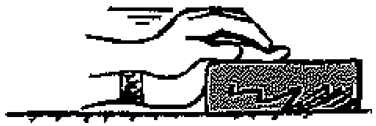
Review:

Net force causes acceleration

Force of hand accelerates the brick

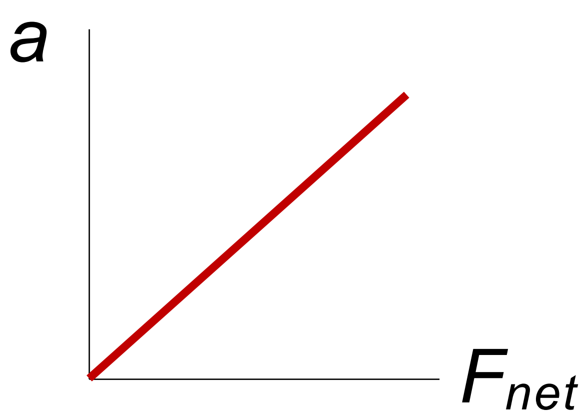
Twice as much force produces twice as much acceleration



1. You push on a crate that sits on a smooth floor, and it accelerates. If you apply four times the net force, how much greater will be the acceleration?

2. If you push with the same increased force on the same crate on a very rough floor, how will the acceleration compare with pushing the crate on a smooth floor? *(Think before you read the answer below!)*

Graph of acceleration a vs. net force F_{net}



This is a direct or linear relationship.

$$a \sim F_{net}$$

If F_{net} is doubled, then a ….. doubles.

If F_{net} is tripled, then a…. triples.

If F_{net} is halved, then a… is halved.

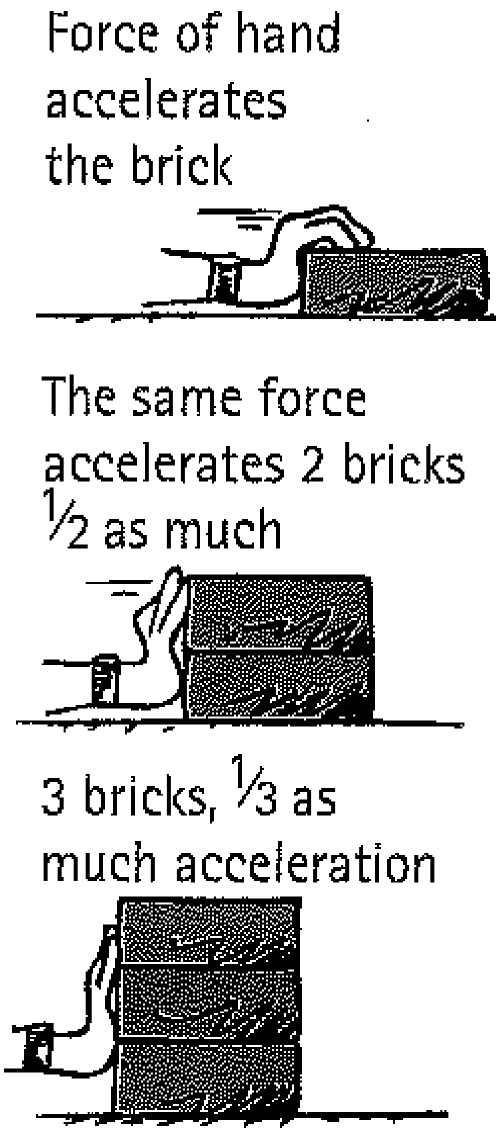
If F_{net} is quartered, then a.. is quartered…..

Mass Resists Acceleration

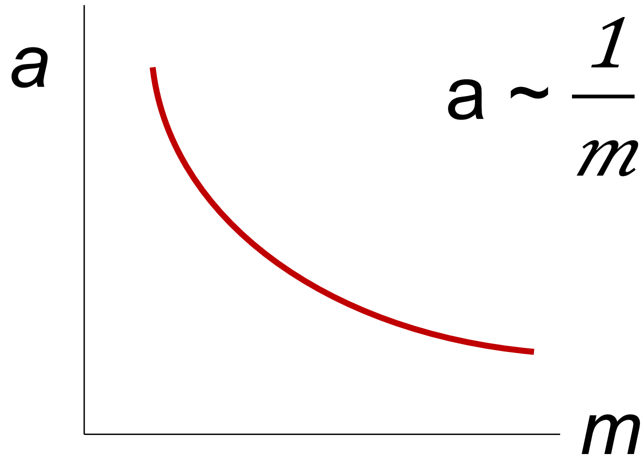
- The same force applied to
  - twice the mass produces *half* the acceleration.
  - 3 times the mass, produces 1/3 the acceleration.

$$\text{Acceleration} \sim \frac{1}{\text{mass}}$$

  - Acceleration is *inversely* proportional to mass.



Graph of acceleration *a* vs. mass m (assuming the same net force)

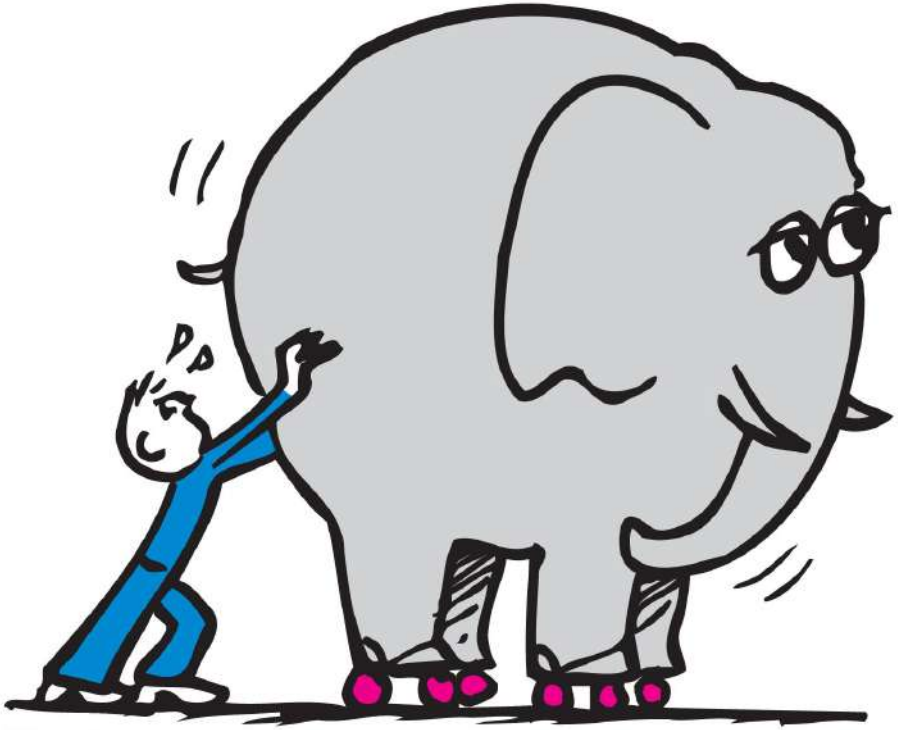


$$a \sim \frac{1}{m}$$

If m is doubled, then a …..	*halves.*
If m is tripled, then a….	*is 1/3 as great.*
If m is halved, then a…	*is doubled.*
If m is quartered, then a..	*is quadrupled.*

Newton's Second Law of Motion

- Isaac Newton was the first to connect the concepts of force and mass to produce acceleration.



Newton's Second Law of Motion, Continued

- Newton's second law (the law of acceleration) relates acceleration and force.

- In words:
  - *The acceleration produced by a net force on an object is directly proportional to the net force, is in the same direction as the net force, and is inversely proportional to the mass of the object.*

Newton's Second Law of Motion, in pictures

Newton's 2nd Law of Motion: in equation:

Net Force causes *a*

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

mass resists *a*

- Example:
  - If net force acting on object is doubled ⇒ object's acceleration will be doubled.
  - If mass of object is doubled ⇒ object's acceleration will be halved.

Newton's Second Law of Motion
CHECK YOUR NEIGHBOR

Consider a cart pushed along a track with a certain force. If the force remains the same while the mass of the cart decreases to half, the acceleration of the cart

A. remains relatively the same.
B. halves.
C. doubles.
D. changes unpredictably.

Newton's Second Law of Motion
CHECK YOUR ANSWER

Consider a cart pushed along a track with a certain force. If the force remains the same while the mass of the cart decreases to half, the acceleration of the cart

C. **doubles.**

Explanation:

Acceleration = net force / mass

Because, mass is in the denominator, acceleration *increases* as mass *decreases*. So, if mass is *halved*, acceleration *doubles*.

Newton's Second Law of Motion CHECK YOUR NEIGHBOR, Continued

Push a cart along a track so twice as much net force acts on it. If the acceleration remains the same, what is a reasonable explanation?

A. The mass of the cart doubled when the force doubled.
B. The cart experiences a force that it didn't before.
C. The track is not level.
D. Friction reversed direction.

Newton's Second Law of Motion CHECK YOUR ANSWER, Continued

Push a cart along a track so twice as much net force acts on it. If the acceleration remains the same, what is a reasonable explanation?

A. **The mass of the cart doubled when the force doubled.**

Explanation:

Acceleration = net force / mass

If force doubles, acceleration will also double. But it does not, so mass must also double to cancel the effects of force doubling.

1. **In Chapter 3, acceleration was defined as the time rate of change of velocity; that is, *a* = (change in *v*)/time. Are we in this chapter saying that acceleration is instead the ratio of force to mass; that is, *a* = *F*/*m*? Which is it?**

$$a = \frac{\Delta v}{t} \qquad a = \frac{net\ force}{m}$$

Which of these equations is a *definition* of acceleration?

$$a = \frac{\Delta v}{t}$$

Which of these explains the *cause* of acceleration?

$$a = \frac{net\ force}{m}$$

2. **A jumbo jet cruises at constant velocity of 1000 km/h when the thrusting force of its engines is a constant 100,000 N. What is the acceleration of the jet? What is the force of air resistance on the jet?**

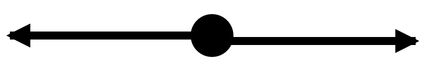
Constant velocity:

$$a = \frac{\Delta v}{t} = 0$$

Therefore:

$$a = \frac{net\ force}{m} = 0$$

Means the net force = 0



air resistance = 100,000 N

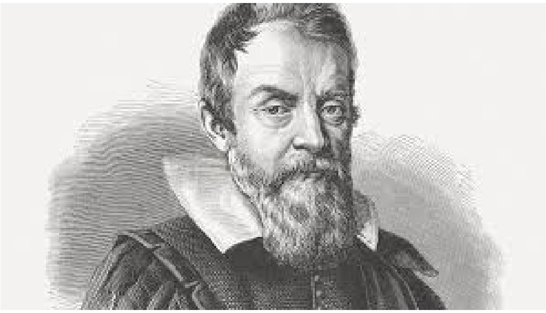
thrust = 100,000 N

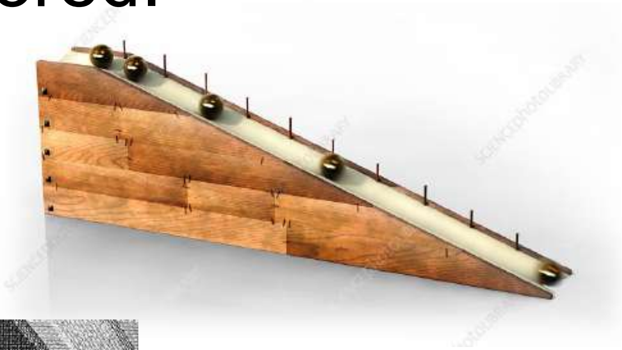
Can you have forces without acceleration? yes

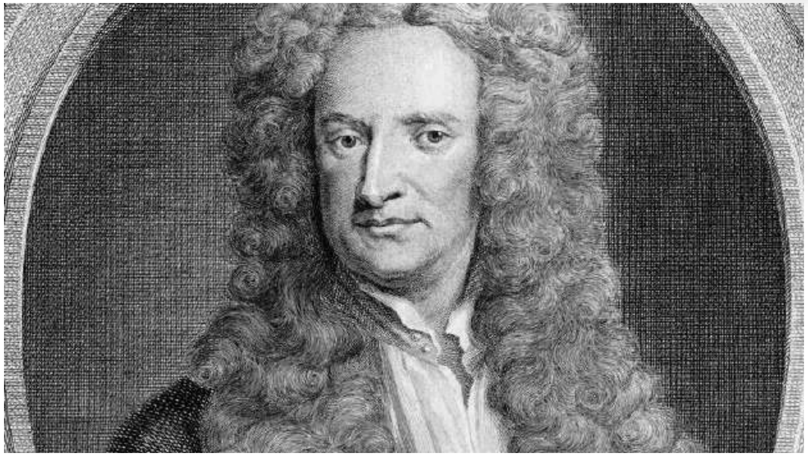
Can you acceleration without a net force? no

Free Fall

Galileo found that heavier and light objects fall at the same rate (acceleration) when air resistance can be ignored.



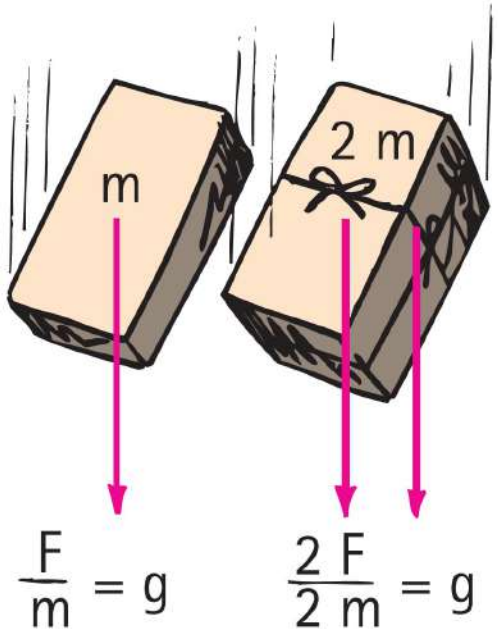




Newton explained **why** this happens, using his 2nd law.

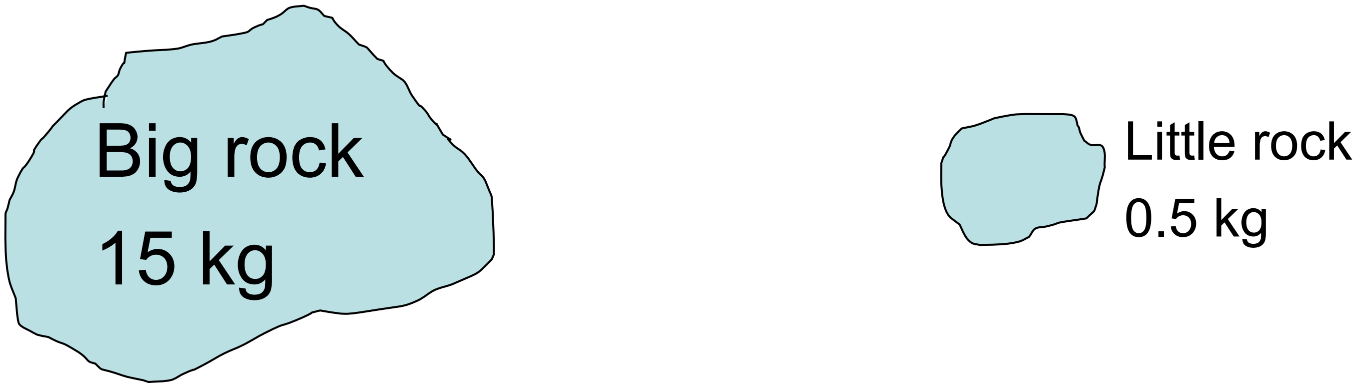
Free Fall

- The *greater* the mass of the object…
  - the *greater* its force of attraction toward the Earth.
  - the *smaller* its tendency to move, that is, the greater its inertia.
  - So, acceleration of both sets of bricks is the *same*. (Twice the force on twice the mass gives the same acceleration *g*!)



  - The acceleration of both sets of bricks is the same, $10\ m/s^2$ (more precisely, $9.8\ m/s^2$).

Which is pulled down with a greater force? big big



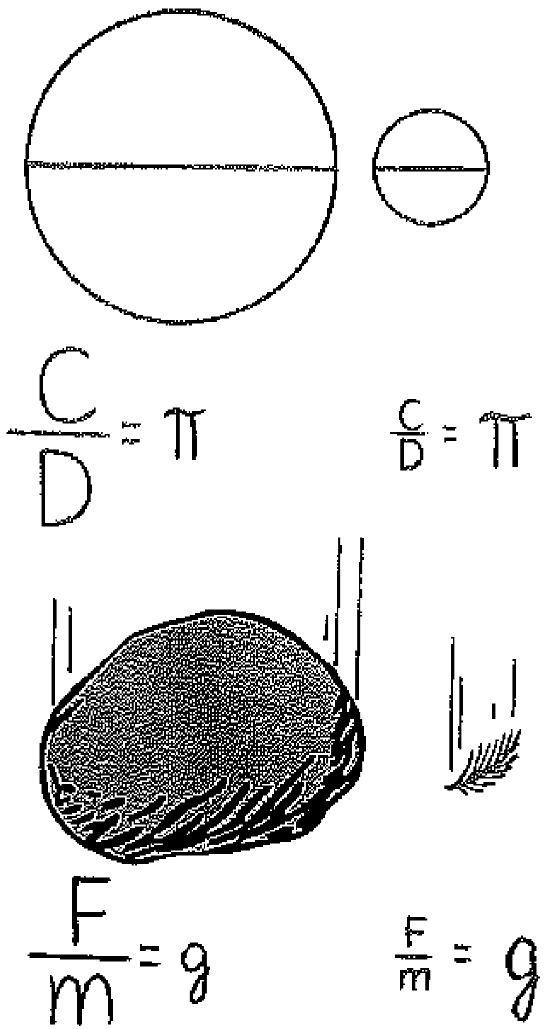
Which resists accelerating more? big

Which accelerates more? neither

CHECK POINT

In a vacuum, a coin and a feather fall at the same rate, side by side. Would it be correct to say that equal forces of gravity act on both the coin and the feather when in a vacuum?

acceleration is a ratio of two quantities like the circumference of a circle:



π is a constant: 3.14….

It is the same for big and small circles, even though C and D are different.

Acceleration due to gravity is a constant = 9.8 m/s^2.

It is the same for big and small objects, even if F and m are different (if we can ignore air resistance.)

Feather and hammer on moon:

A feather and a hammer fall at the same rate when there is no air—on the Moon.

https://www.youtube.com/watch?v=oYEgdZ3iEKA

Free Fall
CHECK YOUR NEIGHBOR

At one instant, an object in free fall has a speed of 40 m/s. Its speed 1 second later is

A. also 40 m/s.
B. 45 m/s.
C. 50 m/s.
D. None of the above.

Free Fall
CHECK YOUR ANSWER

At one instant, an object in free fall has a speed of 40 m/s. Its speed 1 second later is

C. **50 m/s.**

Comment:
We assume the object is falling downward. If it were traveling upward with no force on it but gravity, it would nevertheless be in "free fall." Then 1 second later its speed would be 30 m/s.

Free Fall
CHECK YOUR NEIGHBOR, Continued

A 5-kg iron ball and a 10-kg iron ball are dropped from rest. For negligible air resistance, the acceleration of the heavier ball will be

A. less.
B. the same.
C. more.
D. undetermined.

Free Fall
CHECK YOUR ANSWER, Continued

A 5-kg iron ball and a 10-kg iron ball are dropped from rest. For negligible air resistance, the acceleration of the heavier ball will be

B. the same.

Free Fall
CHECK YOUR NEIGHBOR, Continued-1

A 5-kg iron ball and a 10-kg iron ball are dropped from rest. When the free-falling 5-kg ball reaches a speed of 10 m/s, the speed of the free-falling 10-kg ball is

A. less than 10 m/s.
B. 10 m/s.
C. more than 10 m/s.
D. undetermined.

Free Fall
CHECK YOUR ANSWER, Continued-1

A 5-kg iron ball and a 10-kg iron ball are dropped from rest. When the free-falling 5-kg ball reaches a speed of 10 m/s, the speed of the free-falling 10-kg ball is

B. **10 m/s.**

Comment:
Note both are in "free fall." Hence their equal speeds.

Homework:

On page 68, do #16-24

due Friday @ 4:00 pm