Force and Motion

Chapter 4 Forces & Newton’s Laws

- Kinematics
  - study of motion
- Mechanics
  - forces that cause the motion

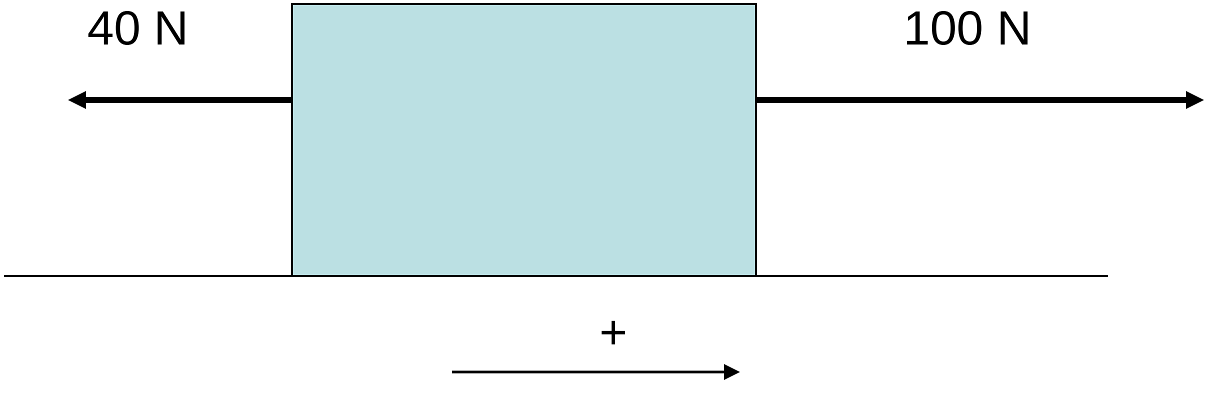
Force

- A force is exerted when two “systems” interact.
- Contact forces
  – surfaces in contact
  – rope or cable attached to an object
- Non-contact “action-at-a-distance” forces
  – fields exert gravitational, electric, magnetic forces
- Forces cause, or try to cause, a change in the state of rest or motion of an object
- Forces cause object to change velocity = accelerate
- Vector quantity

Net Force

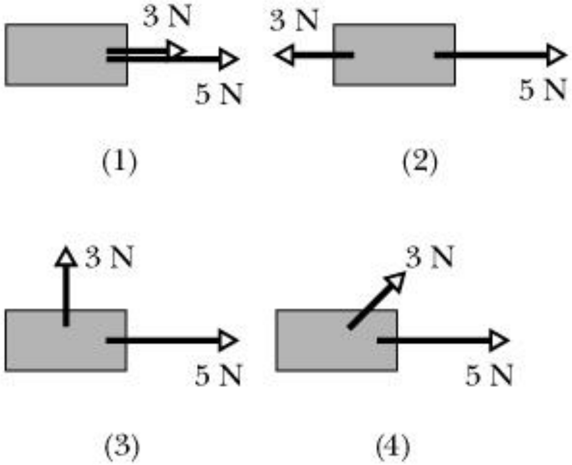
- ΣF "sigma F" = net force
  - vector sum of forces acting on object
- Paycheck example
  - do you receive a gross or net paycheck?

$$\Sigma F = 100 + (-40) = 60 \text{ N}$$



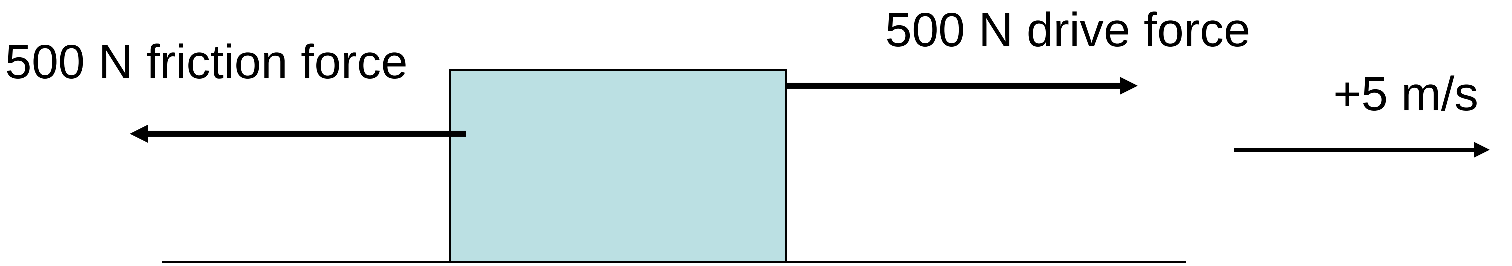
Applied force vs Net force

- Net force is a vector sum of the actual applied forces.



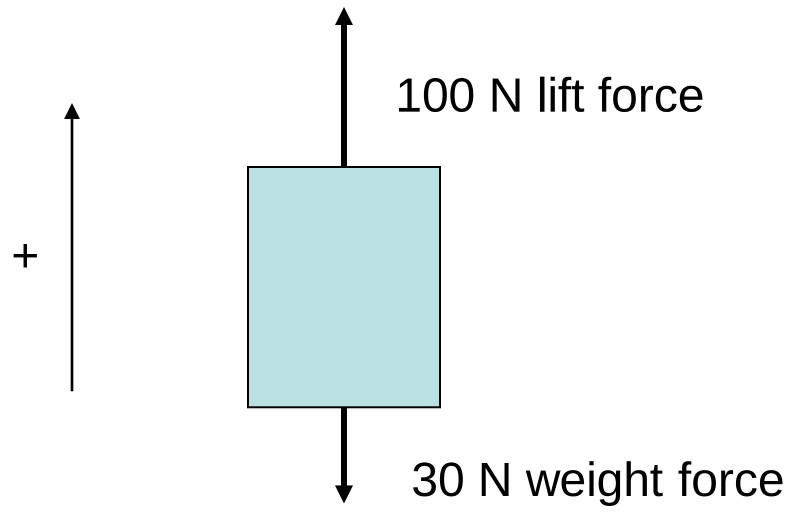
Balanced Forces

- Forces of equal magnitude acting on an object in opposite directions
- $\Sigma F = 0$ (does not mean no forces act)
- Object moves with constant velocity
  - stays at rest or at constant speed in a straight line



Unbalanced Forces

- Opposing forces of different magnitudes that do not ‘cancel each other out’

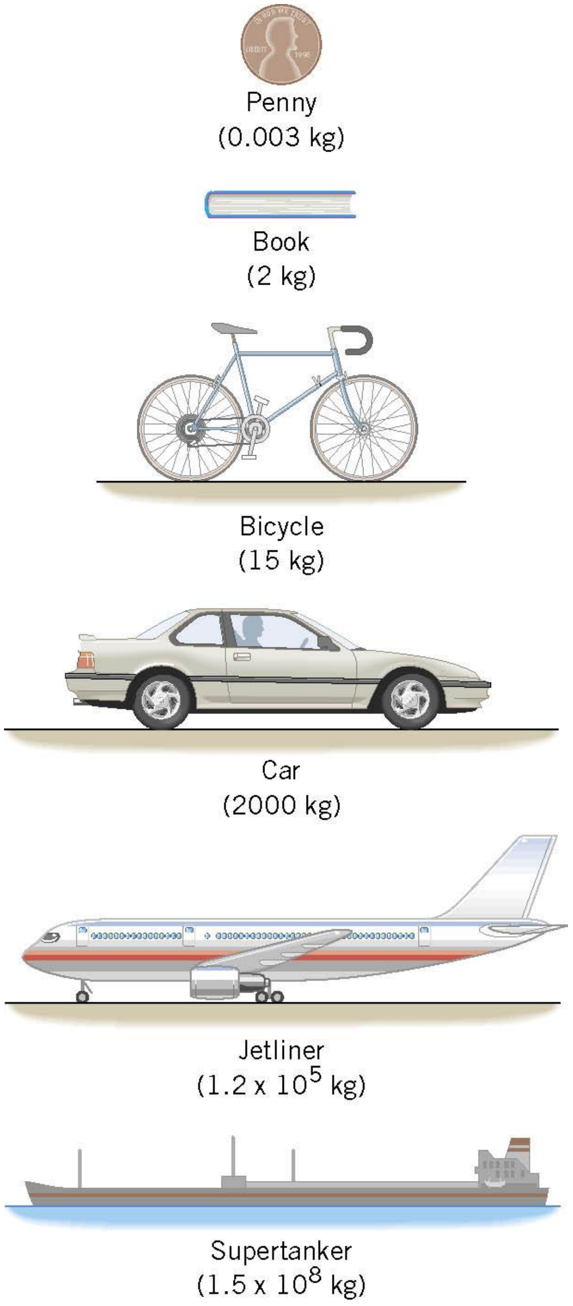


$\Sigma F = 70$ N

- unbalanced forces cause acceleration in the direction of the unbalanced net force

Inertia

- Tendency of an object to remain at rest or in motion at a constant velocity
- The resistance of an object to a change in its state of rest or motion
- MASS is a measure of inertia



Newton's 1^{st} Law of Motion

- An object's inertia will keep it at rest or in motion at a constant speed in a straight line (= constant velocity) unless acted on by a net force.
- Law of Inertia
- $\Sigma F = 0$

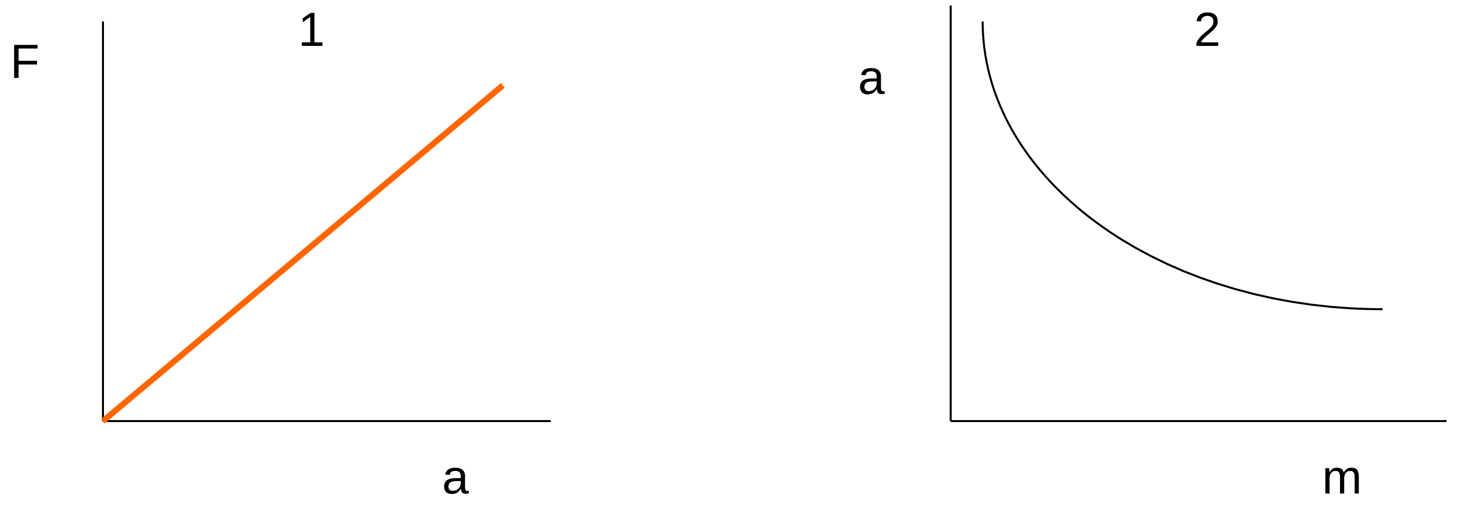
Newton's 2nd Law of Motion

- When a net force acts on an object it accelerates in the direction of the net force.
- Acceleration is *directly* proportional to the magnitude of the net force applied to a constant mass
- Acceleration is *inversely* proportional to the mass of the object for a constant net force
- $a = \frac{\Sigma F}{m}$

$$\Sigma F = (m)(a)$$

left side of 2nd law		right side is a mathematical
is vector sum	=	product of mass and acceleration value

- Which of Newton's Laws is represented by the graphs below?



Newton's 2nd Law

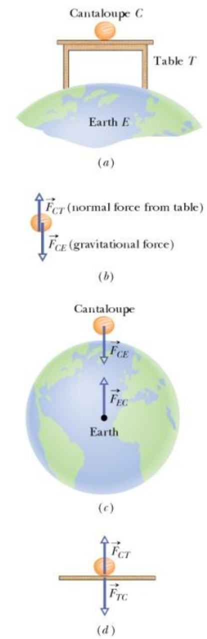
slope of graph 1 = constant mass that force is applied to

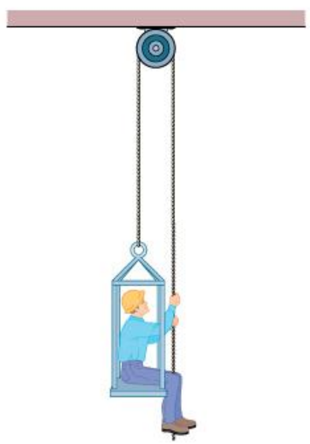
constant force applied to increasing mass in graph 2

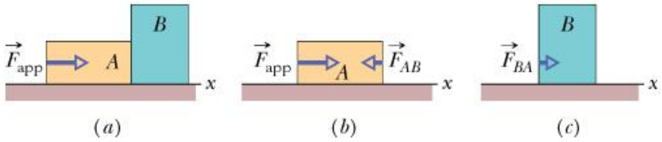
definition of "inertial mass" – resistance to acceleration

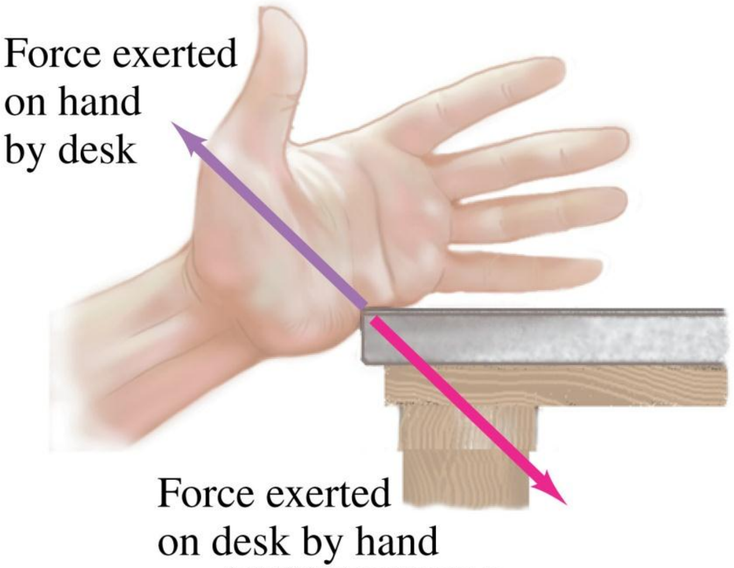
Forces come in pairs

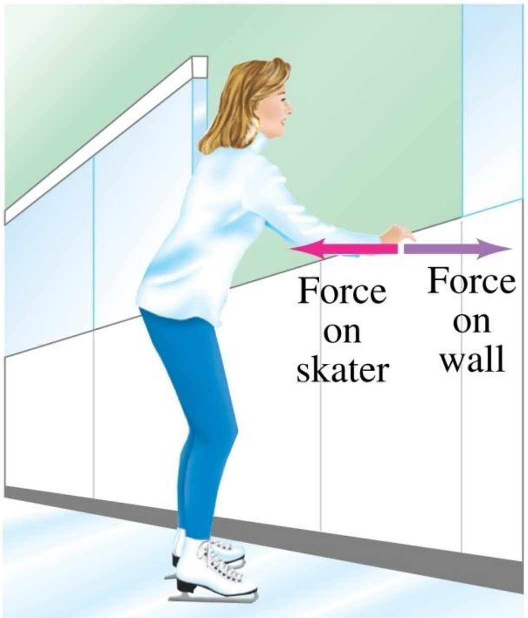
- 3rd Law
- action-reaction force pairs
  - never act on the same object

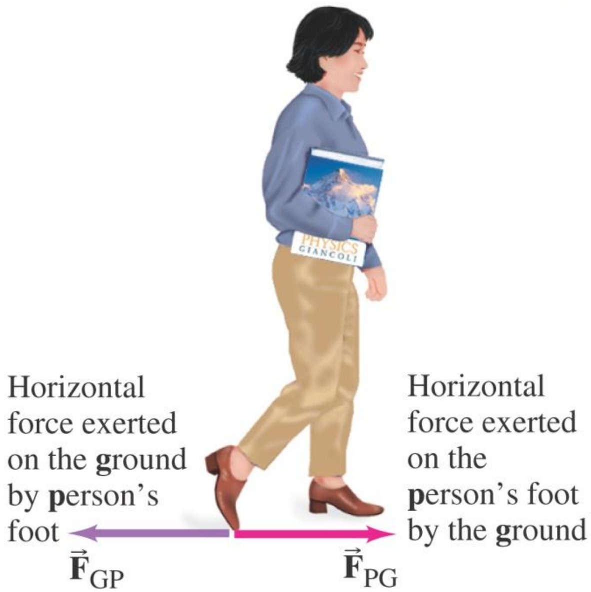






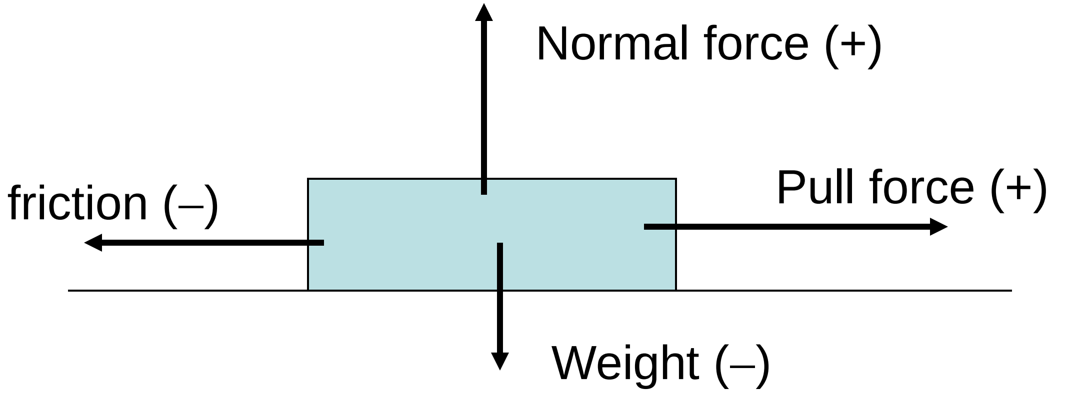

Force exerted
on hand
by desk
Force exerted
on desk by hand


Force
on
skater
Force
on
wall

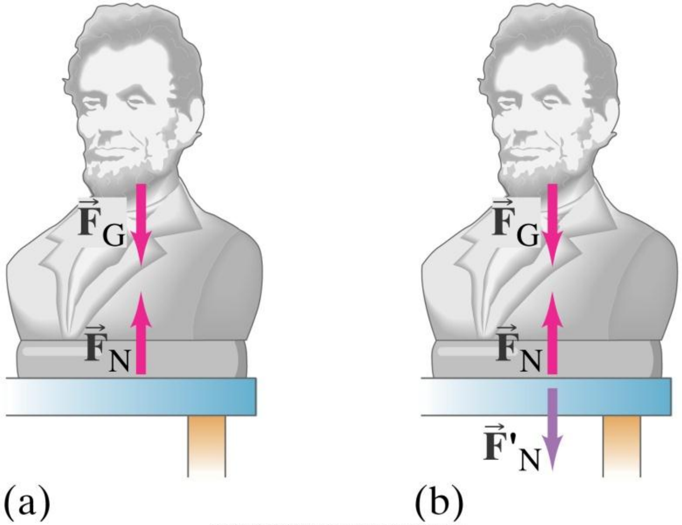

Horizontal
force exerted
on the ground
by person's
foot
Horizontal
force exerted
on the
person's foot
by the ground
PHYSICS
GIANCOLI
$\vec{F}_{GP}$
$\vec{F}_{PG}$

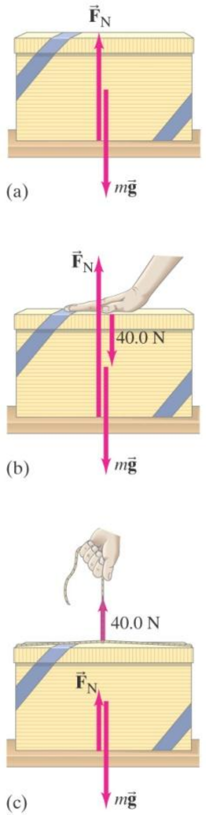
Free Body Diagram

- simple drawing of the object in a problem
- ALL forces acting on the object are shown with arrows for force vectors.
- Tail of arrow is attached to object
- Arrow points in direction of force and is labeled correctly with name or abbreviation
- Signs are important in problem solving



Normal force and gravitational force





F_G gravitational force

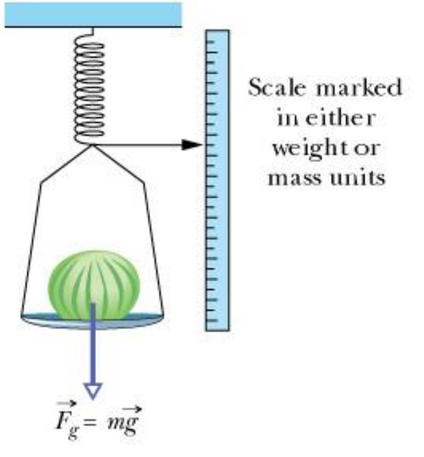
- force exerted on a mass when in a gravity field created by another mass
- Weight in Newtons = (mass in kg)•g = m•9.8 at Earth's surface

Normal force not always equal to the weight of an object

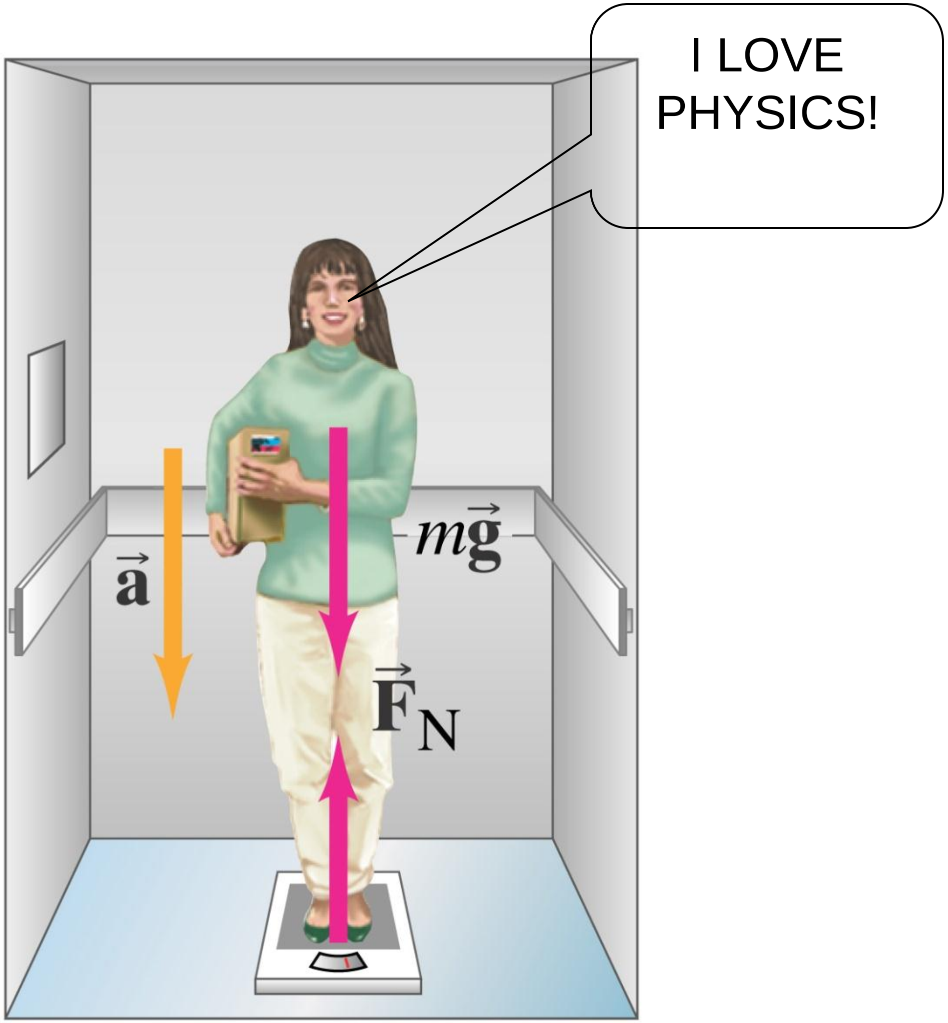
$\Sigma F = 0$ to solve for F_N

Mass vs Weight

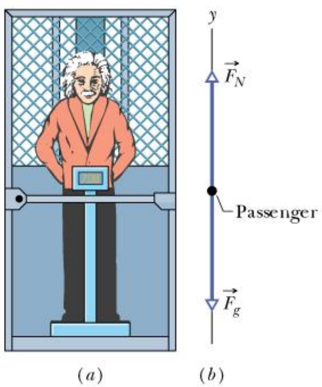
- Mass (kg)as source of gravitational forces
  - constant at all points
  - measure of object's inertia
- Weight (F_g) = mg (N)
  - varies with strength of gravitational attraction

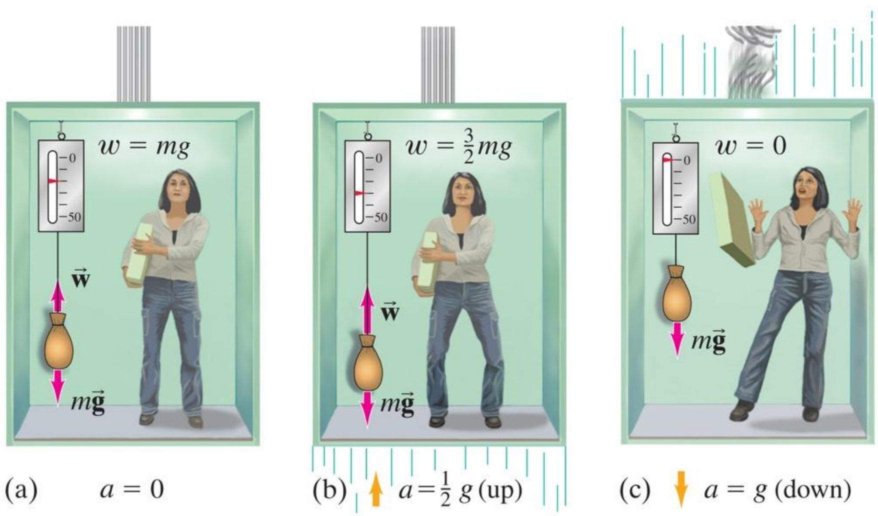


Elevator Problems



- Accelerating up or down will change the “apparent” gravitational acceleration rate *g*





Al’s weight scale reading (F_N) is his apparent weight

$F_N - F_g = ma_{elev}$

$F_N = m(g + a_e)$

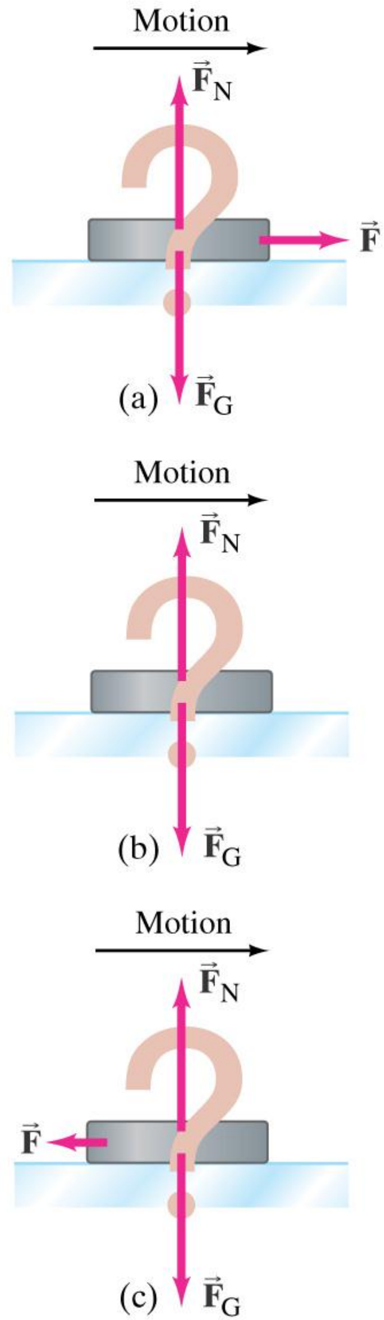
(a_e = + if up and – if down)

Accelerating up = heavier

Accelerating down = lighter

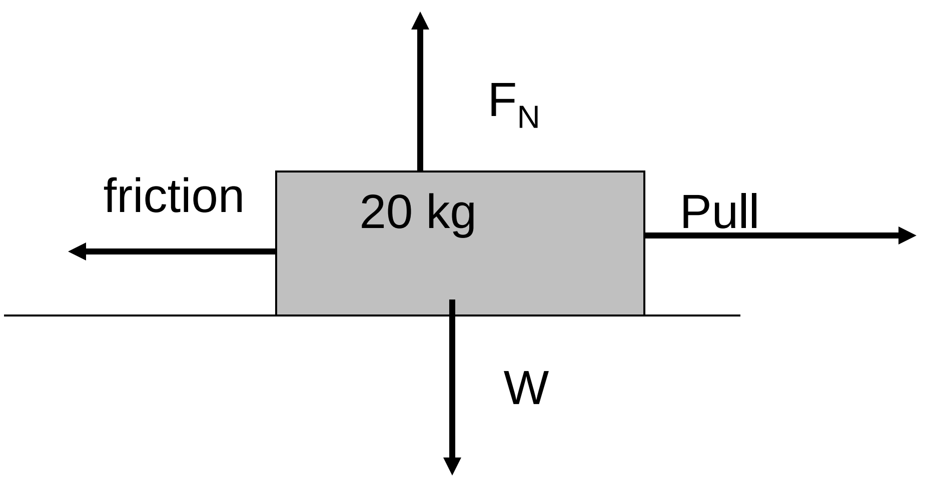
Free fall down: apparent weight = 0

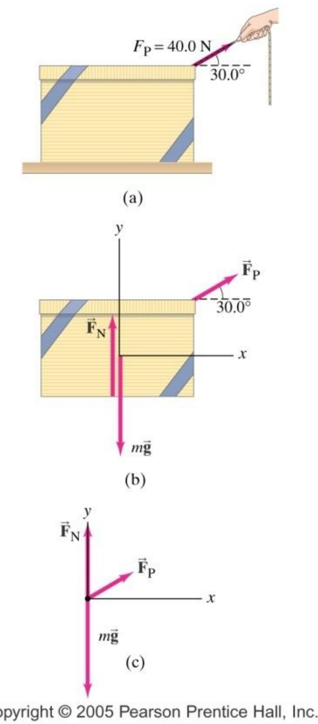
Which one is the correct FBD for an ice puck sliding across frictionless ice?



Problem solving with 2^{nd} Law

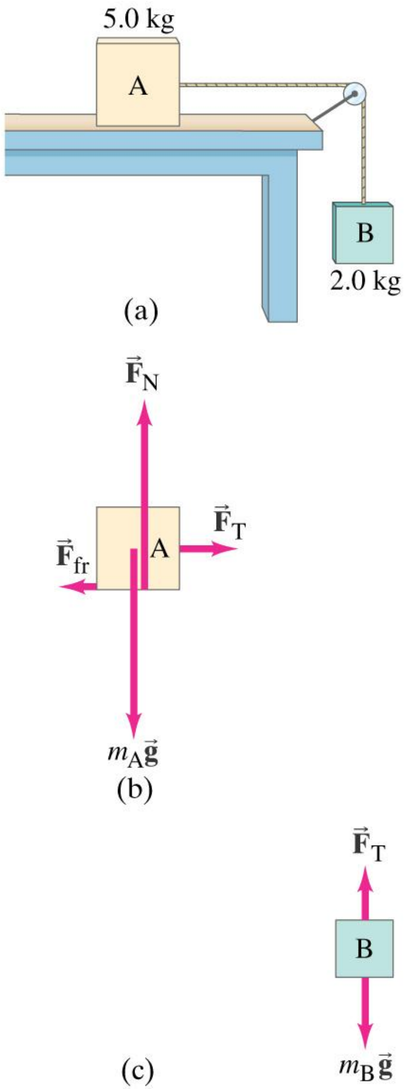
- draw free body diagram
- solve x, y directions independently
- $\Sigma F = ma_x$ Pull + (– friction) = ma_x
- $\Sigma F = ma_y$ Normal force+(– weight)= ma_y
- resolve vectors into components if necessary





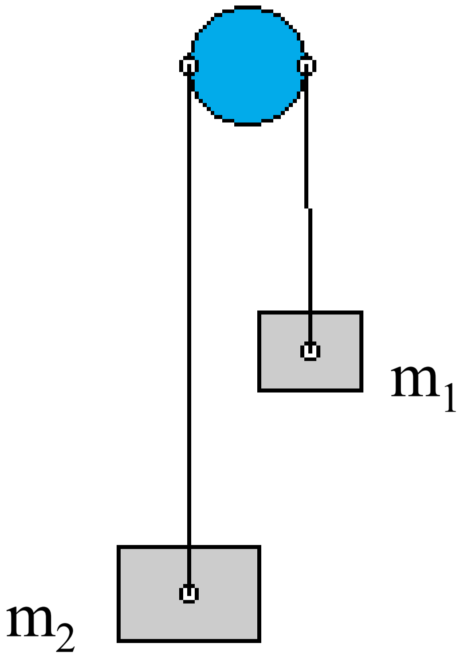
you may need to use kinematic equations to solve for acceleration or use the acceleration value from above in kinematic equations

2 body/pulley problems

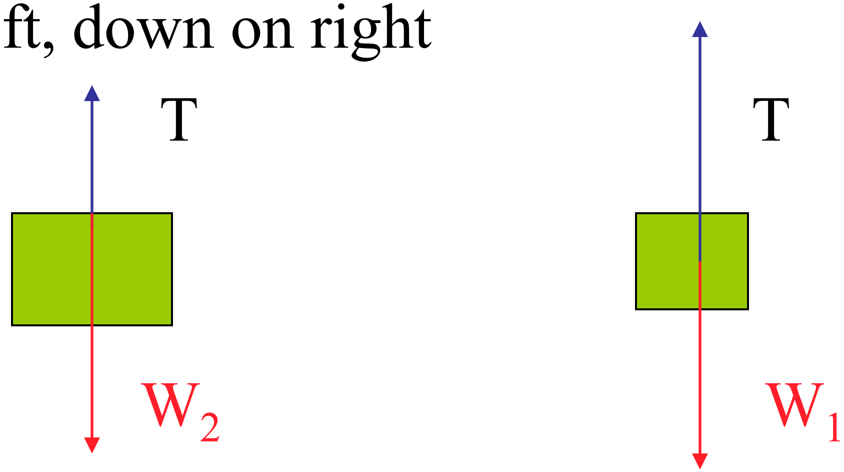


- Apply 2nd law to direction of motion – across table and down is + direction, opposite is – direction
- Tension in rope is constant at all points
- Both masses accelerate at same rate
- Must use total mass of system
- Isolate the hanging mass to solve for tension

Atwood machine



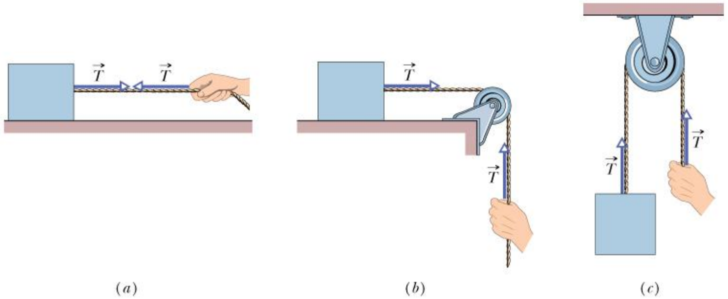
A pulley merely changes the direction of the tension force.
It is easiest to choose a “rotation” direction as + or –
+ up on left, down on right

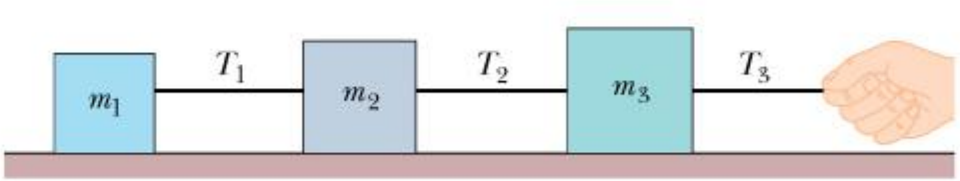


$$T - W_2 = m_2 a \qquad W_1 - T = m_1 a$$

Tension forces

- Created by applying force to a rope, cable
- Equal at all points in rope

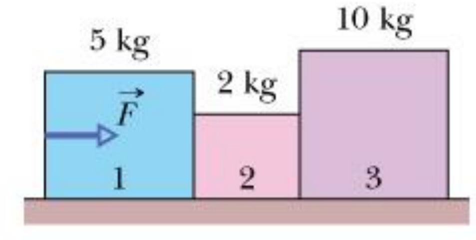




Is T_1=T_2=T_3?

Multi-body Problems

- NO!
- $\Sigma F = ma$
- All boxes accelerate at same rate
  - applied force is directly proportional to mass that is accelerating

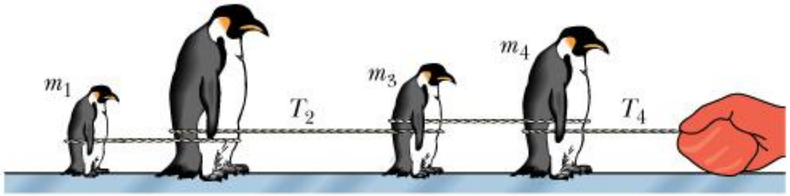


F = 34 N to accelerate 17 kg at 2 m/s^2

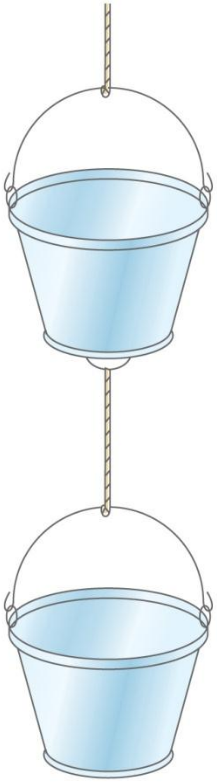
F_2 = 12 x 2 = 24 N

F_3 = 10 x 2 = 20 N

Example: Thrust force to lift a jet much greater than contact force to accelerate the pilot in the jet



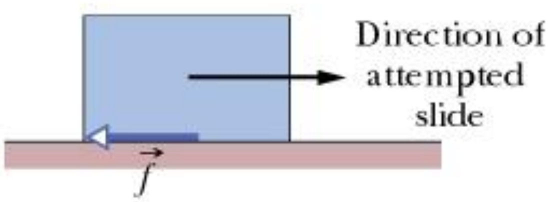
tension forces between object always less than external pull force

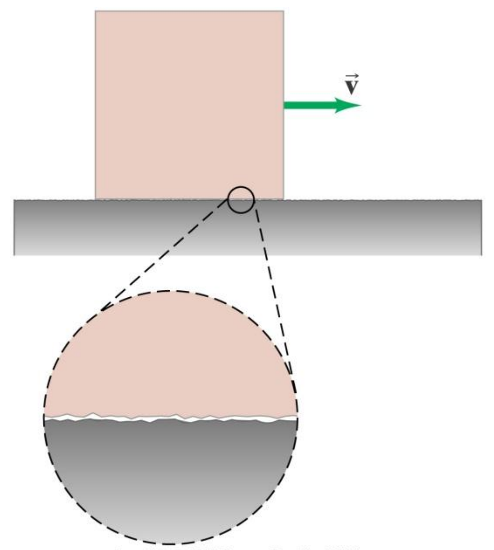


2 scale demo

Friction

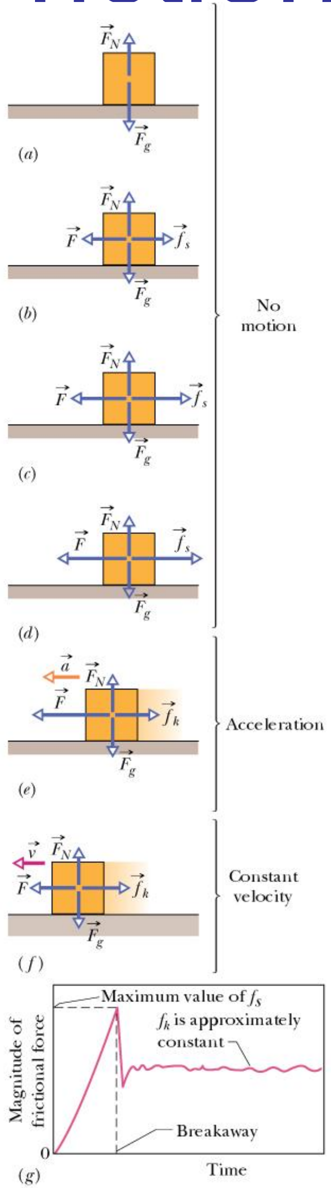
- Friction forces ALWAYS oppose actual or attempted motion between 2 surfaces
- Static friction: no motion $f_s \leq \mu_s F_N$
- Kinetic friction: sliding motion $f_k = \mu_k F_N$

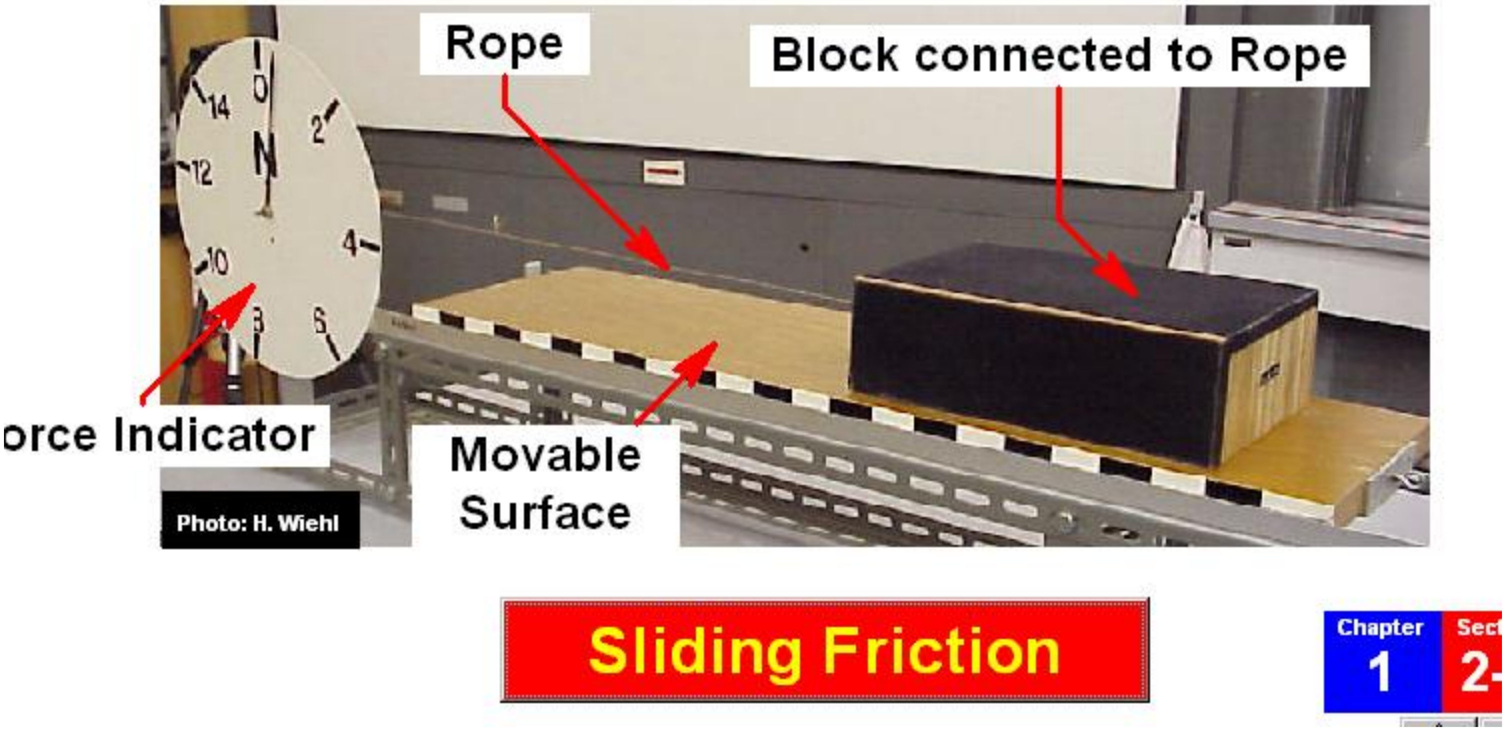




Static, Kinetic Friction

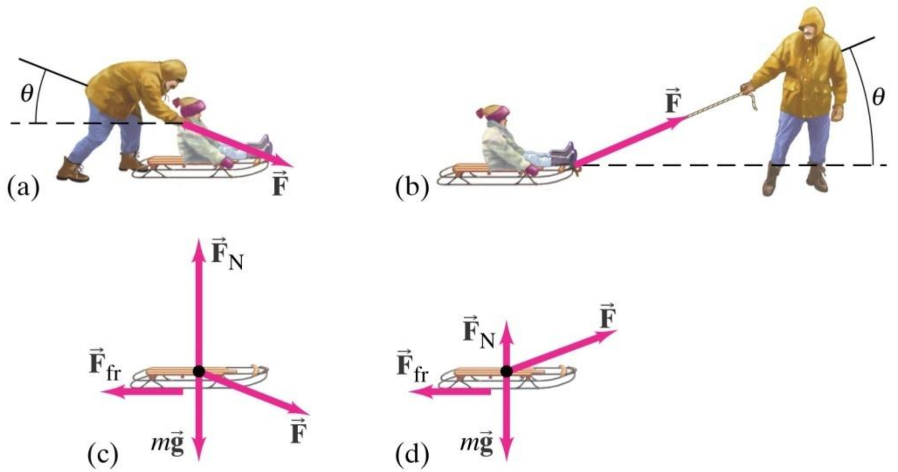
- Static friction changes in response to applied force
- Static friction maximum
  - $f_{s,max}=\mu_s F_N$
  - "on the verge of motion"
  - "just started moving"
- Kinetic friction constant
- coefficient of friction μ is measure of roughness of two surfaces in contact

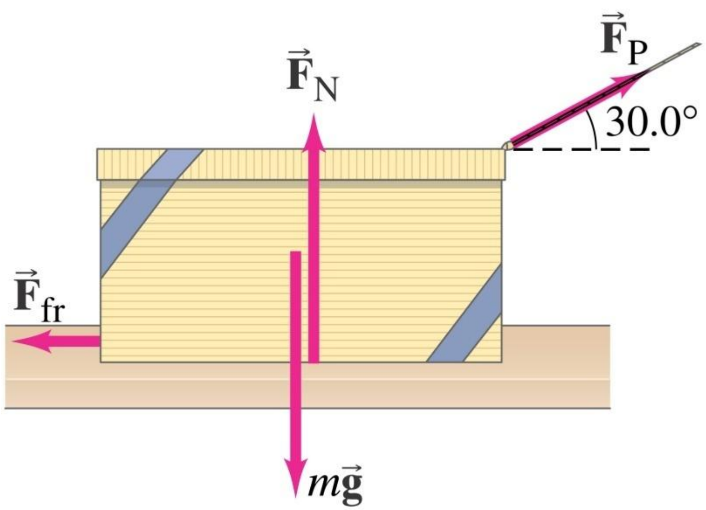



Rope
Block connected to Rope
orce Indicator
Movable Surface
Photo: H. Wiehl
Sliding Friction
Chapter 1
Sect 2-

demo

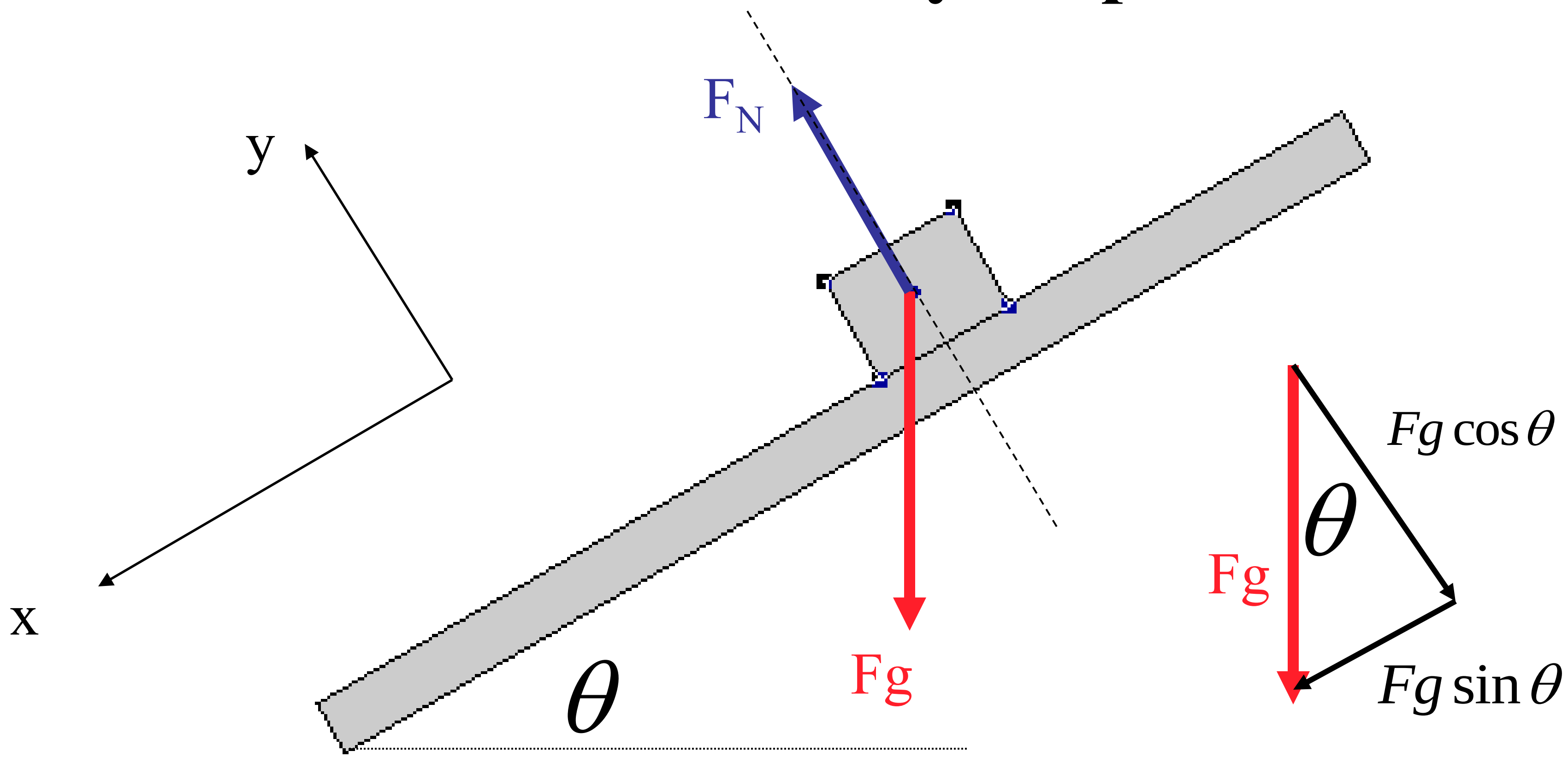
Include friction force in free body diagram





How does angle affect friction force?

Inclines: Which way is up?



Must resolve weight correctly before summing forces in x, y

normal force F_N not equal to weight

Apply 2nd law problem solving techniques

- $\Sigma F_x = ma_x$
- $\Sigma F_y = ma_y$