Chapter 7. NEWTON'S LAWS

A PowerPoint Presentation by

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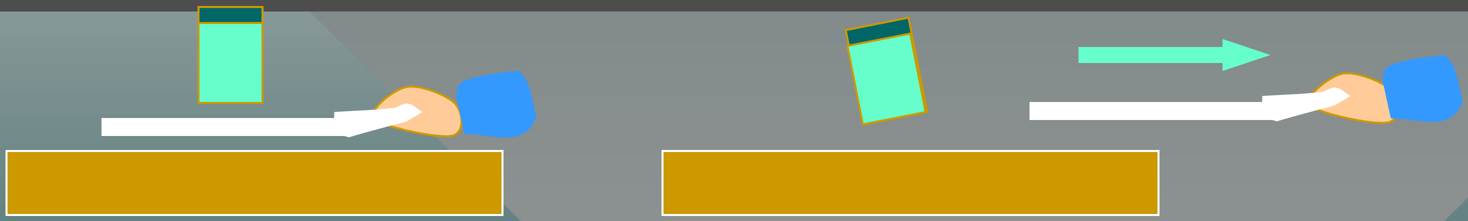
The space shuttle *Endeavor* lifts off for an 11-day mission in space. All of Newton's laws of motion - the law of inertia, action-reaction, and the acceleration produced by a resultant force - are exhibited during this lift-off. Credit: NASA Marshall Space Flight Center (NASA-MSFC).

Objectives: After completing this module, you should be able to:

- Write Newton's second law using appropriate units for mass, force, and acceleration.
- Demonstrate your understanding of the distinction between mass and weight.
- Draw free-body diagrams for objects at rest and in motion.
- Apply Newton's second law to problems involving one or more bodies in constant acceleration.

Newton's First Law Reviewed

<u>Newton's First Law:</u> An object at rest stays at rest, and an object in motion stays in motion in a straight line at constant speed (constant velocity) in the absence of a outside (net/resultant) force.



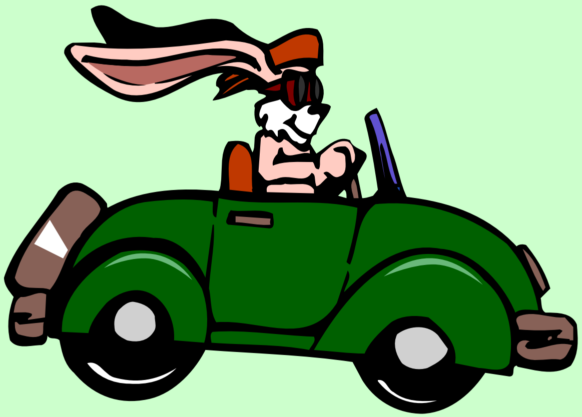
A glass is placed on a board and the board is jerked quickly to the right. The glass tends to remain at rest while the board is removed.

Newton's First Law (Cont.)

<u>Newton's First Law:</u> An object at rest stays at rest, and an object in motion stays in motion in a straight line at constant speed (constant velocity) in the absence of a outside (net/resultant) force.

Assume glass and board move together at constant speed. If the board stops suddenly, the glass tends to maintain its constant speed.

Understanding the First Law:



Discuss what the driver experiences when a car accelerates from rest and then applies the brakes.

(a) The driver is forced to move forward. An object at rest tends to remain at rest.

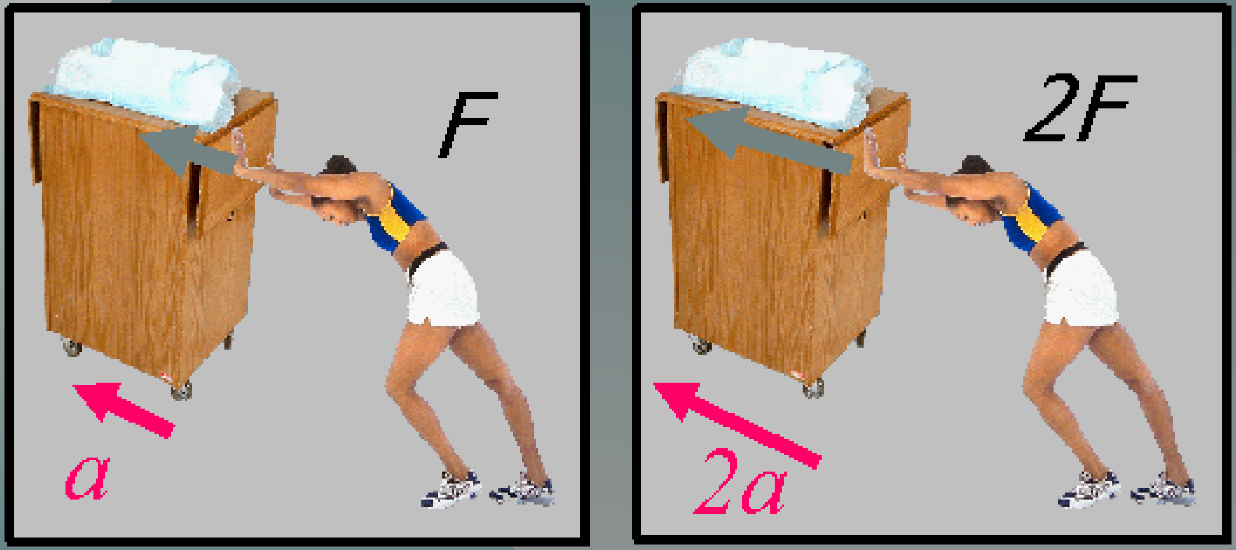
(b) Driver must resist the forward motion as brakes are applied. A moving object tends to remain in motion.

Newton's Second Law:

- Second Law: Whenever a resultant force acts on an object, it produces an acceleration: an acceleration that is directly proportional to the force and inversely proportional to the mass.

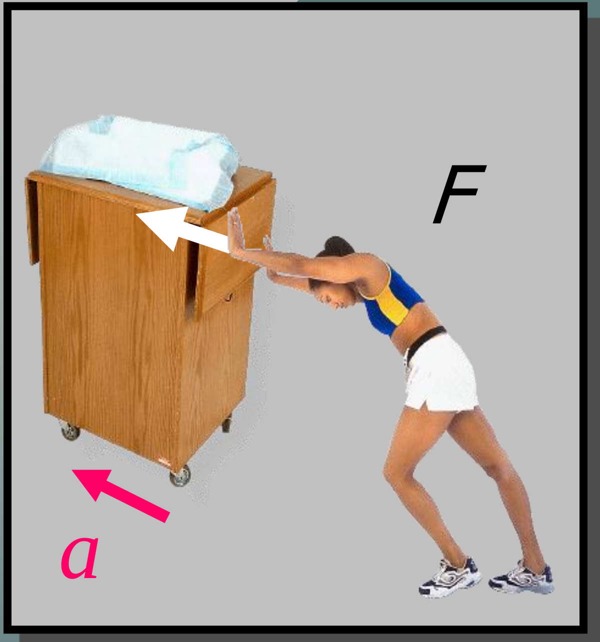
$$a \propto \frac{F}{m}$$

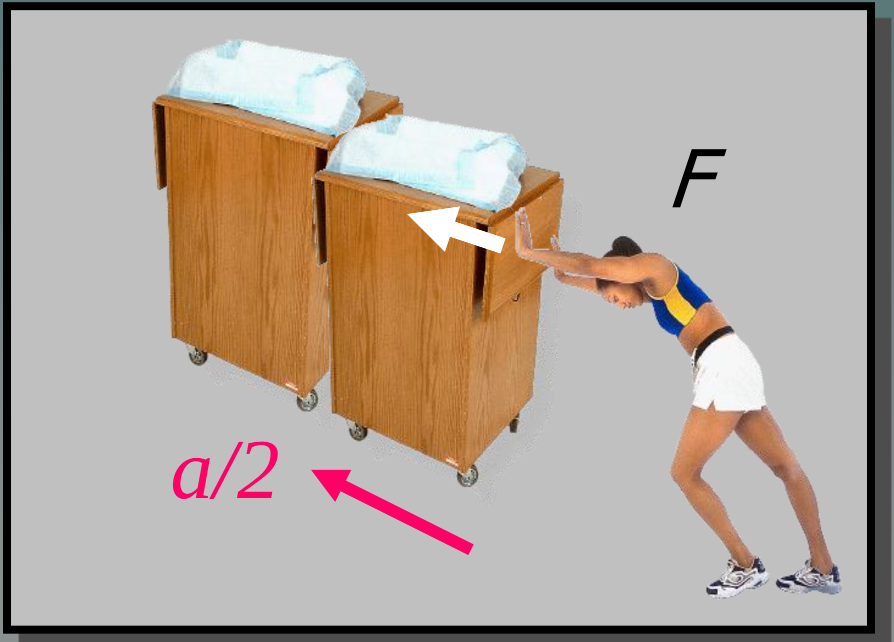
Acceleration and Force With Zero Friction Forces



Pushing the cart with twice the force produces twice the acceleration. Three times the force triples the acceleration.

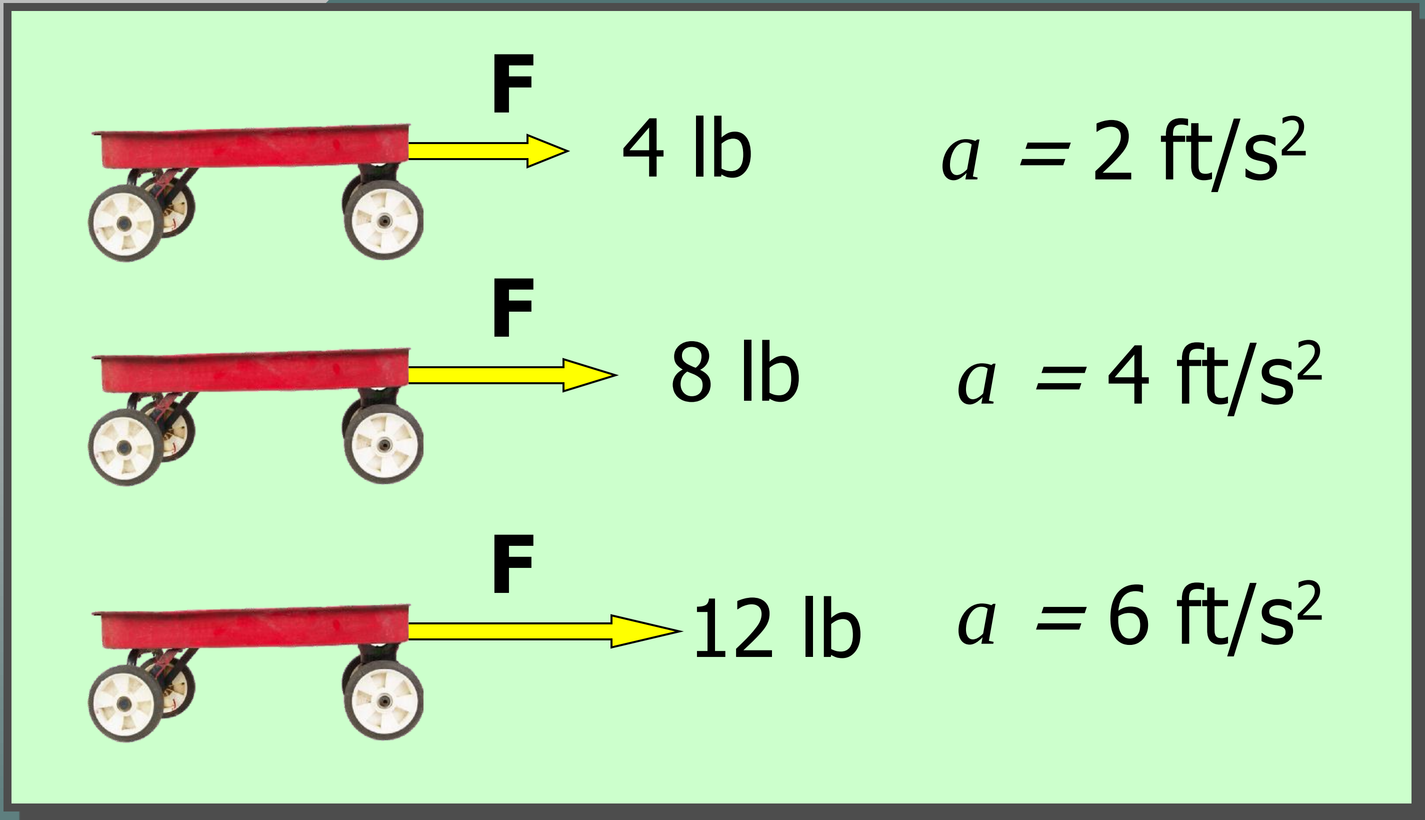
Acceleration and Mass Again With Zero Friction





Pushing two carts with same force F produces one-half the acceleration. The acceleration varies inversely with the amount of material (the mass).

Force and Acceleration



Acceleration a is directly proportional to force F and is in the direction of the force. Friction forces are ignored in this experiment.

Measuring Mass and Force

The SI unit of force is the newton (N) and the unit for mass is the kilogram (kg).

Before presenting formal definitions of these units, however, we will conduct an experiment by slowly increasing the force on a given object.

Although the force in newtons will become our standard, we begin by using the more familiar unit of force--the pound (lb).

Two Systems of Units

USCU system: Accept lb as unit of force, ft as unit of length, and s as unit of time. Derive new unit of mass, the slug.

$$F\,(\text{lb}) = m\,(\text{slugs})\; a\;(\text{ft/s}^2)$$

SI system: Accept kg as unit of mass, m as unit of length, and s as unit of time. Derive new unit of force, the *newton* (N).

$$F\,(\text{N}) = m\,(\text{kg})\; a\;(\text{m/s}^2)$$

Newton: The Unit of Force

One newton is that resultant force which imparts an acceleration of 1 m/s² *to a mass of* 1 kg.

$$F\,(\text{N}) = m\,(\text{kg})\; a\,(\text{m/s}^2)$$

What resultant force will give a 3 kg mass an acceleration of 4 m/s²? Remember $F = m\,a$

3 kg

$F = ?$

$a = 4\ \text{m/s}^2$

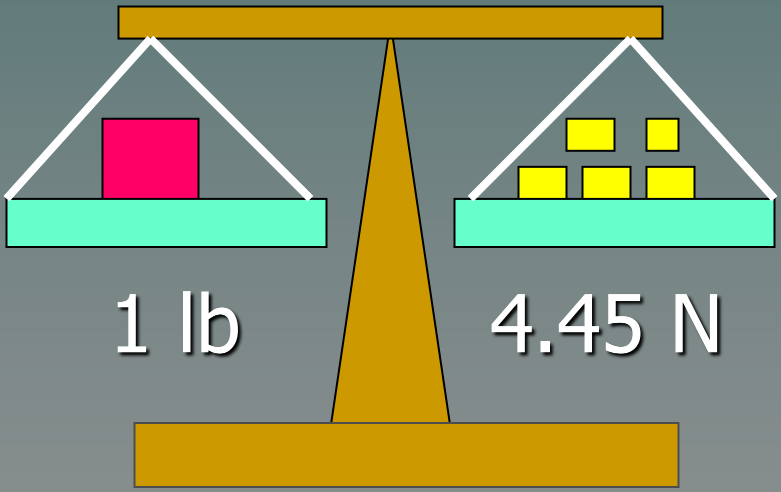
$$F = (3\text{ kg})(4\text{ m/s}^2)$$

$$F = 12\text{ N}$$

Comparing the Newton to the Pound

1 N = 0.225 lb

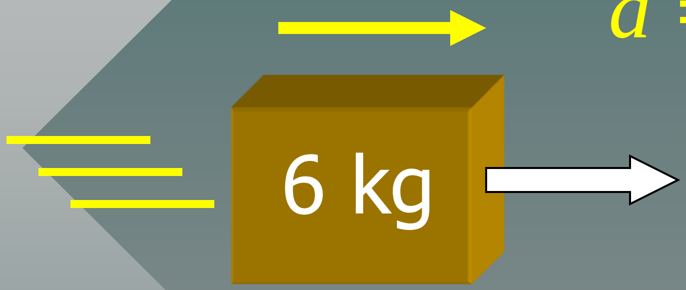
1 lb = 4.45 N



A 160-lb person weighs about 712 N

A 10-N hammer weighs about 2.25 lb

Example 2: What resultant force F is required to give a 6 kg block an acceleration of 2 m/s^2?



$a = 2\text{ m/s}^2$

$F = ?$

$$F = ma = (6\text{ kg})(2\text{ m/s}^2)$$

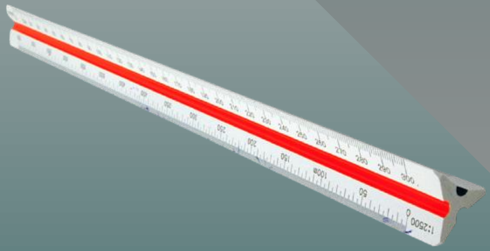
$$F = 12\text{ N}$$

Remember consistent units for force, mass, and acceleration in all problems.

A Word About Consistent Units

Now that we have *derived* units of *newtons* and *slugs*, we can no longer use units that are inconsistent with those definitions.

Acceptable measures of LENGTH are:



SI units: *meter* (m)

USCU units: *foot* (ft)

Unacceptable units are: centimeters (cm); millimeters (mm); kilometers (km); yards (yd); inches (in.); miles (mi)

Consistent Units (Continued . . .)

Acceptable measures of MASS are:

SI units: kilogram (kg)

USCU units: slug (slug)

Unacceptable units are: grams (gm); milligrams (mg); newtons (N); pounds (lb); ounces (oz)

The last three unacceptable units are actually units of force instead of mass.

Consistent Units (Continued . . .)

Acceptable measures of FORCE are:

SI units: *newton* (N)

USCU units: *pound* (lb)

Unacceptable units are: kilonewtons (kN); tons (tons); ounces (oz); kilograms (kg); slugs (slug)

The last two unacceptable units are not force units—they are units for mass.