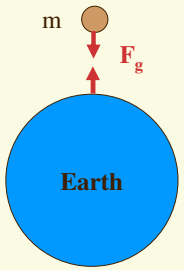
## Recall: Newton's Laws of Motion

1. Law of Inertia: In the absence of external forces, an object at rest remains at rest, and an object in motion continues in motion with constant velocity.
2. $$\sum \vec{F} = m\vec{a}$$

## Weight

✓ Force of gravity on an object

**Example:** free fall near the surface of earth




weight = $F_g$ = ma

= mg

$a_E = F_g/M_E = g(m/M_E)$ << g

**Note:**
$F_{g1}/F_{g2} = m_1/m_2$

## Q1

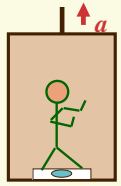
A student is standing in an elevator on a bathroom scale. When the elevator is at rest, the scale reads 70 N. When the elevator is moving upward with a constant non-zero speed, the scale reads:

1. More than 70 N.
2. 70 N
3. Less than 70 N.

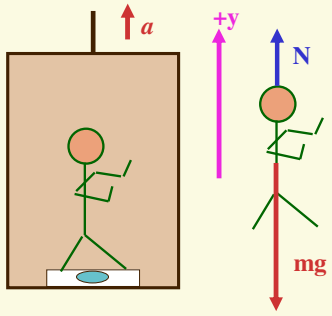

## Q2

A student is standing in an elevator on a bathroom scale. When the elevator is at rest, the scale reads 70 N. When the elevator is moving upward with a constant non-zero acceleration, the scale reads:

1. More than 70 N.
2. 70 N
3. Less than 70 N.



## Apparent Weight in Elevator




$\Sigma F_y = N - mg$

$= ma$

$N = mg + ma$

$= m(g + a)$

## Newton's 3rd Law

3. If two objects interact, the force **F**12 exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force **F**21 exerted by object 2 on object 1.

$$\vec{F}_{12} = -\vec{F}_{21}$$


Q3&4

## Q3

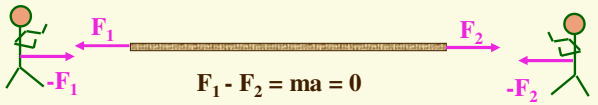
Two teams involved in a "tug-of-war" are in a draw. The rope is not moving, and apparently is not going to move.

Why does $F_1 = -F_2$?

1. Newton's 3rd Law
2. We approximate the rope to be massless.
3. The rope has zero acceleration.
4. Both teams have the same weight


## NOTE:

- ✓Newton's 3rd Law forces come in pairs
- ✓Each force is equal in magnitude
- ✓Each force is opposite in direction
- ✓Each force acts on DIFFERENT bodies!

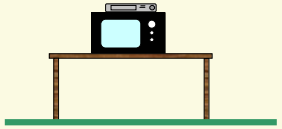



$F_1 - F_2 = ma = 0$

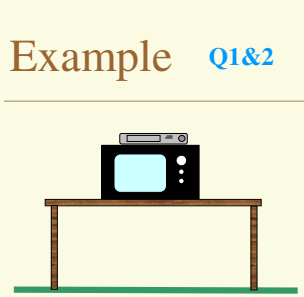
## Q4&5

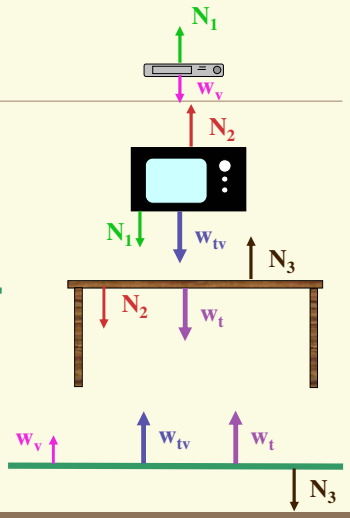
A VCR sits on a TV which sits on a table, which rests on the earth. Considering the force of gravity due to the earth, and considering normal forces, how many vertical forces are acting on the table?

1. One
2. Two
3. Three
4. Four



## Example Q1&2



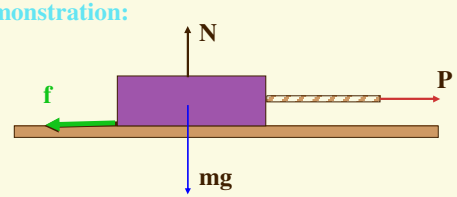



**3 vertical forces act on the table.**

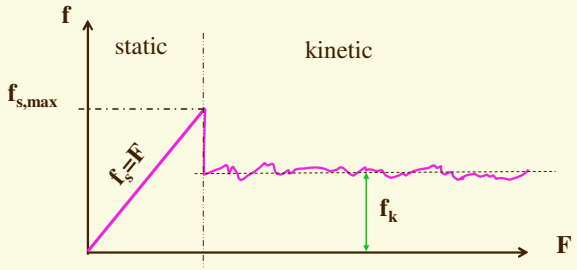
## Friction

- ✓Viscous fluids (drag)
- ✓Contact forces at surfaces

Demonstration:




## Friction (continued)




- ✓Static
- ✓Kinetic

What controls f?

## Static Friction

- ✓ Surfaces are at rest, relative to each other
- ✓ $f_s \leq f_{s,max}$
  - Whatever is needed to keep the object at rest
  - Cannot exceed $f_{s,max}$
- ✓ Directed opposite to the sum of the other forces parallel to the surface.
- ✓ $f_{s,max} = \mu_s N$ (approximation)

  $\mu_s$ is the coefficient of static friction

**It's variability can be tricky!**

## Kinetic Friction

- ✓ Surfaces are in motion, relative to each other
- ✓ Directed opposite to the direction of motion
- ✓ $f_k = \mu_k N$ (approximation)

  $\mu_k$ is the coefficient of kinetic friction
- ✓ Typically, $\mu_k < \mu_s$
- ✓ Friction coefficients depend on the materials and surface roughness

**Note: N is not always equal to mg**