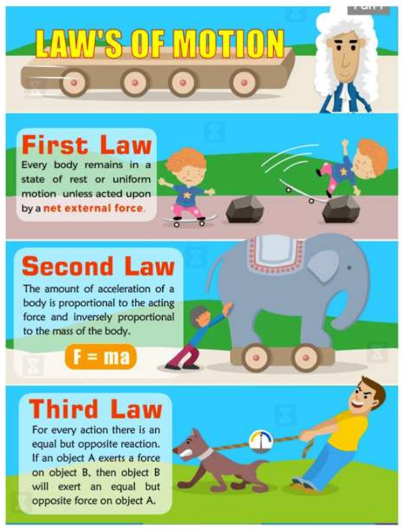
Lecture 5 – Motion and Newton's Laws



Clicker Question

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$$\left.\begin{array}{l} \underline{T = 100\text{ N}} \\ W = mg = 100\text{ N} \end{array}\right\} F_{net} = ma = 0$$

Clicker Question

Bob is standing in an elevator that is accelerating downward at 3 m/s^2. Bob's mass is 100 kg. What is the normal force that the elevator floor exerts on Bob's shoes?

A. 700 N down
B. 700 N up
C. 300 N down
D. 300 N up
E. 1300 N down
F. 1300 N up

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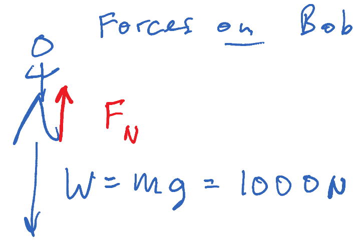
Forces on Bob



Newton's 2nd Law: $F = ma$

$F_N - W = ma = -300\ N$

$F_N = W - 300N = 700\ N$

Clicker Question

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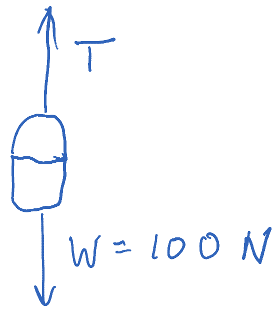


$$F_{net} = T - W = ma$$

$$T - W = 10\,\text{kg}\left(-4\,\frac{\text{m}}{\text{s}^2}\right) = -40\,\text{N}$$

$$T = -40\,\text{N} + 100\,\text{N} = \underline{\underline{60\,\text{N}}}$$

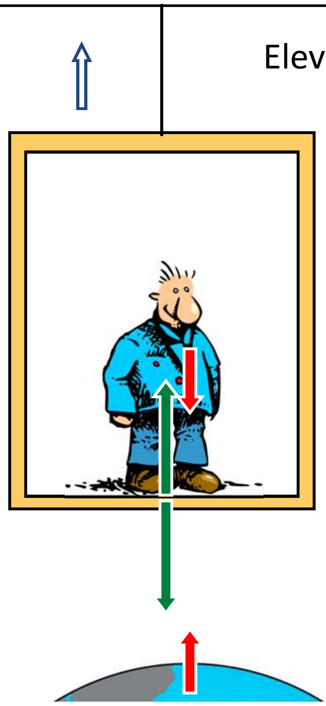
Newton's Law of Force Pairs

Newton's 3rd Law

If object A exerts a force on object B, then object B exerts an equal and opposite force on object A.

- Force pairs are sometimes called "action & reaction".
- There is no difference in principle between the two.
- So no way to decide which is "action" and which "reaction".
- Note that action/reaction force pairs always act on different bodies!

Elevator is accelerating upward at 10 m/s^2



Clicker Question

A skydiver is falling at terminal velocity. The Newton 3rd law (action/reaction) partner to the **skydiver's weight** is given by:

A. The force of gravity pulling up on the Earth.
B. The force of air resistance pushing up on the skydiver.
C. The skydiver's body pushing down on the air via air resistance.
D. The force of gravity pulling down on the skydiver.
E. At terminal velocity, that force is zero.

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Clicker Question

An apple that weighs 2 N is dangling from a tree. The gravitational force that the apple exerts on the Earth is

A. 2 N downward
B. 2 N upward
C. Zero
D. Much smaller than 2 N, but not zero

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Head-on collision!

Which is greater, the force of the car on the truck, or the force of the truck on the car?

A. The force the truck exerts on the car is greater.
B. The force the car exerts on the truck is greater.
C. The forces are the same.
D. It depends on which vehicle is moving faster.

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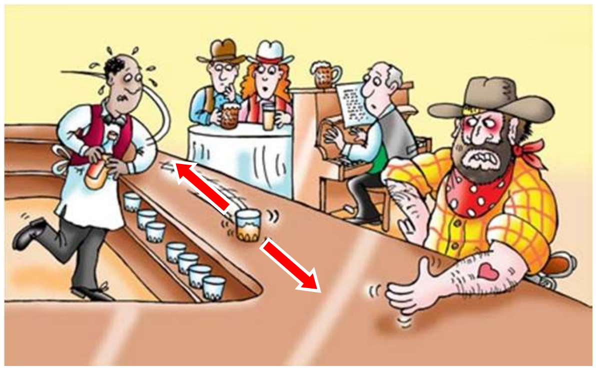
Static frictional forces

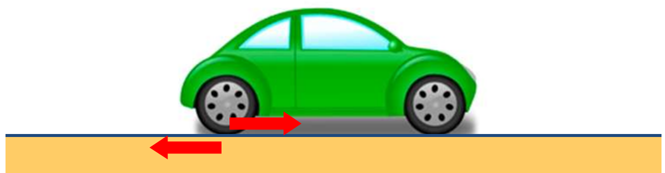
Sliding frictional forces



How does a car move?

But what is it, really?

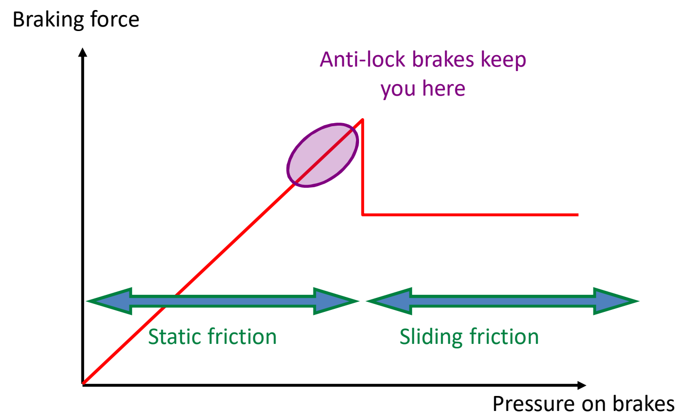
How does a car move?



Force of static friction!

Automotive physics I: Antilock brakes

Static friction can be stronger than sliding friction!



Clicker Question

Which statement about friction is correct?

A. Static friction is always greater than sliding friction.
B. Static friction is always less than sliding friction.
C. Static friction is always the same as sliding friction.
D. Static friction is never zero.
E. Static friction can be greater or less than sliding friction.

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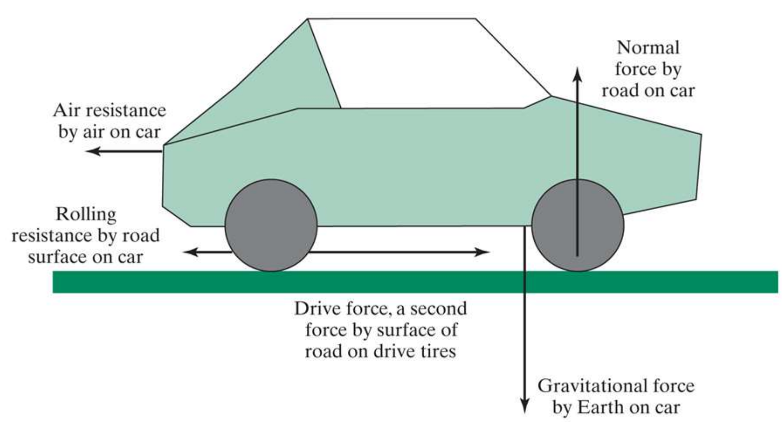
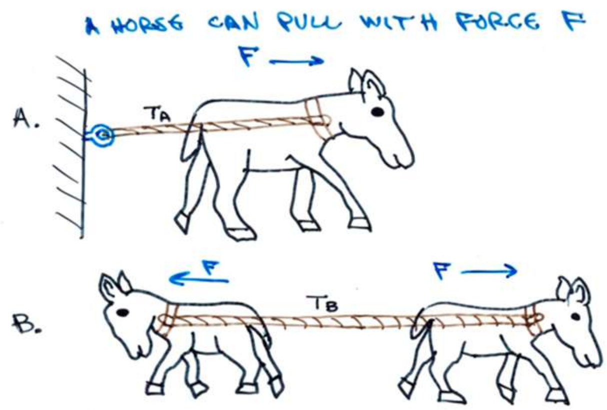
Summary: Newton Meets the Automobile

Note that the drive wheels are powered by the engine through the transmission. This is the forward force that moves the car.



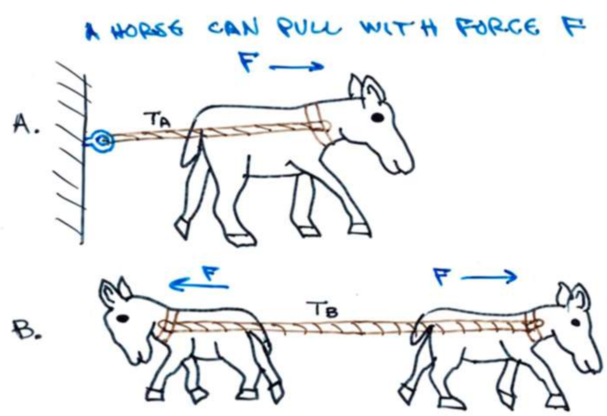


Which is true?

A) Rope tension T_B is the same as T_A

B) Rope tension T_B is twice T_A

C) Rope tension T_B is half T_A



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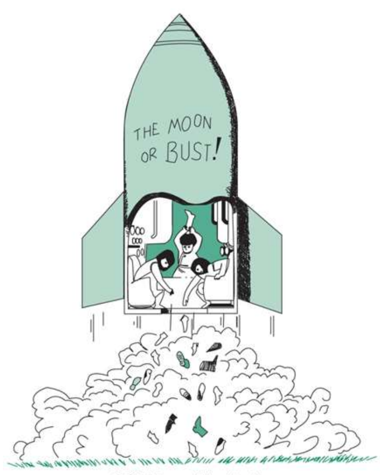
Rocket Propulsion: Recoil

"Rapid Unscheduled Disassembly"

Rocket Propulsion: Recoil



Self-propelled objects move by pushing back against the surroundings:

- A car pushes back on the road in order to move forward.
- A swimmer pushes the water back in order to move forward
- An airplane engine pushes air back in order to move forward.

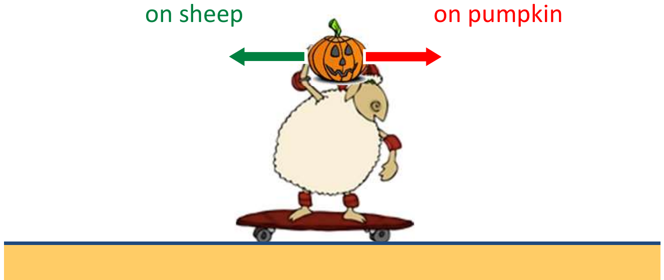
But suppose you are in a spaceship. There's nothing around to push backward – how are you going to move forward?

Rocket Propulsion: Recoil

- The rocket fuel acts as a "propellant".
- Combustion products of burning fuel are pushed out the back at high speed.
- The reaction force on the rocket pushes the rocket forward.
- This is also called "recoil".

Rocket Propulsion: Recoil

Rocket Propulsion: Recoil

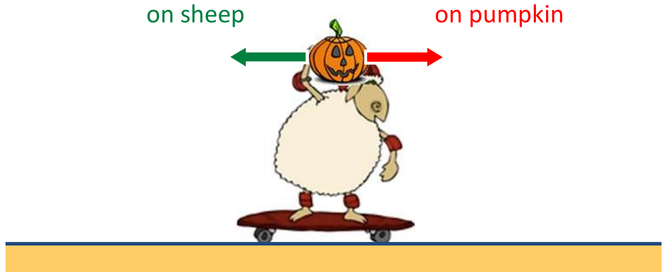


PEANUTS

Rocket Cart Demo

Momentum

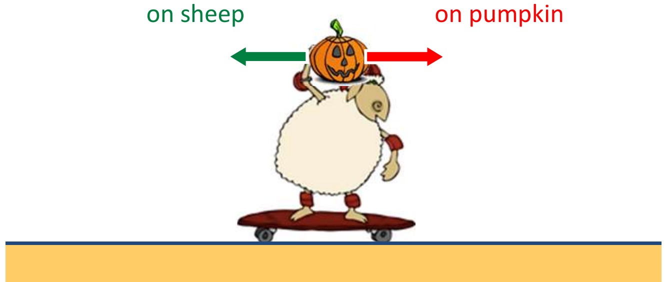
Momentum = mass × velocity



Conservation of Momentum

Force by pumpkin on sheep

Force by sheep on pumpkin



$$\text{Force on sheep} = -\,\text{Force on pumpkin}$$

$$(\text{mass})_{sheep} \times (\text{acceleration})_{sheep} = -\,(\text{mass})_{pumpkin} \times (\text{acceleration})_{pumpkin}$$

$$(\text{mass})_{sheep} \times (\text{velocity change})_{sheep} = -\,(\text{mass})_{pumpkin} \times (\text{velocity change})_{pumpkin}$$

$$(\text{momentum change})_{sheep} = -\,(\text{momentum change})_{pumpkin}$$

$$(\text{momentum change})_{sheep} + (\text{momentum change})_{pumpkin} = 0$$

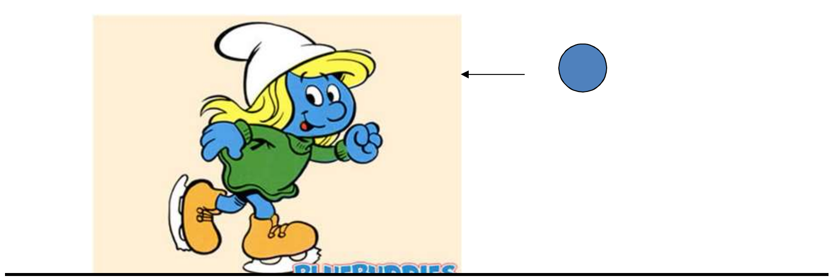
$\text{total momentum change} = 0$ “momentum is conserved”

$$(\text{total momentum})_{before} = (\text{total momentum})_{after}$$

Initially:

30 kg
0 m/sec

0.5 kg
15 m/sec



What is the final velocity of Smurfette after she catches the ball?

Solution

Momentum = mass × velocity

$(\text{Total momentum})_{before} = (\text{Total momentum})_{after}$

Define left to be negative and right to be positive.

Before collision: Total Momentum = (30kg*0m/s) – (0.5kg*15m/s)

After collision: Total Momentum = - (30kg +0.5kg) * v

(velocity of Smurf and ball is the same after the catch.)

(30kg*0m/s) – (0.5kg*15m/s) = - 30.5kg *v

Solving for v ➔ v= 0.25 m/s to the left