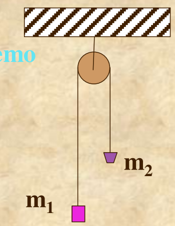
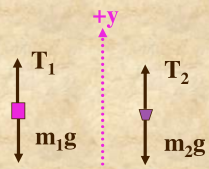
Some Applications: 1. Atwood Machine

(Massless string & pulley)

Demo





$T_1 = T_2 = T$ Why?

1: $T - m_1g = m_1a_1$

2: $T - m_2g = m_2a_2$

Solve: $a = (m_2-m_1)g/(m_1+m_2)$

$T = m_1(g + a) = \ldots$

Caution: $a_1 = -a_2$
$= a$

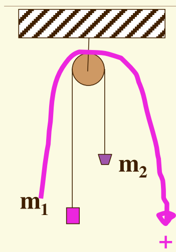
T=?

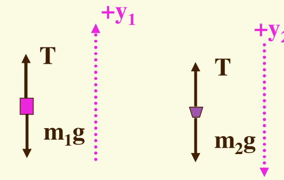
a=?

Check

Alternative 1

Sign errors are common if you're not careful!





1: $T - m_1g = m_1a$

2: $m_2g - T = m_2a$

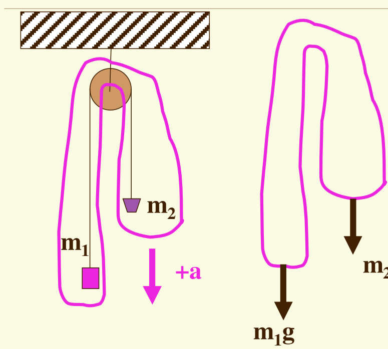
Solve: $a = (m_2-m_1)g/(m_1+m_2)$

$T = m_1(g + a) = \ldots$

NOTE: $T = m_1g$ only if $a=0$

Alternative 2

(Fast for acceleration)



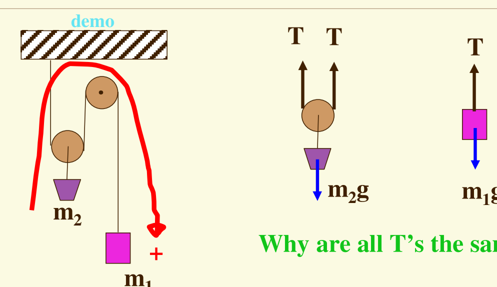
$m_2g - m_1g = (m_1+m_2)a$

Solve:
$a = (m_2-m_1)g/(m_1+m_2)$

For tension T, a separate free body diagram is still needed

Pulley Systems

Case 1.
$a = 0$



Why are all T's the same?

T=?

m_1=?

OK?

$2T - m_2g = 0$
$m_1g - T = 0$

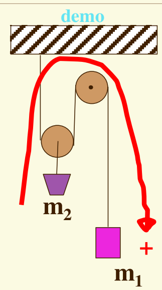
$T = m_1g$

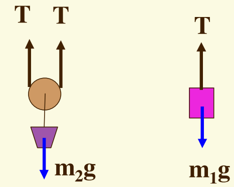
$m_1 = m_2/2$

Pulley Systems

Case 2.

$a \neq 0$





Why are all T's the same?

T=?

m_1=?

OK? $2T - m_2g = m_2a_2$

$m_1g - T = m_1a_1$

Caution! $a_1 = 2a_2$

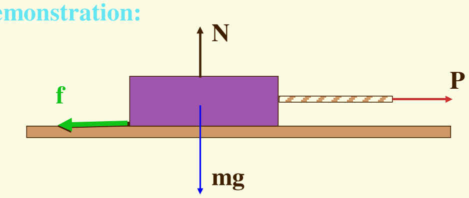
NOTE: $T \neq m_1g$

Friction

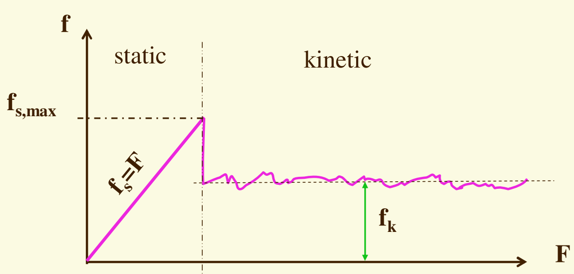
✓ Viscous fluids (drag)

✓ Contact forces at surfaces ←

Demonstration:



Friction (continued)



✓ Static

✓ Kinetic

question & demo:
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)

μ_s is the coefficient of static friction

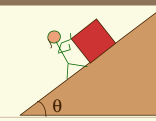
It's variability can be tricky!

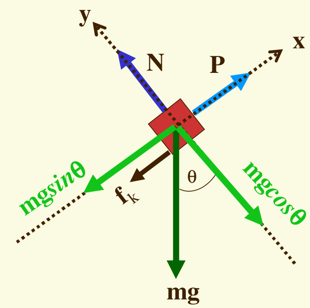
Kinetic Friction

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

Example





$\Sigma F_x = P - mg\,sin\theta - f_k = ma_x$

$f_k = \mu_k N$

$\Sigma F_y = N - mg\,cos\theta = ma_y = 0$

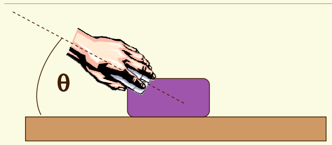
$N = mg\,cos\theta$

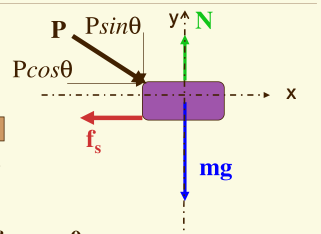
$f_k = \mu_k mg\,cos\theta$

Solve for a_x

Example

What is the maximum P such that the block doesn't move?





Maximum P requires $f_{s,max}$.

$f_s = f_{s,max} = \mu_s N$

$\Sigma F_x = P cos\theta - f_s = P cos\theta - f_{s,max} = 0$

$P cos\theta - \mu_s N = 0$

$\Sigma F_y = P sin\theta - mg + N = 0$

Eliminate N and solve for P.