

Lecture 06:

Forces and Newton's Laws

part 1

May the force be with... Nah, too easy a joke

Erik Lascaris

Announcements

- Discussion sections this week in SCI-B58
 - You'll work together in small group, solving a problem (the "Quiz")
 - After 20-25 min your TF will discuss and explain the problem
- HW #2 was due yesterday!
 - Not enough time to finish it? Email me for an extension.
(Better to finish late than to lose an opportunity to learn physics!)
 - Warning: you'll need to work harder, because you need to finish HWs before midterm!
- HW #3 is online!
 - Due next Tuesday at midnight
- I'm trying to record these lectures using video
 - If successful, will be posted on Blackboard or Piazza

Some notes about velocity & acceleration

Problems with two moving objects

- Two cars...
- Two cyclists..

Rule: if two objects are moving, you got twice the number of equations!

$$x_1 = x_{1i} + v_{1i}t + \frac{1}{2}a_1t^2$$

$$v_1 = v_{1i} + a_1t$$

$$v_1^2 = v_{1i}^2 + 2a_1(x_1 - x_{1i})$$

$$x_2 = x_{2i} + v_{2i}t + \frac{1}{2}a_2t^2$$

$$v_2 = v_{2i} + a_2t$$

$$v_2^2 = v_{2i}^2 + 2a_2(x_2 - x_{2i})$$

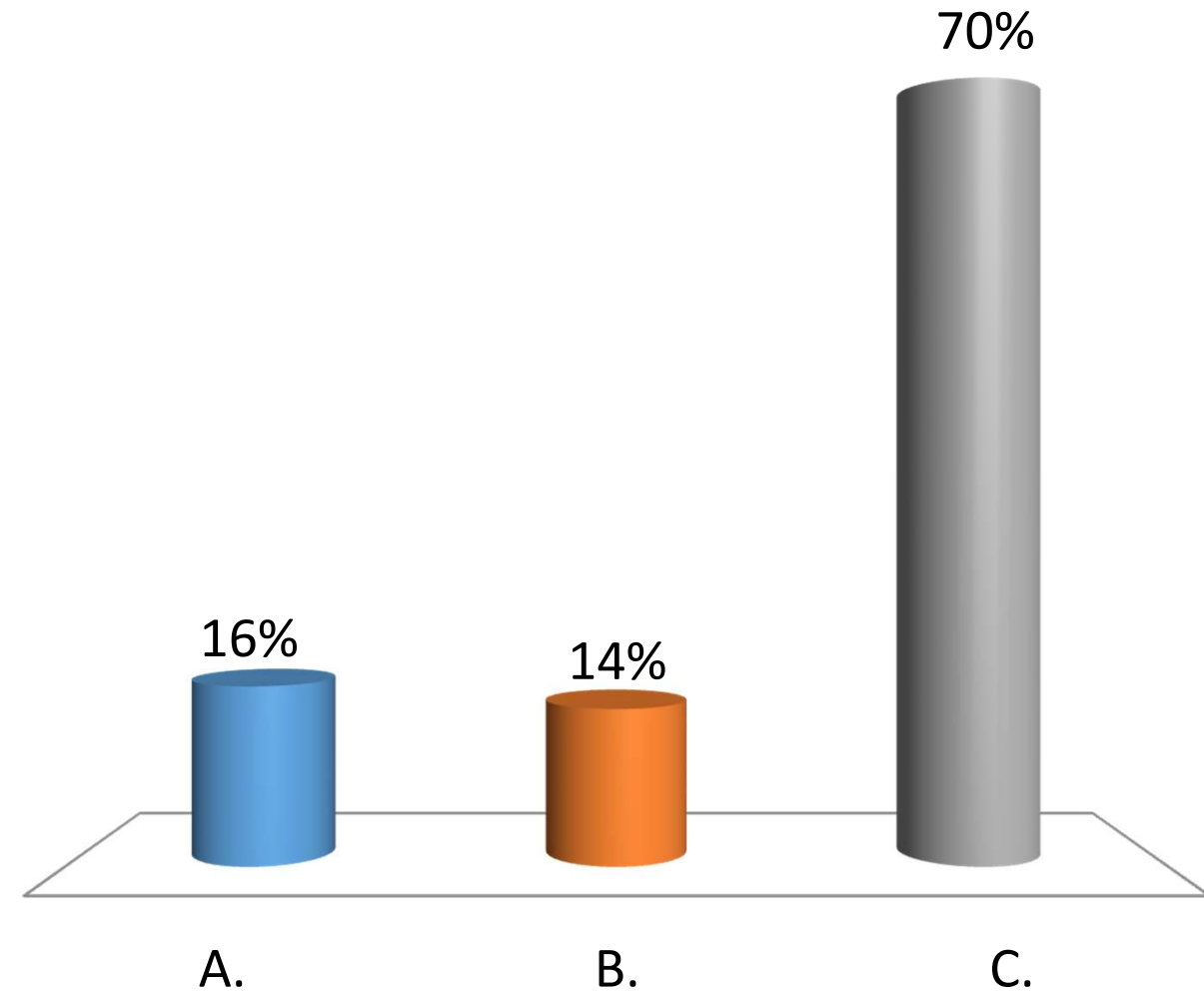
Make sure to use different labels for things that may have different values!

What is the initial velocity v_{2i} of car 2?

Problem from HW #2:

...
Note that car 2 starts from rest with an initial position of 0 m. With these settings, car 2 will not catch car 1 before the simulation stops, but assume that the motions continue beyond this point. However, you can use the simulation with different settings to test your ideas about when something will happen. Car 1 travels at constant velocity.
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- A. It doesn't say in the problem
- B. You can probably calculate it
- C. It's definitely zero.



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- A. It doesn't say in the problem
- B. You can probably calculate it
- C. It's definitely zero. $v_{2i} = 0$**

**Keep an eye out for "hints"
in a physics problem!**

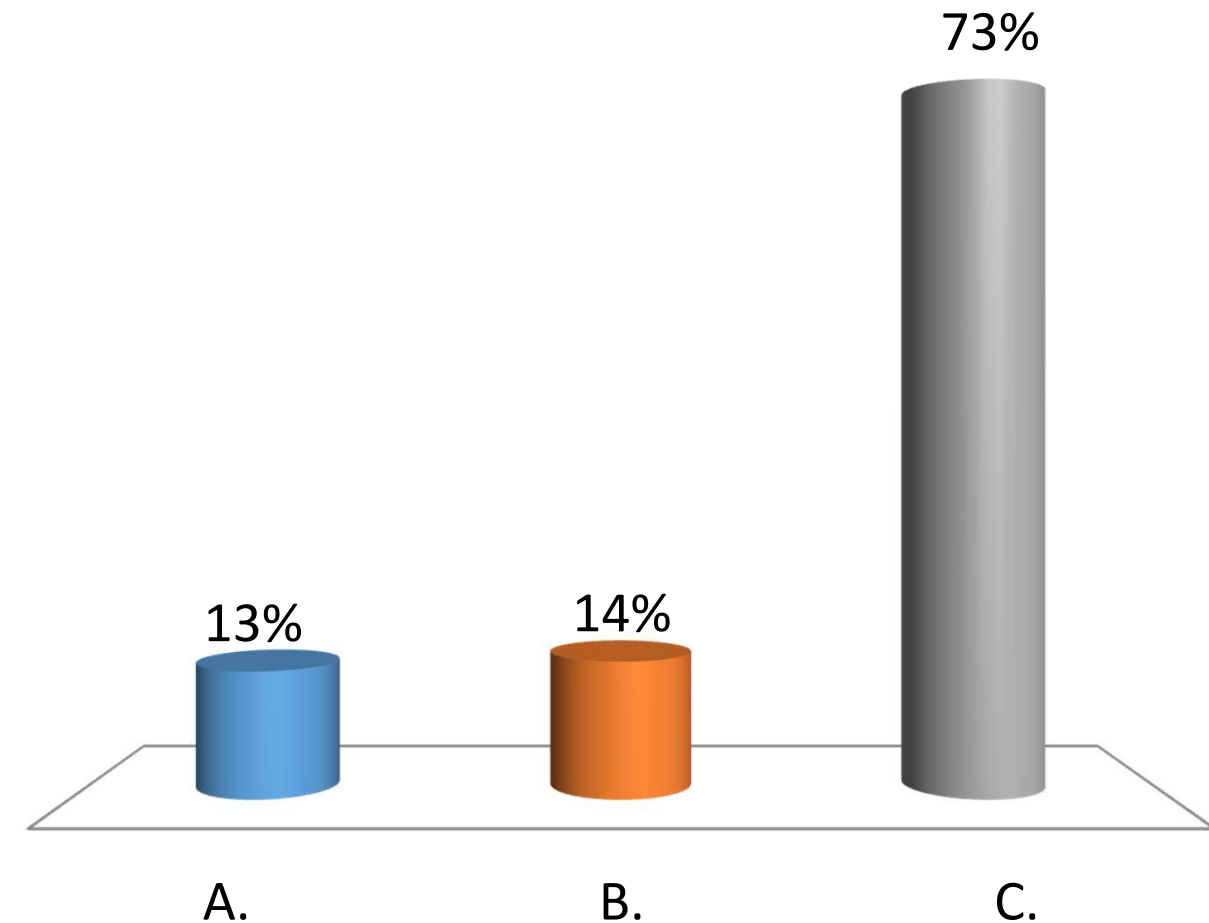
Phrases like "**starts from rest**" or "**initially at rest**" indicate $v_i = 0$.

What is the acceleration a_1 of car 1?

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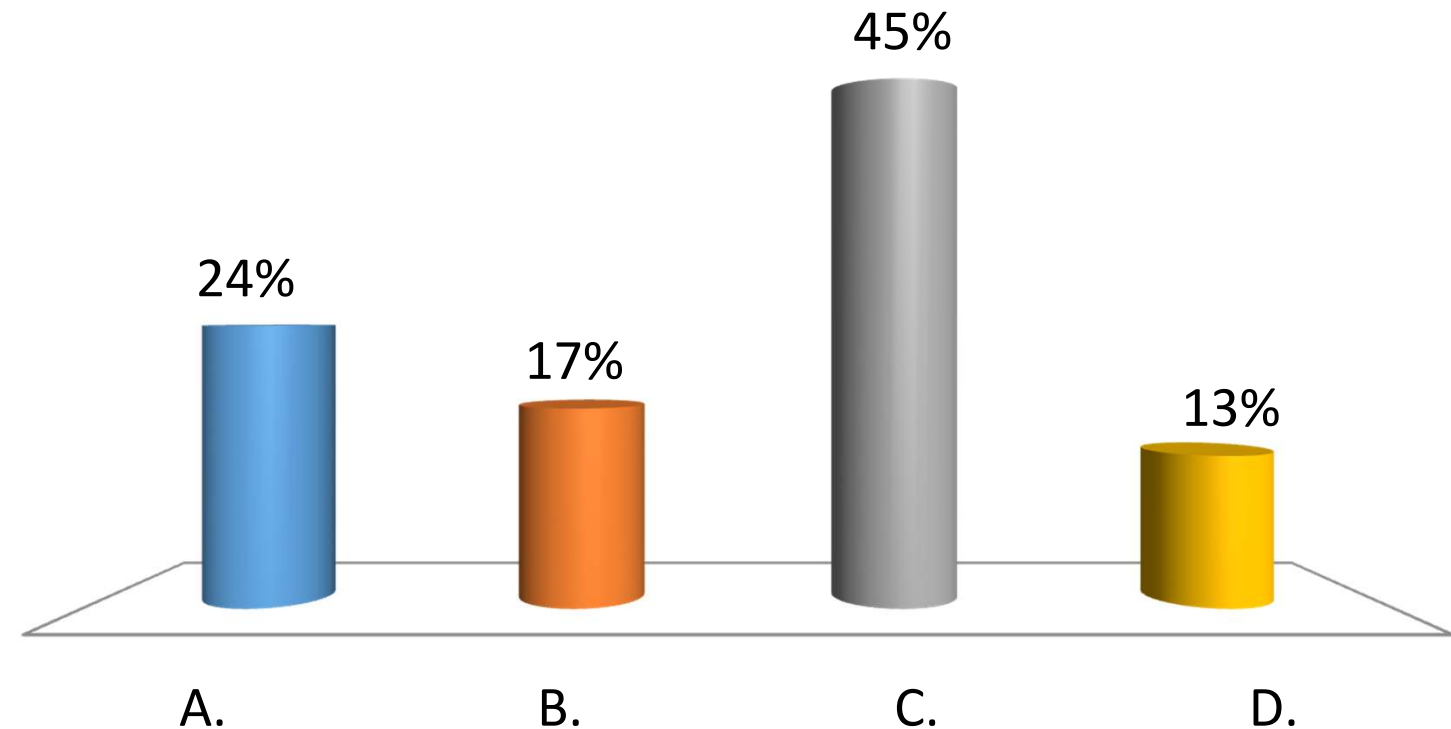
Notice that "**constant velocity**" means car 1 does not speed up, so there is no acceleration: **$a_1 = 0$** .

True or False?

Claim:

The equation $v = d/t$ (speed = distance/time) can always be used.

- A. TRUE! That's the *definition* of speed.
- B. True, you can always use that equation.
- C. False, there are a few exceptions.
- D. FALSE! This only works in *rare* circumstances.



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In most cases, this equation is FALSE!

It is only true for the average speed:

$$v_{\text{avg}} = \frac{d}{t}$$

or if there is no acceleration, $a = 0$:

$$x = x_i + v_i t + \frac{1}{2} a t^2$$

where the distance is $d = x - x_i$

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Forces & Newton's Laws

Today's Concepts

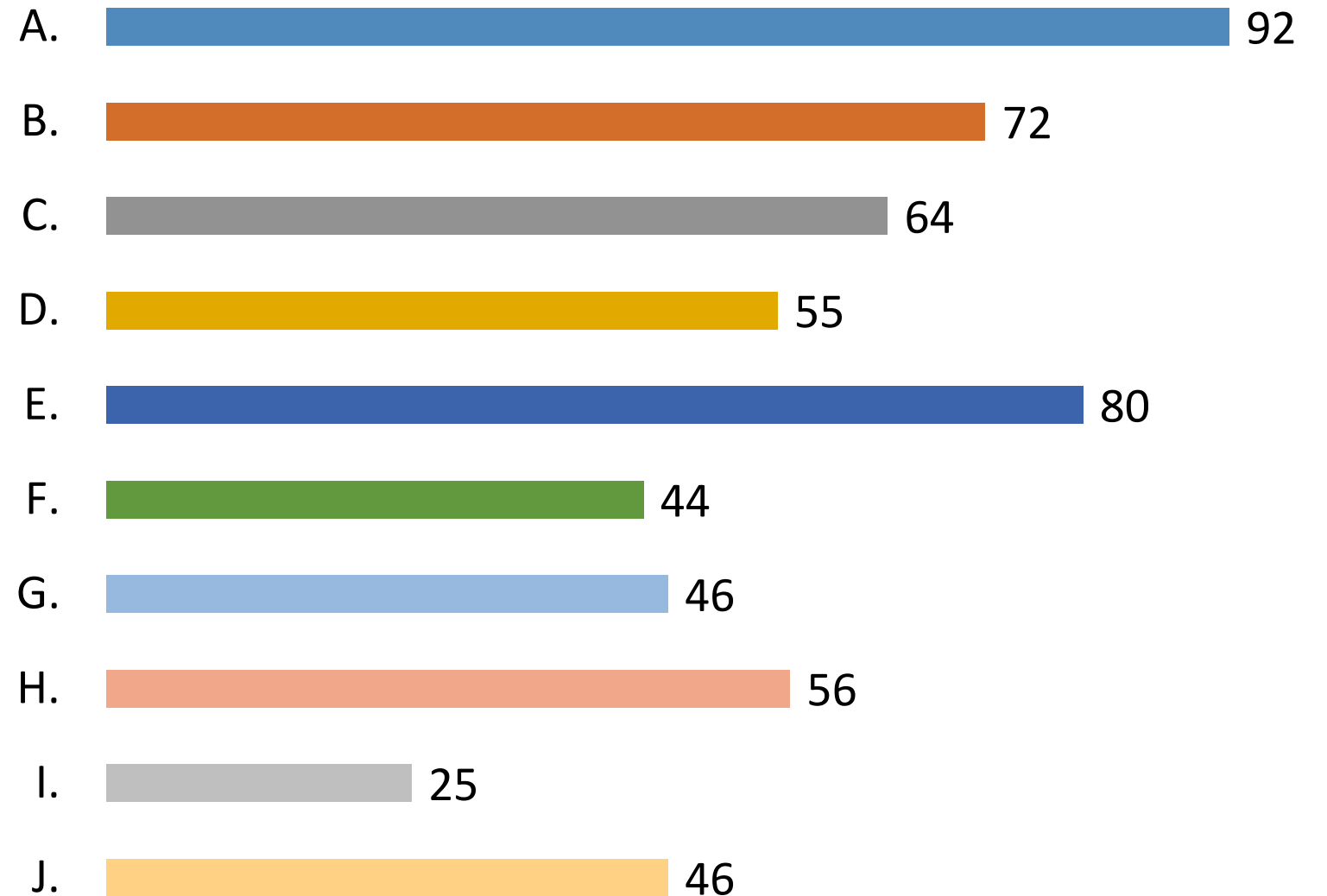
- Force, F
- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Force of gravity, F_g
- Force of tension, F_T
- The normal force, F_N
- Force of friction, F_f
- Spring force, F_s
- Free body diagram

- Will be covered in today's lecture
- Make sure you'll know their meaning!

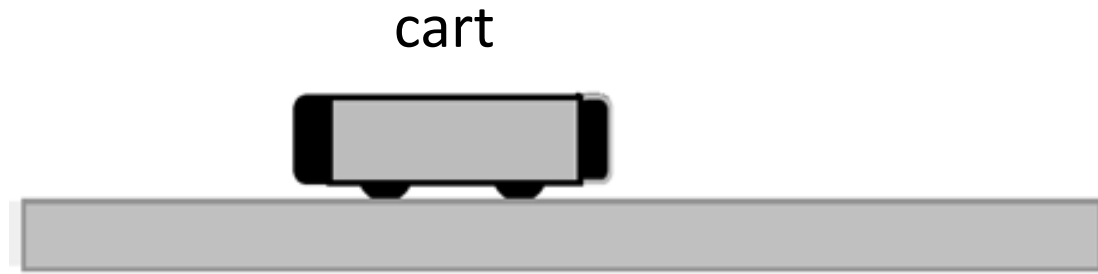
Textbook Chapter 3

Which concepts are you already familiar with?

- A. Force, F
- B. Newton's First Law
- C. Newton's Second Law
- D. Newton's Third Law
- E. Force of gravity, F_g
- F. Force of tension, F_T
- G. The normal force, F_N
- H. Force of friction, F_f
- I. Spring force, F_s
- J. Free body diagram



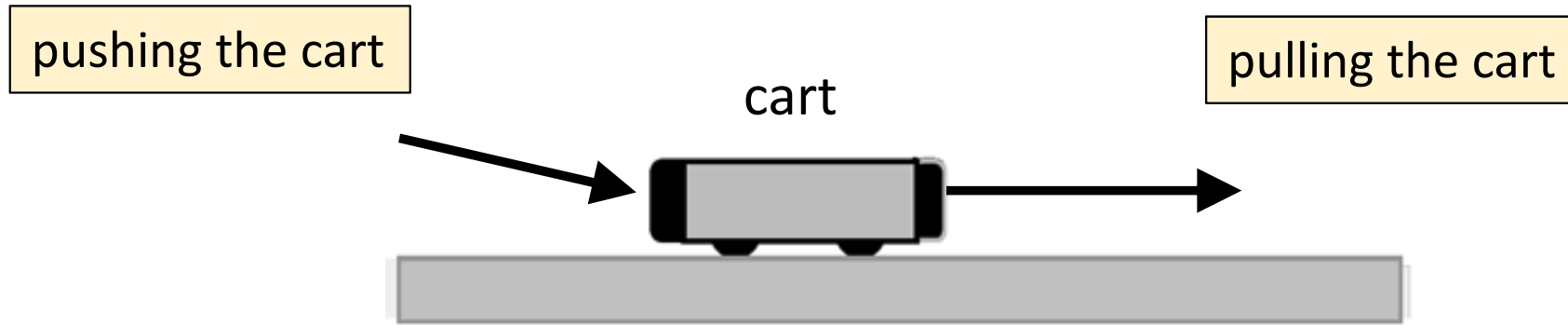
What makes an object move?



ball



What makes an object move?

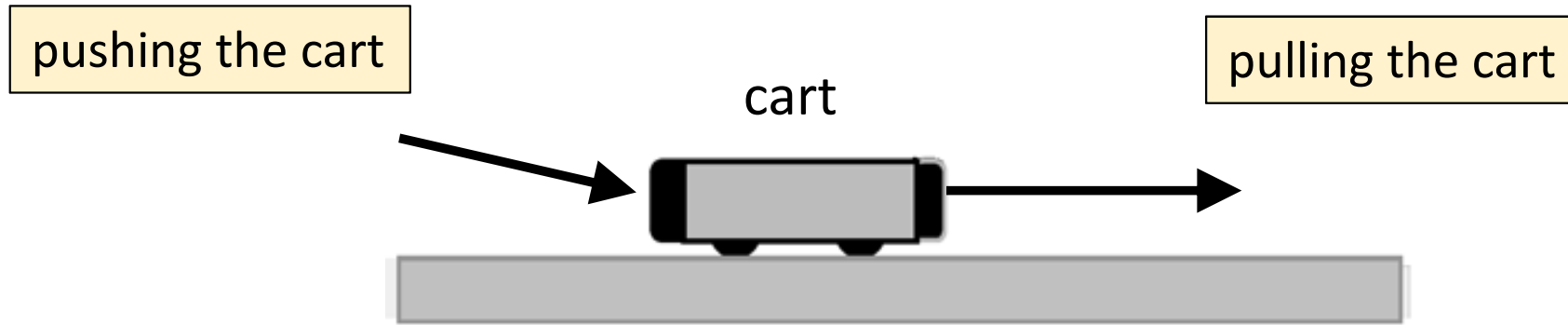


ball



gravity pulling a ball down

What makes an object move?



Objects move because something is pushing or pulling it

We refer to the amount of pushing/pulling as the force.

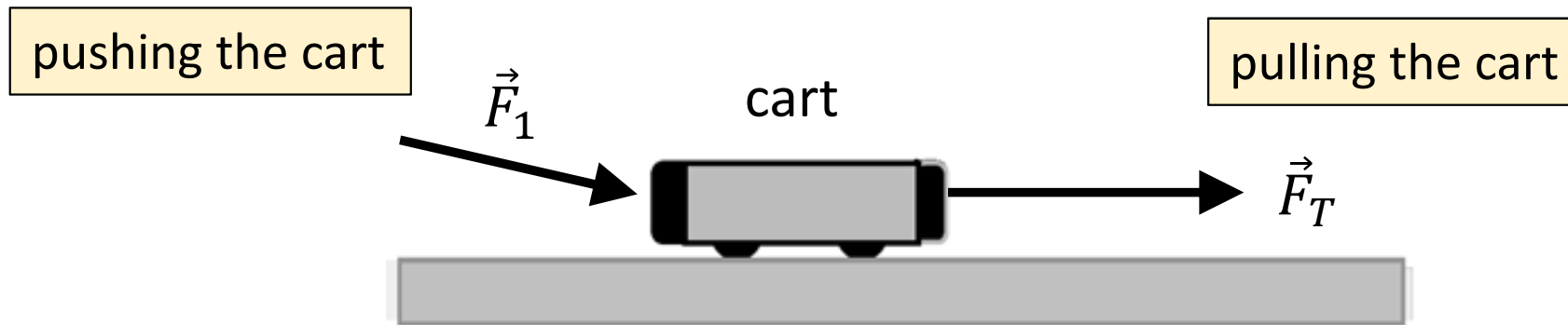
An object moves because a force \vec{F} is applied to it.

ball



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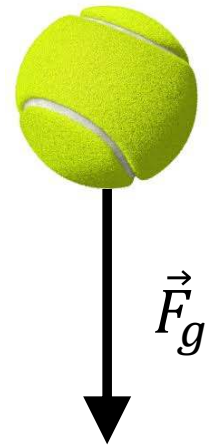


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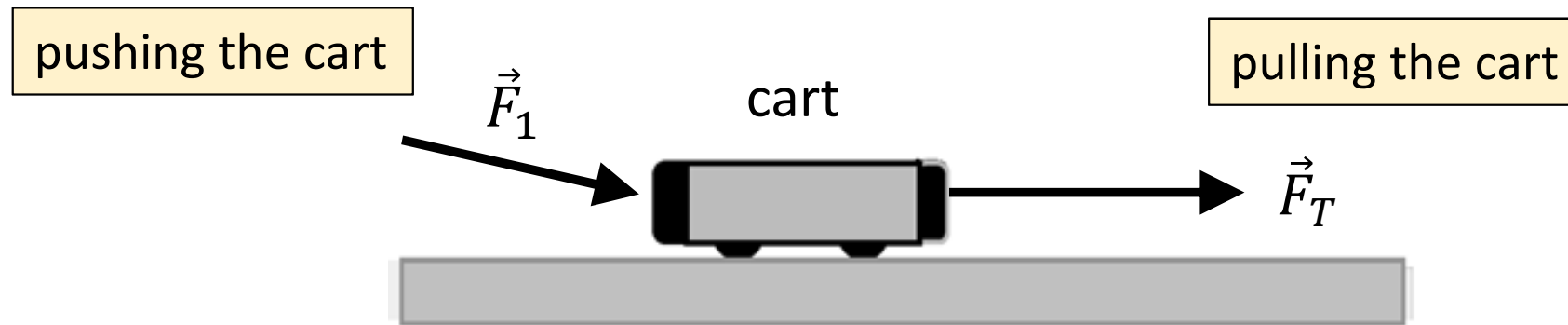
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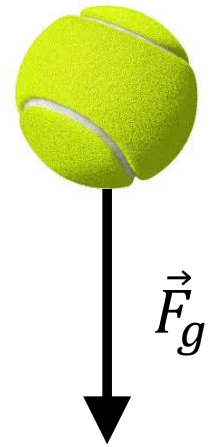


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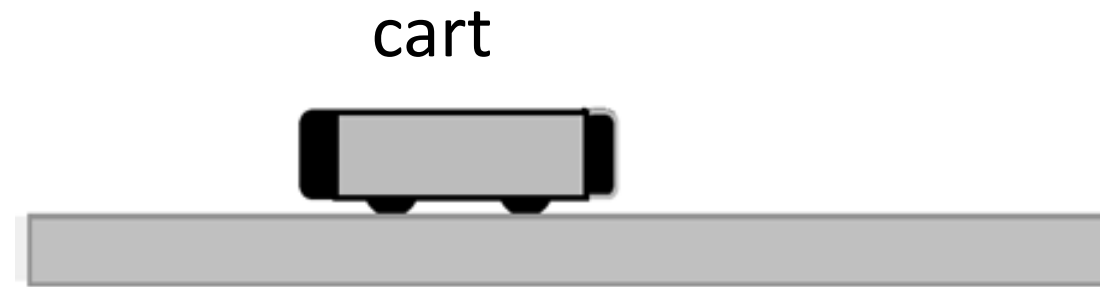


gravity pulling a ball down

Notice that force \vec{F} is a vector!
It has direction and magnitude.

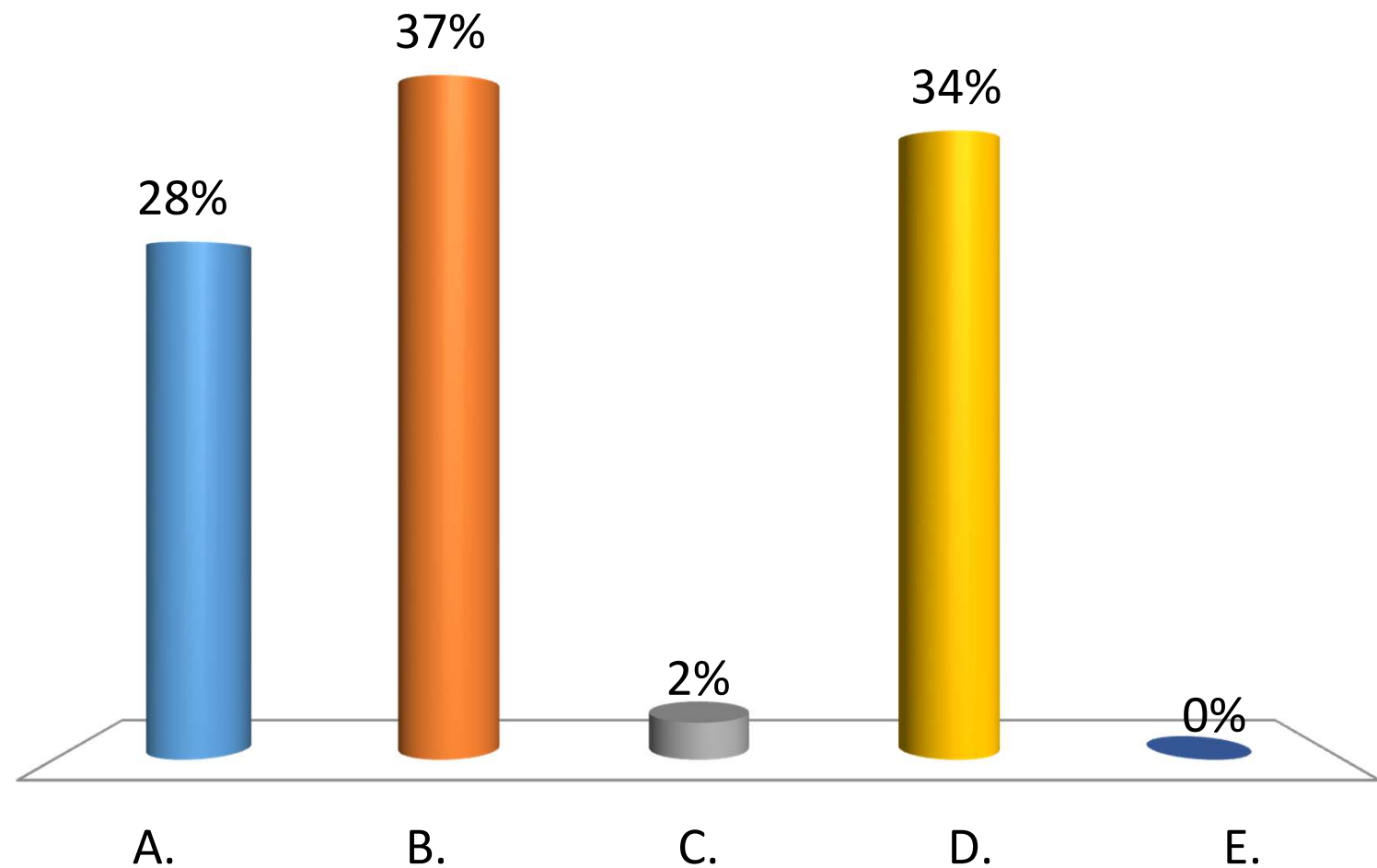
Demo #1

- Which forces are being applied to the cart?



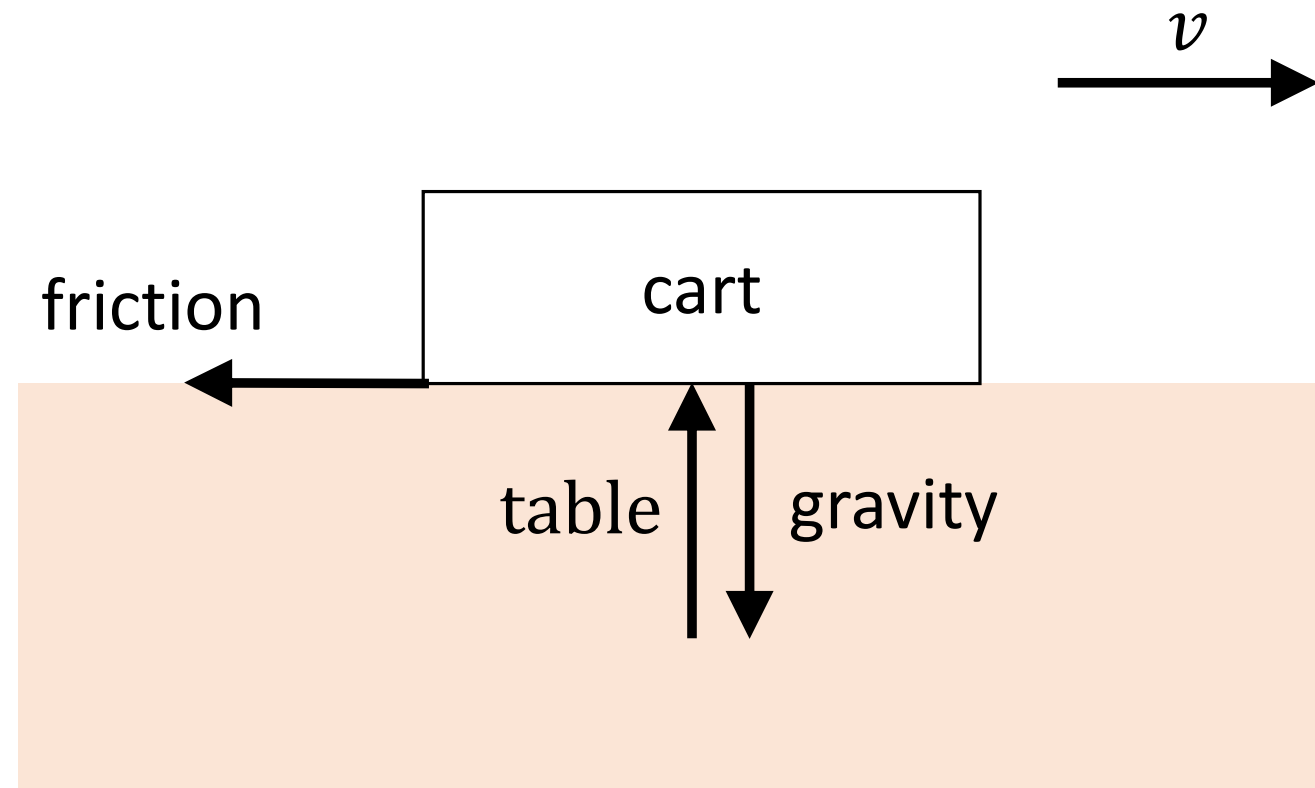
Which forces are acting on the cart?

- A. Force of gravity
- B. Force of friction
- C. Force of tension
- D. Table "pushing" the car up
(cancelling force of gravity)
- E. Force of a spring



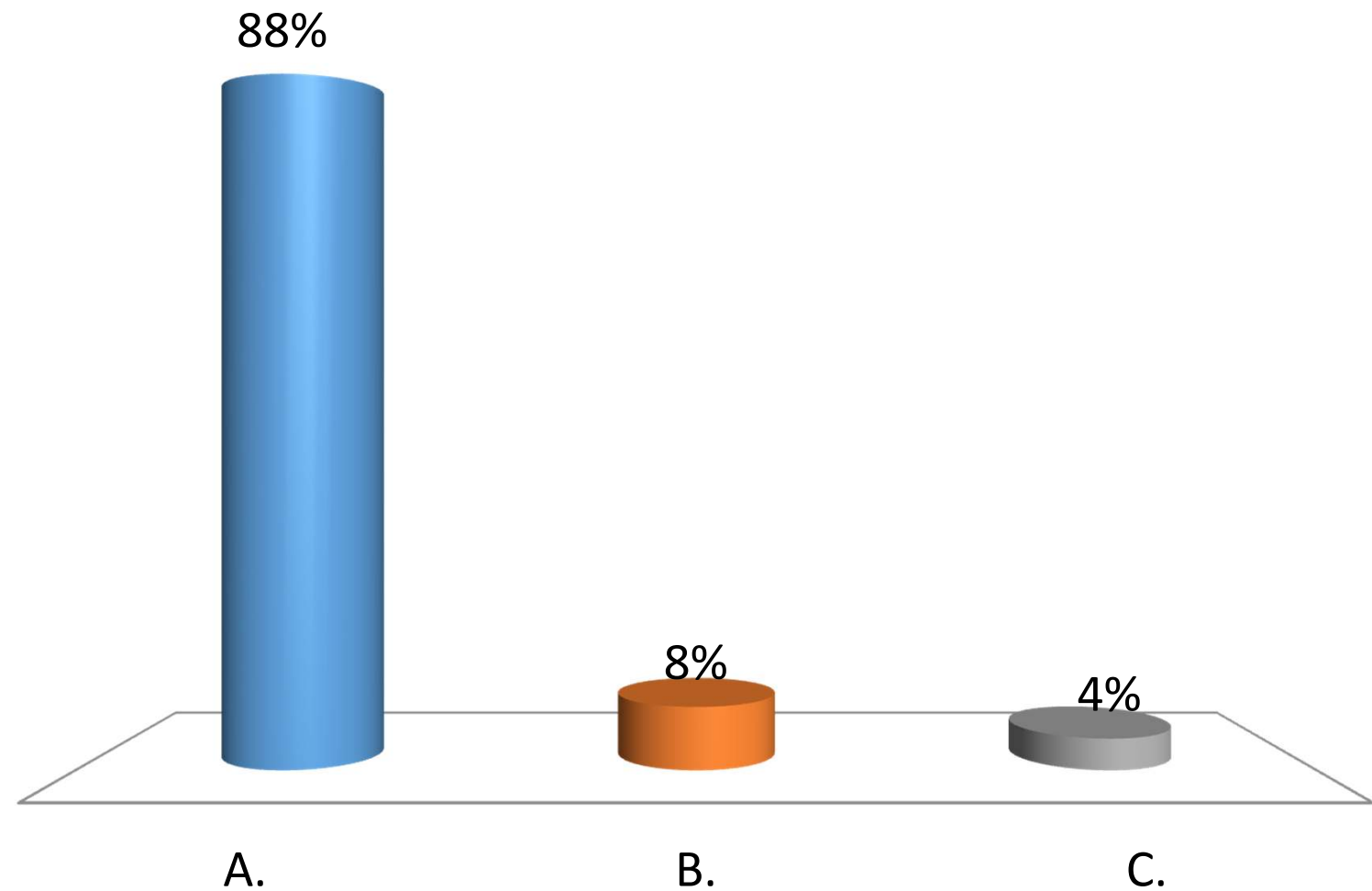
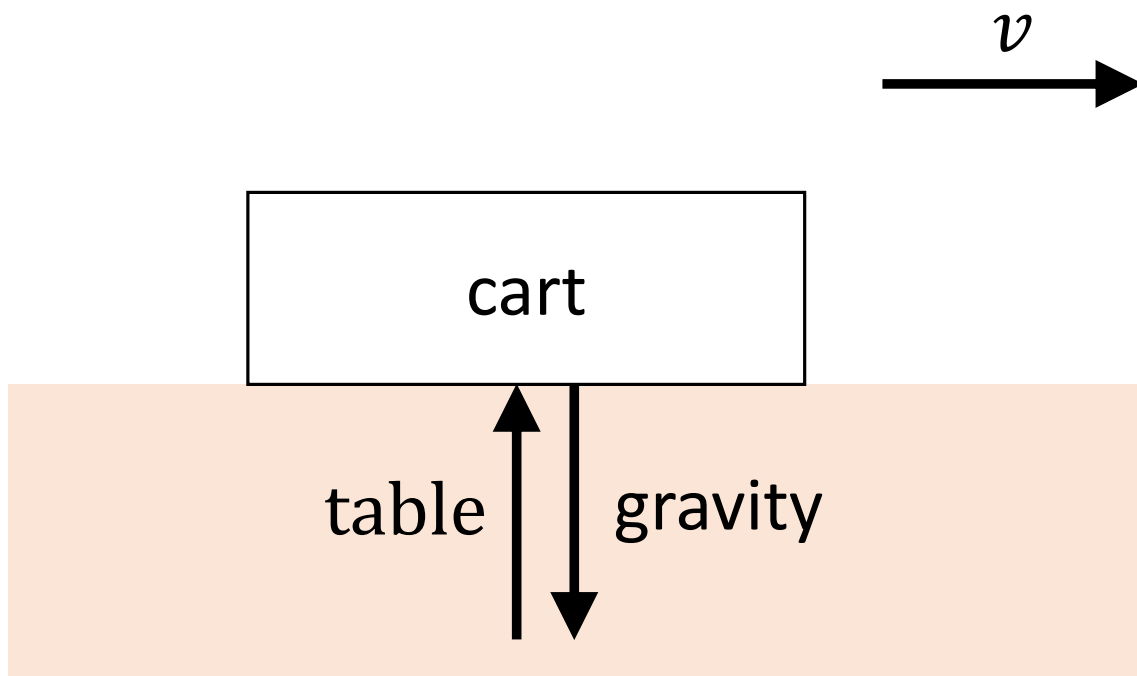
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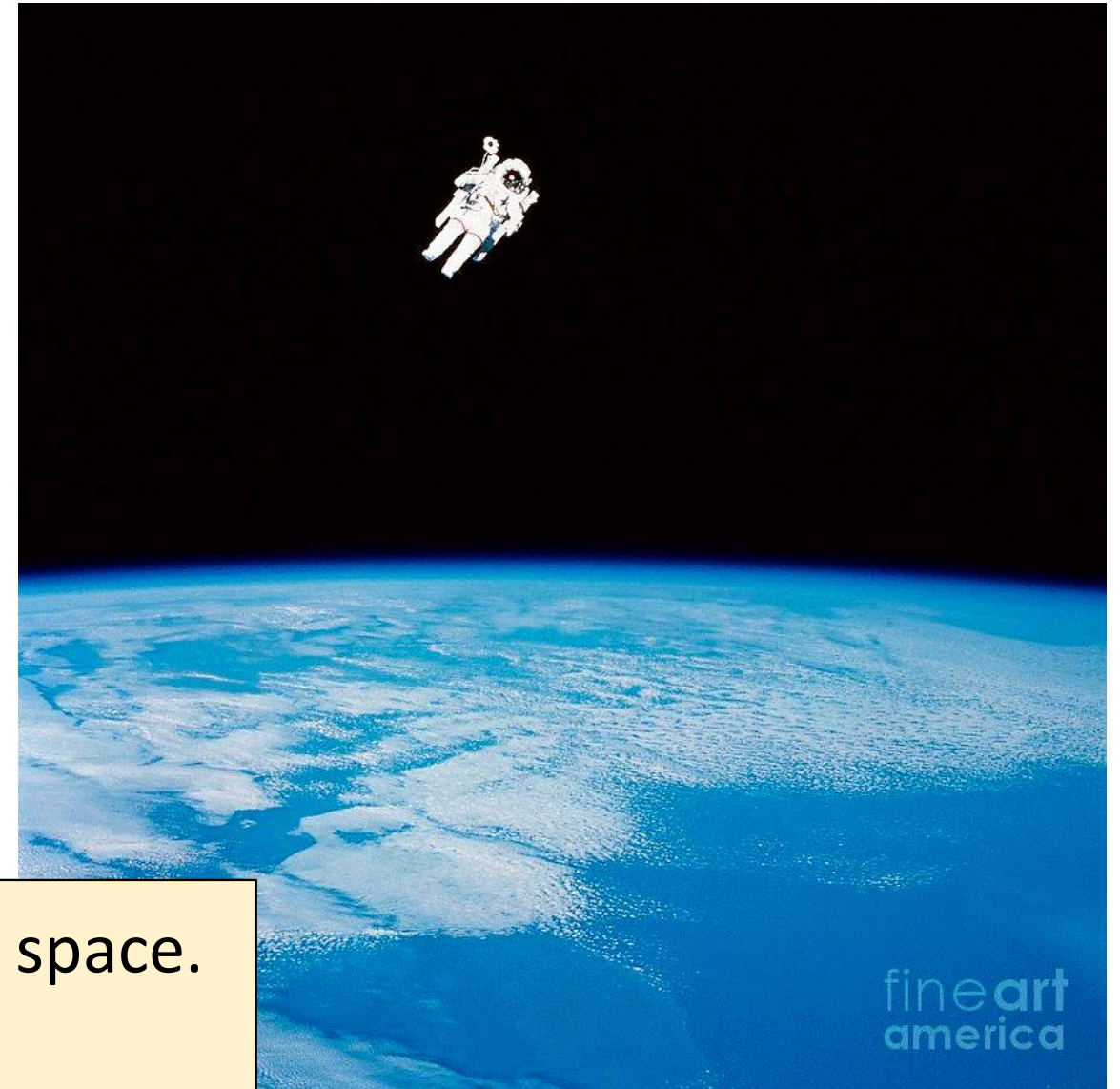
What happens if there was no friction?

- A. Cart would keep moving
- B. Cart would stop eventually
- C. Cart would go faster and faster



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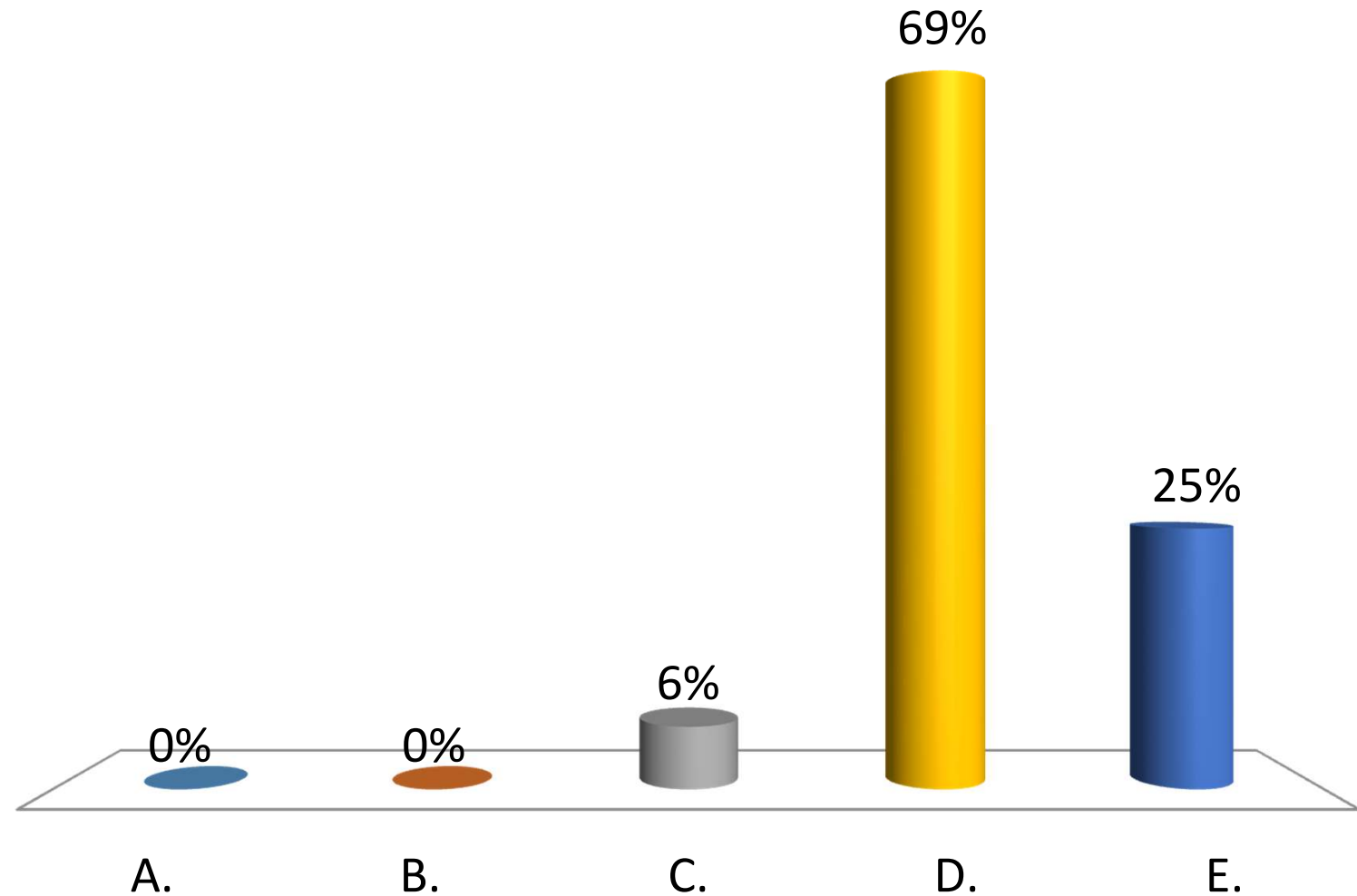
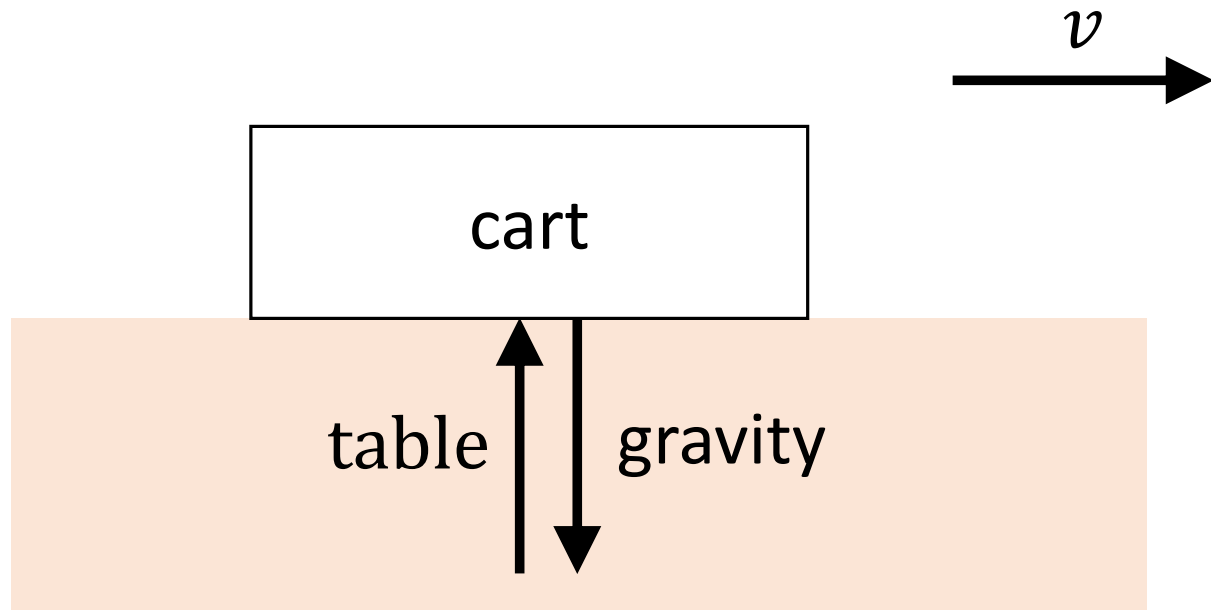
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If this is weird to you, imagine an astronaut in space. One little push, and the poor guy will drift away for ever and ever...

In which direction is the net force?

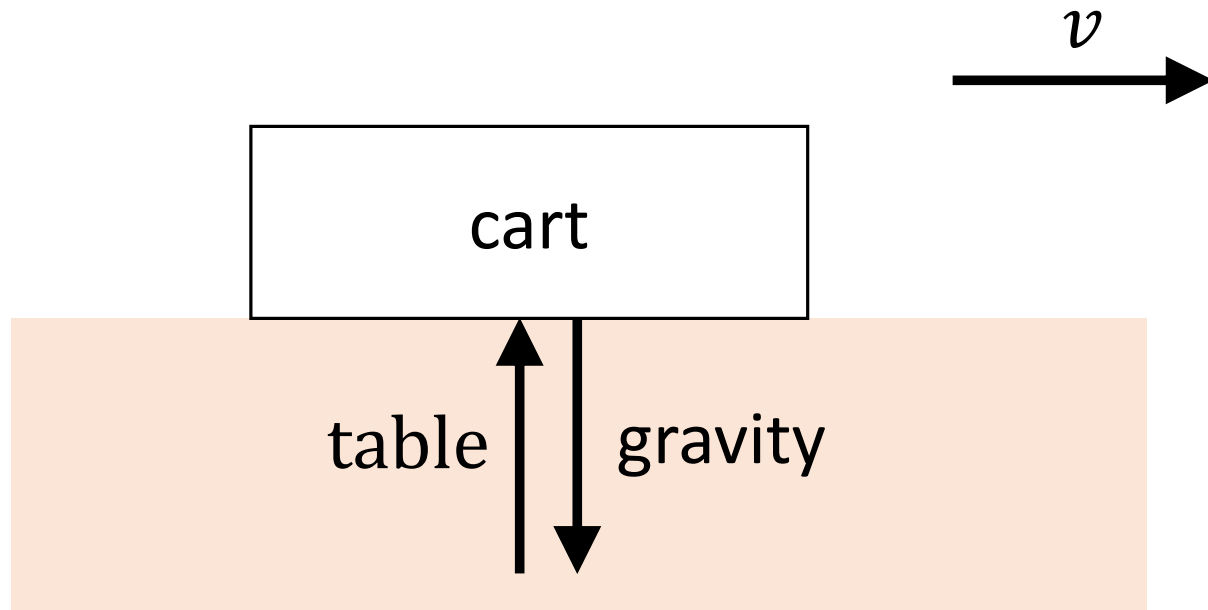
- A. Net force is up
- B. Net force is down
- C. Net force is to the left
- D. Net force is to the right
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Note: it does not matter if the object is moving, or in what direction.
Right now there's no net push, so no net force.



Newton's First Law

Newton's First Law:

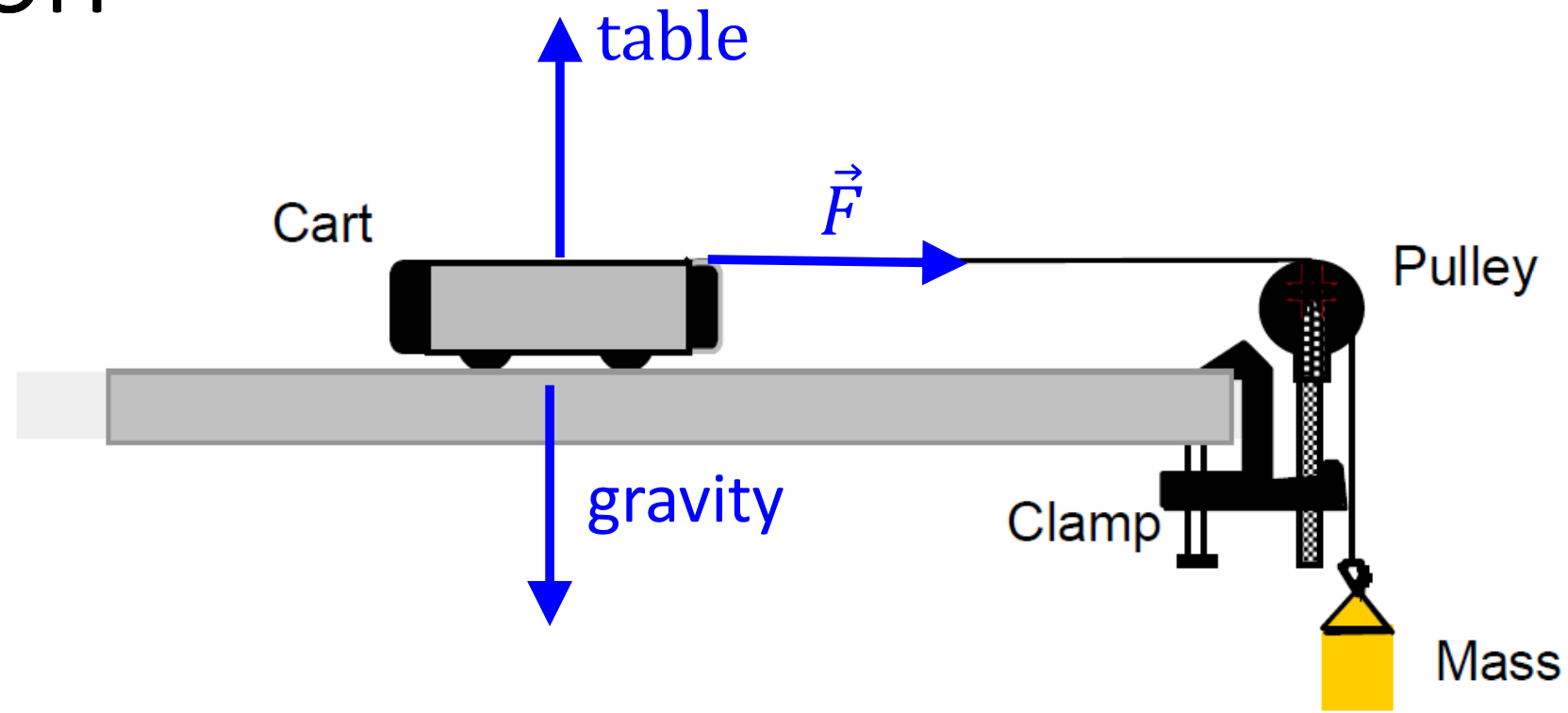
If no force is acting on the object,
its velocity will remain the same!

(the speed v will be constant)
(the acceleration a is zero)



Sir Isaac Newton
1642-1726

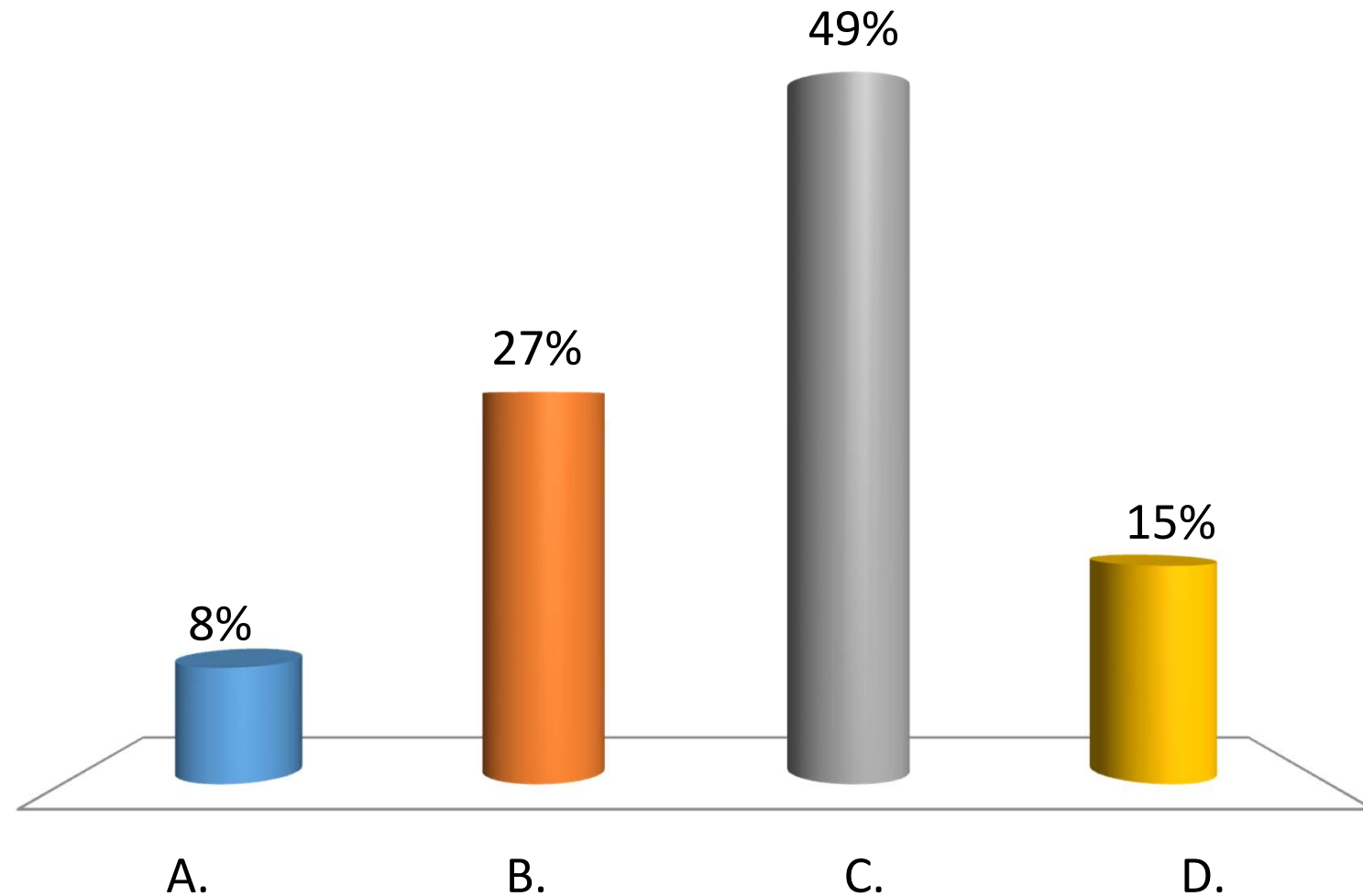
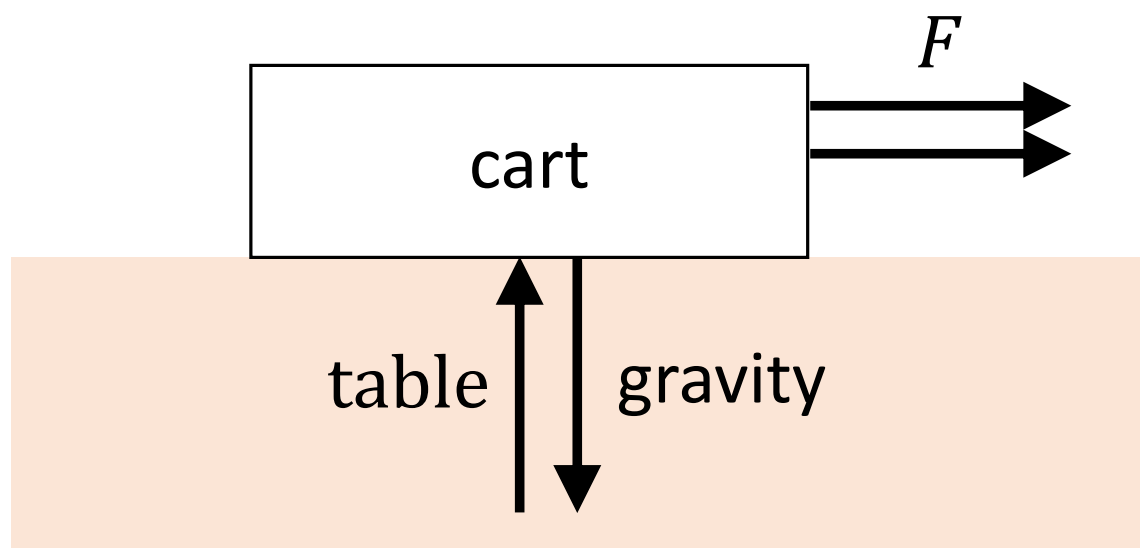
Assumption



- The mass will apply a force on the cart (via the string)
- Assumption: if we use a mass that is 2x heavier, the force is 2x larger

What happens when the block is 2x heavier? (double the force)

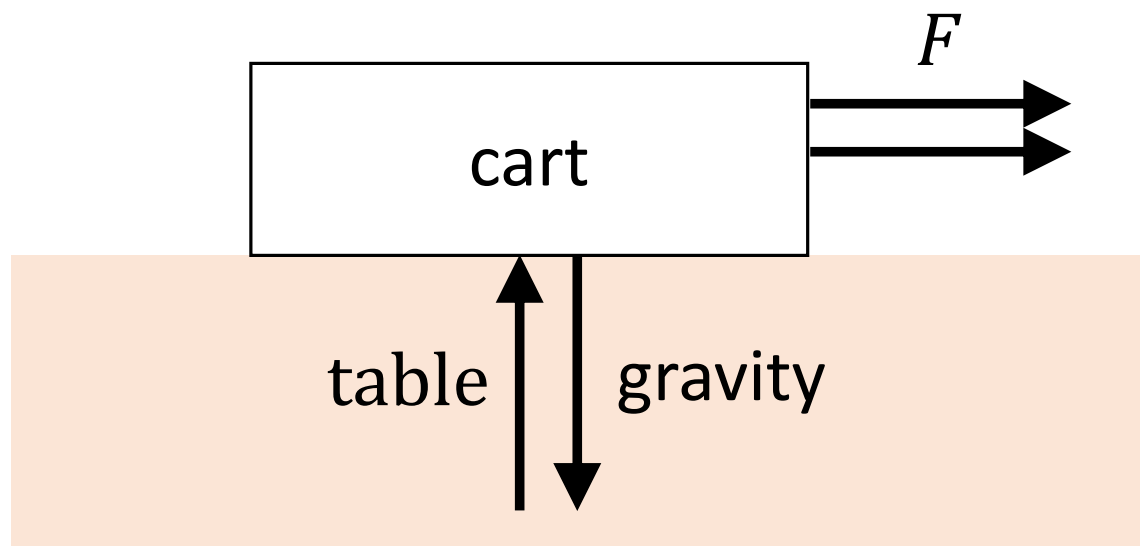
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*footnote: mass of block \ll mass of cart

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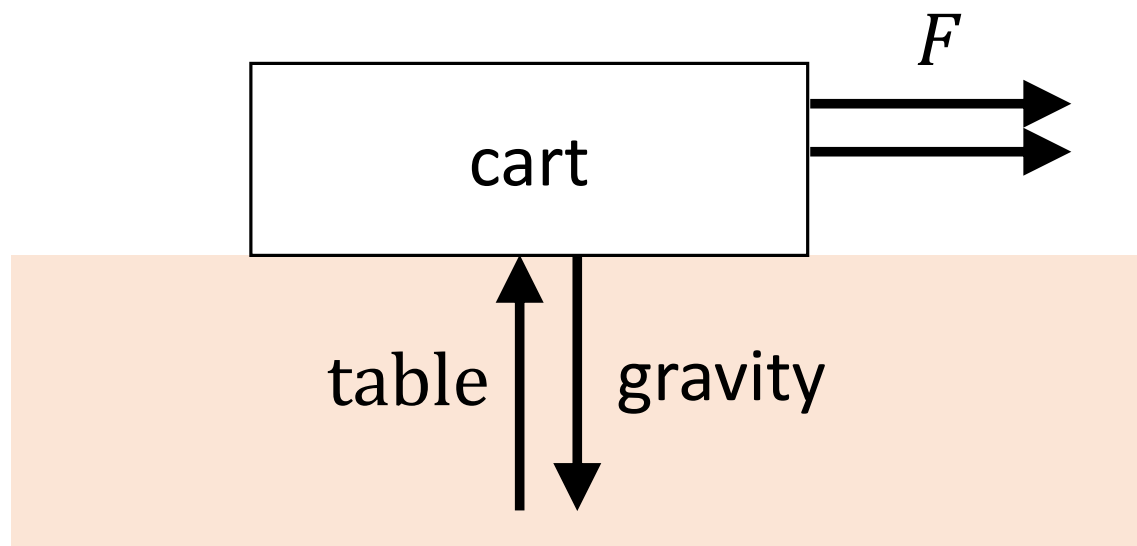
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The acceleration a is proportional to the force F :

$$\vec{a} = (\text{constant}) \times \vec{F}$$



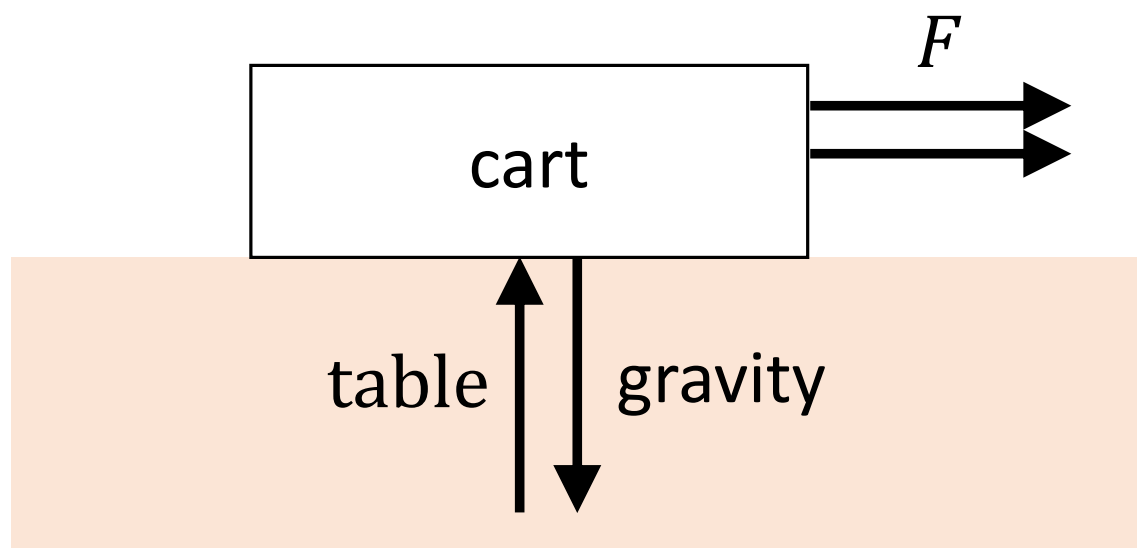
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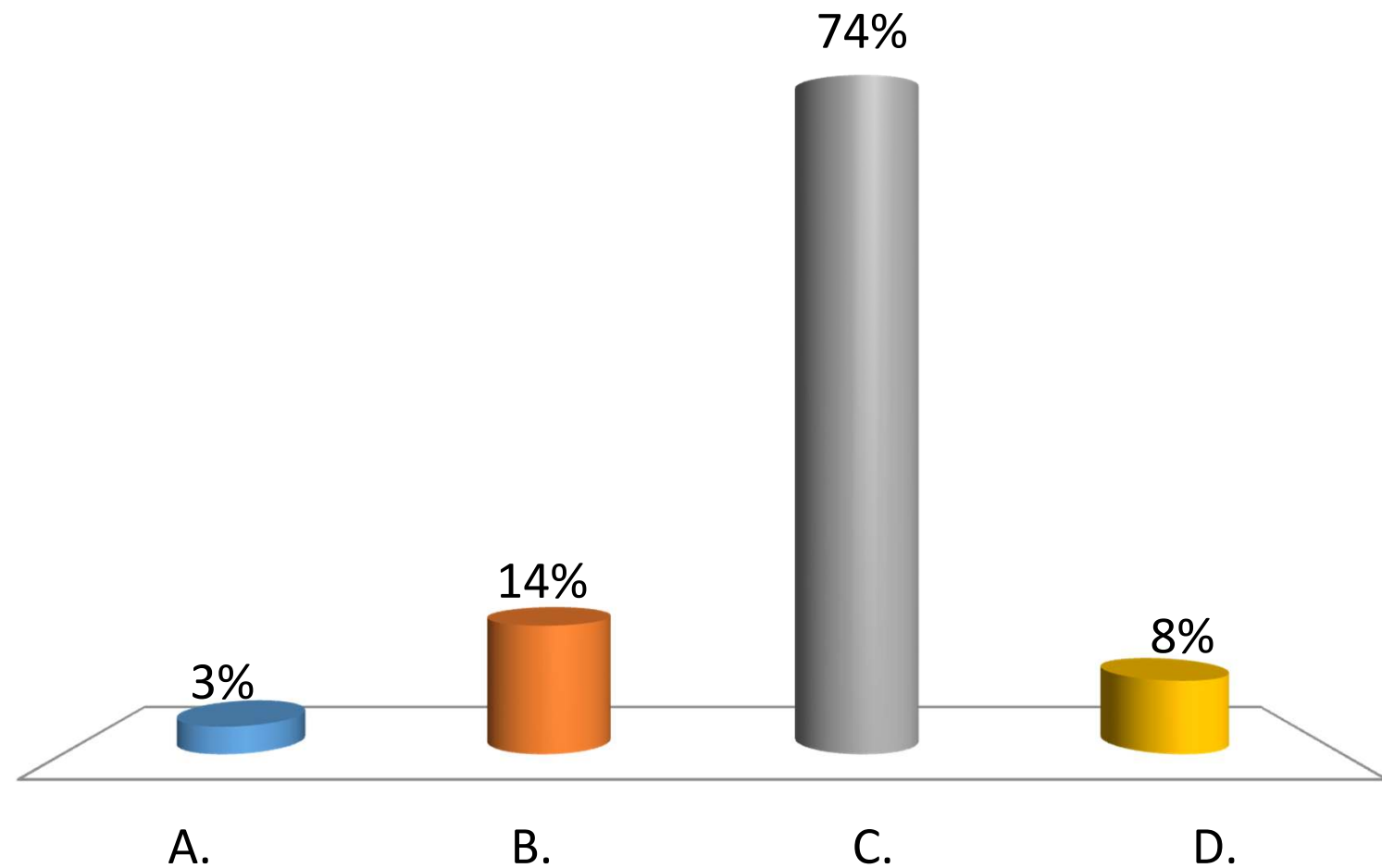
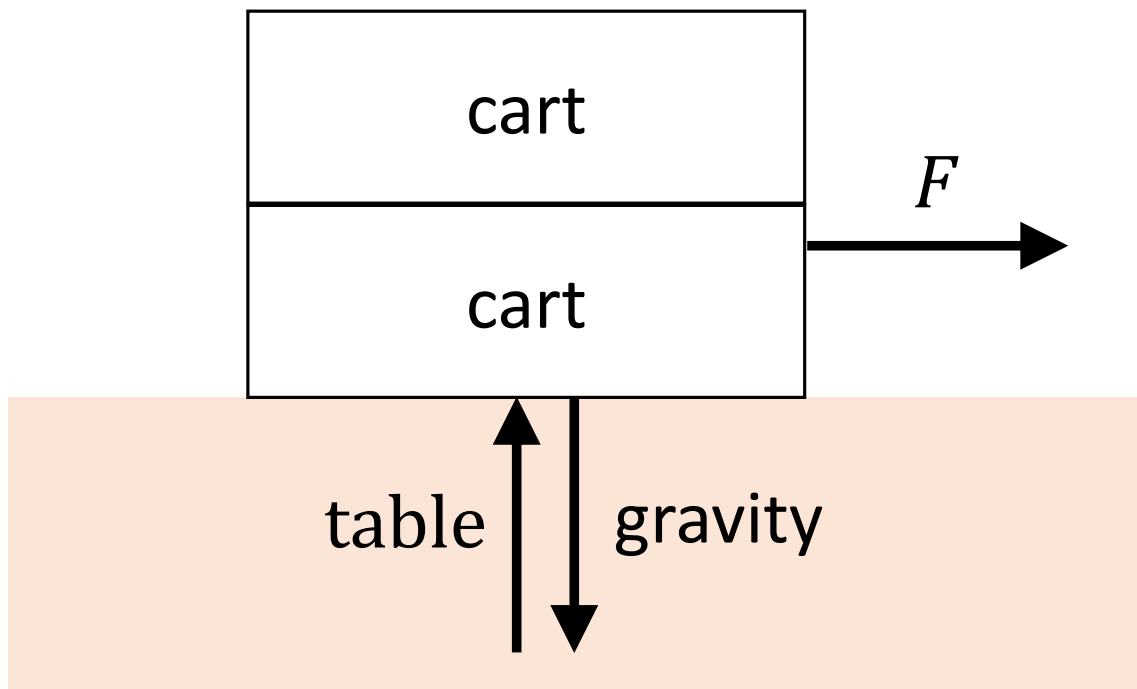


Don't believe me?
You'll test this during lab next week!

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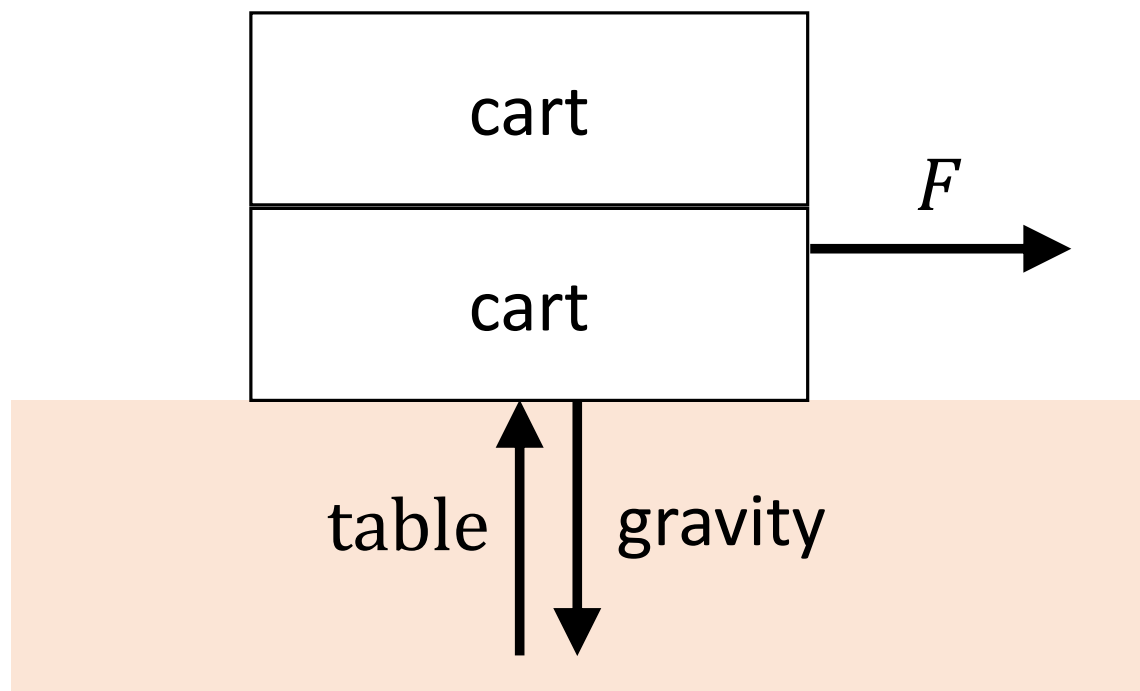
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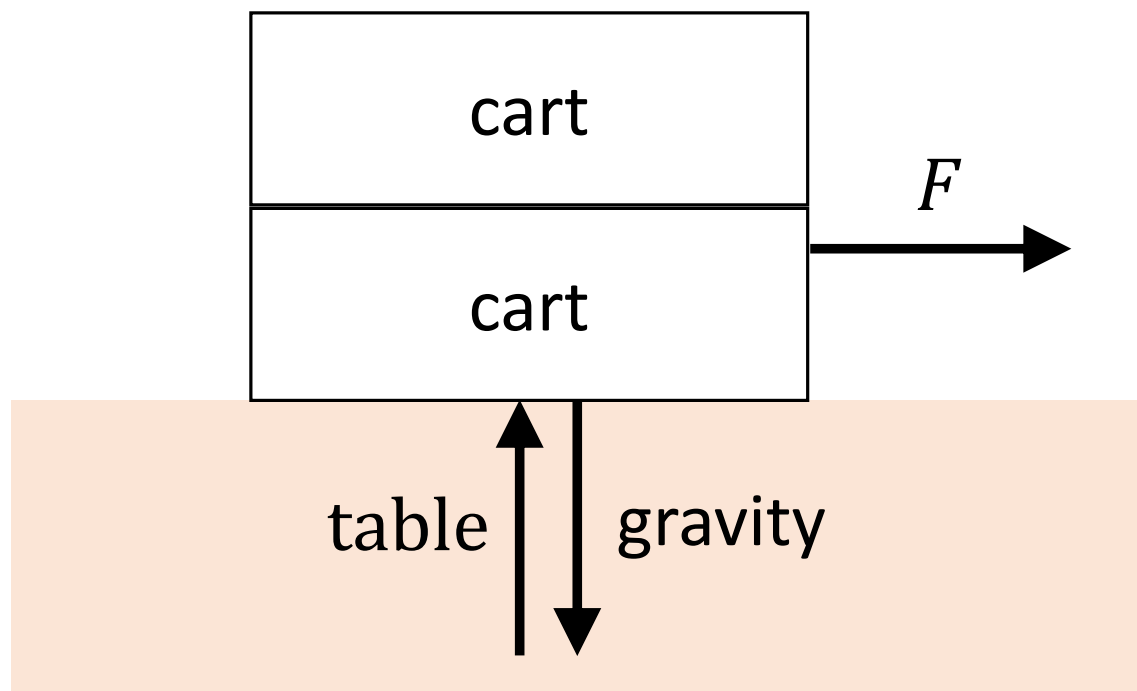
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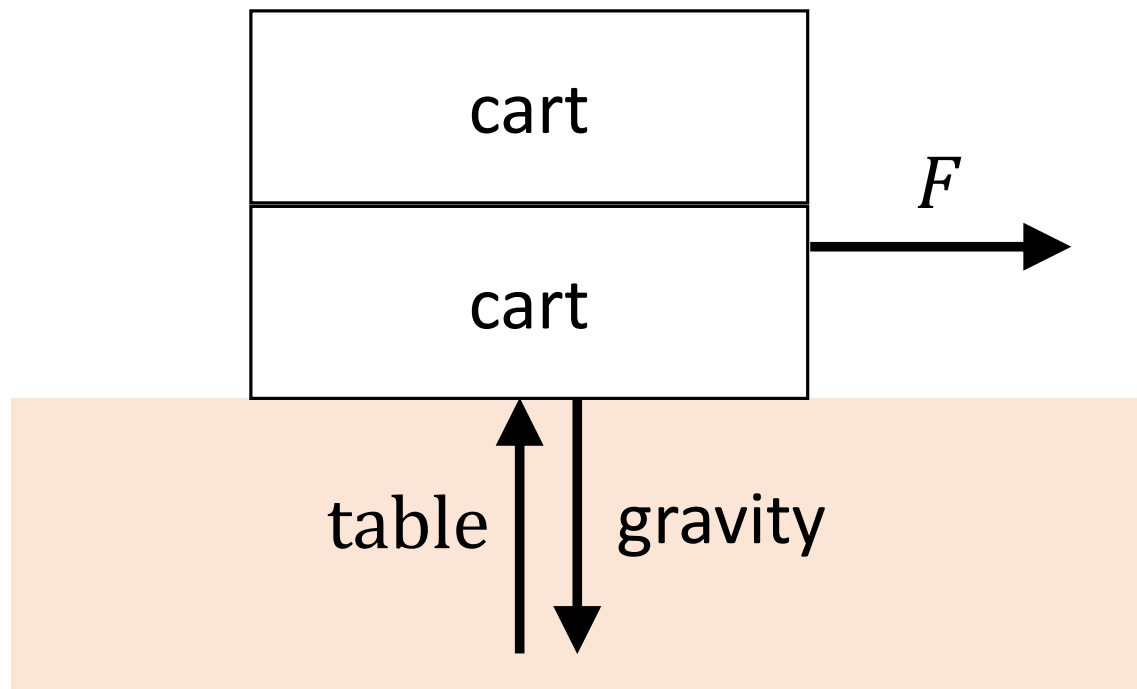
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The acceleration a is
inverse proportional to the mass m :

$$\vec{a} = \frac{1}{m} \times \vec{F}$$



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Newton's Second Law

Newton's Second Law:

If a force is acting on the object,
it will accelerate according to:

$$\vec{a} = \frac{\vec{F}}{m}$$

(often written as $\vec{F} = m\vec{a}$)



Sir Isaac Newton
1642-1726

I deserve an
award for this
sh*t!

Force in newtons

- SI unit of length: meters (m)
- SI unit of time: seconds (s)
- SI unit of mass: kilogram (kg) (yeah sorry about that, it's not the gram)

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- SI unit of time: seconds (s)
- SI unit of mass: kilogram (kg) (yeah sorry about that, it's not the gram)
- SI unit of force: newtons (N)

1 N = force needed to accelerate 1 kg to 1 m/s²

$$\vec{F} = m\vec{a}$$

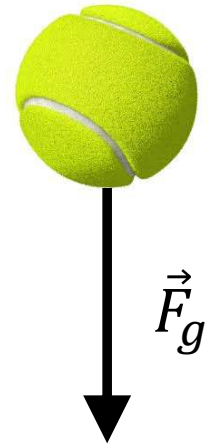
Force of Gravity

- As Galileo pointed out, gravity causes a mass to accelerate by 9.81 m/s^2
- In other words:

The force of gravity is equal to $F_g = mg$
with $g = 9.81 \text{ m/s}^2$

$$\vec{F} = m\vec{a}$$

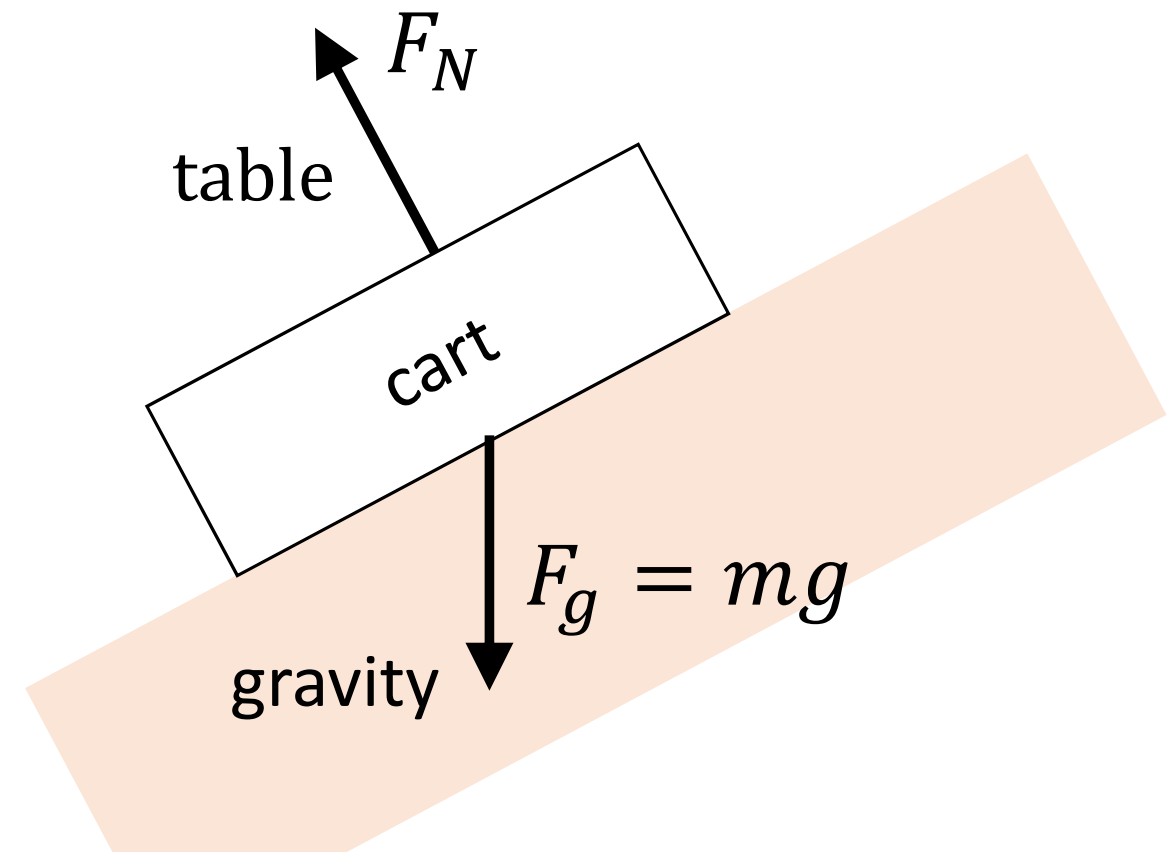
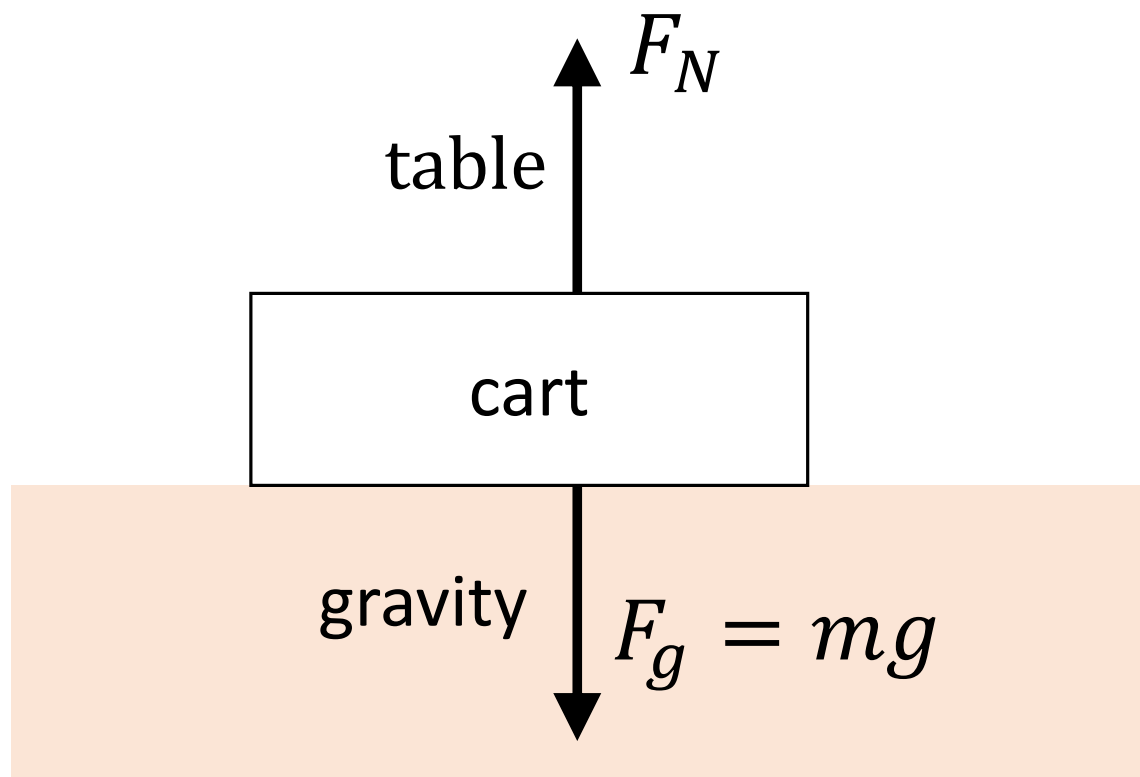
ball



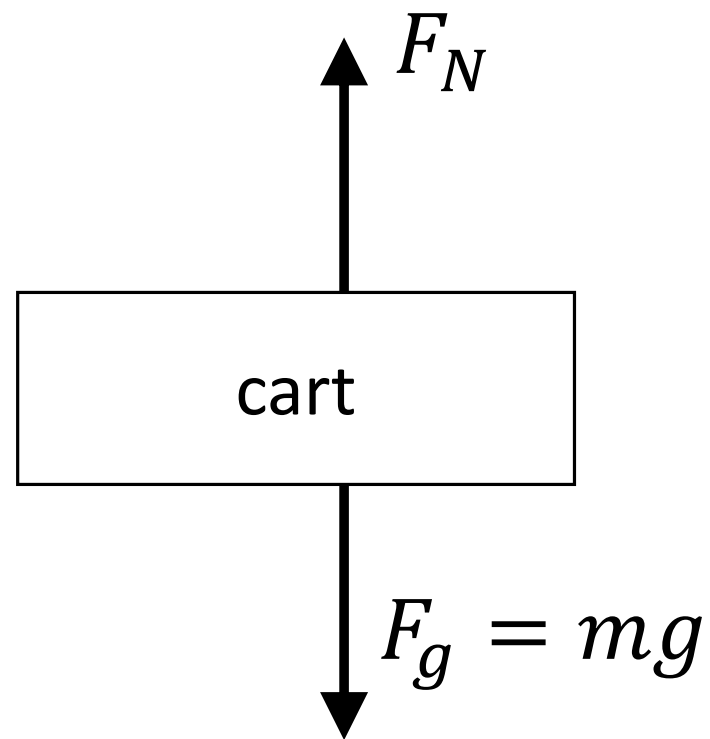
gravity pulling a ball down

Normal force, F_N

- The force that prevents an object from through it, is called the normal force F_N
- Direction of this force is normal to the surface ("normal" means perpendicular)



Free-body diagrams



- To determine the net force, it helps to draw a diagram of just the object
- As if it's floating in space, free from everything else...

- Newton will be back on Friday, with some more laws!



Sir Isaac Newton
1642-1726

Bye!
See ya on Friday!

Thank you!

See you next time: Friday 3 Feb. at 2:30pm