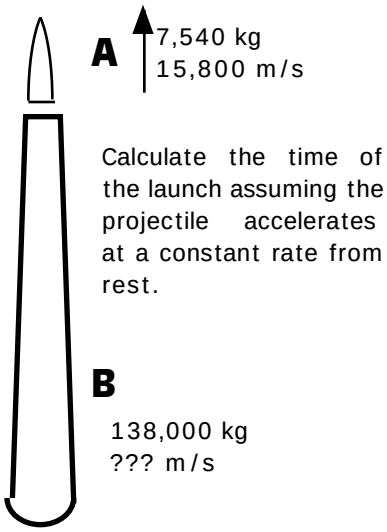

**[D]**



**[E]**

The Baltimore Cannon Club tried to recreate Jules Verne's cannon/ rocket ship. They cast a canon 402 m long to fire the projectile. Given the charge, they calculated a muzzle velocity of 15,800 m/s.

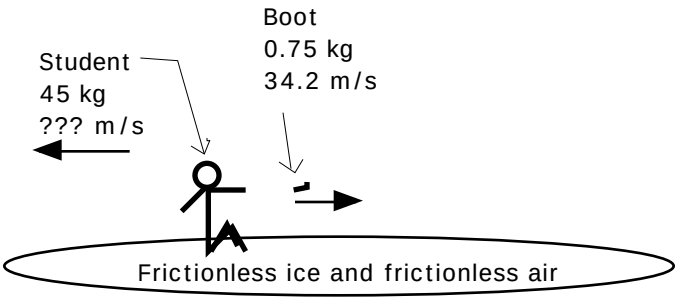





Calculate the time of the launch assuming the projectile accelerates at a constant rate from rest.

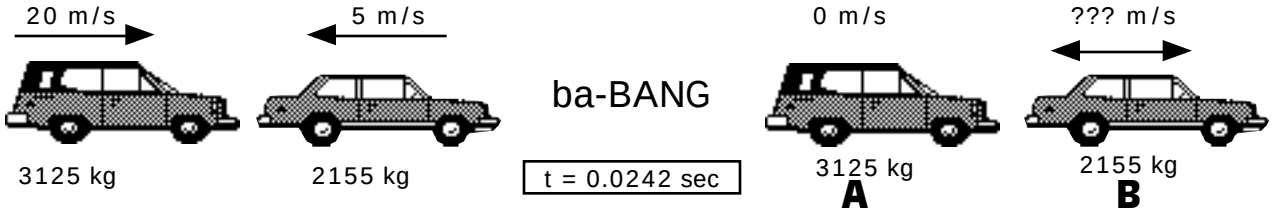
**[F]**

A student is sitting on a lake of frictionless ice at rest. (How he got there nobody knows.) To slide to the other side, he throws his boot.




Additional question: If he has to slide 9.43 m to get to the other side and he slides at a constant velocity, then how much time will it take to reach the shore?

**[G]**




## ANSWERS

| | | | | |
|---|---|---|---|---|
| 1) 700 kg•m/s | 2) 16,000 kg•m/s | 3) 1.88 kg•m/s | 4) 607.39 kg•m/s | 5) 1515.46 kg•m/s |
| 6) 30,369.29 m/s | 7) 1129.81 m/s | 8) 13.59 m/s | 9) 90.6 m/s, 202.94 mph | |
| 10) 8550 kg•m/s | 11) 240 kg•m/s | 12) 3.5 kg•m/s | 13) 6.65 kg•m/s | 14) 20.04 kg•m/s |
| 15) 1050 kg•m/s | 16) 285 N | 17) 2 N | 18) 0.00875 s | 19) 133 N |
| 20) 0.012 s | 21) 21,000 N | 22) | 23) | 24) |
| 25) | 26) | 27) | 28) | 29) |
| 30) | 31) | 32) | 33) | 34) |
| 35) | 36) | 37) -1 m/s | 38) 5 m/s | 39) 9.82 m/s |
| 40) 3.56 m/s | 41a) 5/3 m/s | 41b) ±3333.3 N•s | 42a) -1 m/s | 43b) ±20,000 N•s |
| 44a) 1.33 m.s | 44b) ± 32,000 N•s | 44c) 45,714.29 | 45a) 9.57 m/s | 45b) 154.14 |
| 45c) 3142.86 | 46) 2.21 m.s | 47) 1/3 m/s | 48) 3 m/s | |
| 49[A]a) 43.67 m/s | | 49[A]b) 50,000 N•s | | |
| 49[A]c)−50,000 N•s | | 49[A]d) 223,214.29 N | | |
| 49[B]a) 22.55 M/S LEFT | | 49[B]b) 4,163,265.31N•s | | |
| 49[B]c)-4,163,265.31N•s | | 49[B]d) 769,549,964 N | | |
| 49[C]a) 24.57 m/s | | 49[C]b) 18,581.32 N•s | | |
| 49[C]c) -18,581.32 N•s | | 49[C]d) No Answer | | |
| 49[D]a) 46.87 m/s | 49[D]b) OMIT | 49[D]c) OMIT | 49[D]d) OMIT | |
| 49[E]a) | 49[E]b) | 49[E]c) | 49[E]d) | |

49[F]a) 49[F]b) 49[F]c) 49[F]d) 49[F]Additional)

49[G]a) 49[G]b) 49[G]c) 49[G]d)