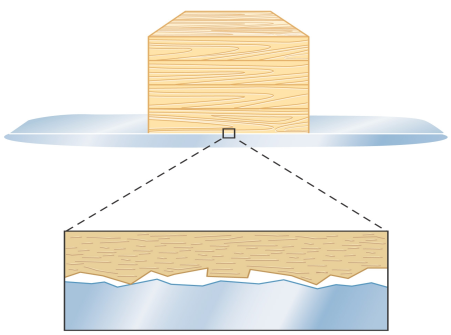
Chapter 5

Force Further Applications

Forces of Friction

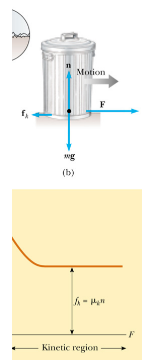
- When an object is in motion on a surface or through a viscous medium, there will be a resistance to the motion
  - This is due to the interactions between the object and its environment
- This resistance is called the *force of friction*

Microscopic Friction



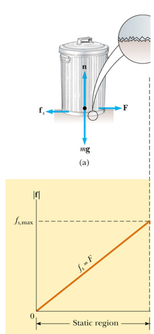
Kinetic Friction

- The force of kinetic friction acts when the object is in motion
- $f_k = \mu * Fn$



Static Friction, f_s

- Static friction acts to keep the object from moving
- If F increases, so does f_s
- If F decreases, so does f_s
- $f_s \leq \mu$ n

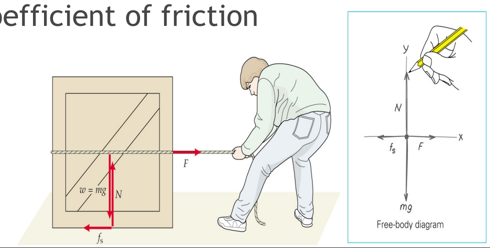


More About Friction

- Friction is proportional to the normal force
- The force of static friction is generally greater than the force of kinetic friction
- The coefficient of friction (µ) depends on the surfaces in contact
- The direction of the frictional force is opposite the direction of motion
- The coefficients of friction are nearly independent of the area of contact

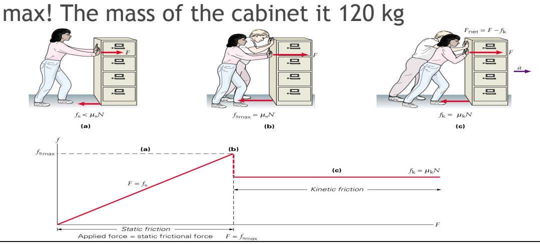
Friction Example 1

If the box has a mass of 25 kg and the person is pulling with a force of 150 N when the static friction breaks what is the coefficient of friction



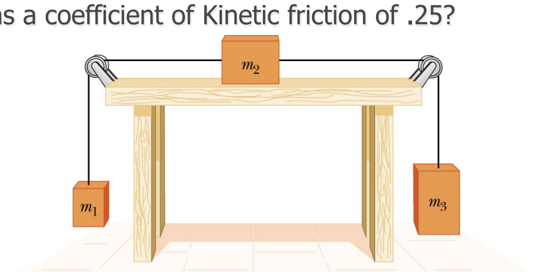
Friction Example 2

Assuming that each person is pushing at the same rate and that the kinetic coefficient of friction is 0.6 and the static coefficient is 0.7; What is the acceleration of the cabinet with 2 people if 1 person's force takes the static coefficient to the max! The mass of the cabinet it 120 kg

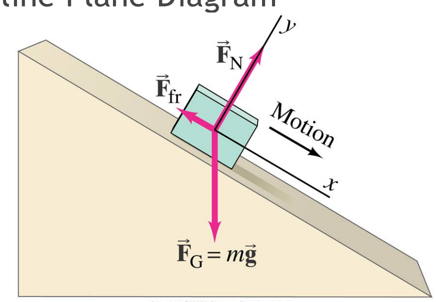


Friction Example 3

If block 1 has a mass of 15 kg and block 2 has a mass of 30 kg and block 3 has a mass of 45 kg what is the acceleration of the system if Block 2 has a coefficient of Kinetic friction of .25?

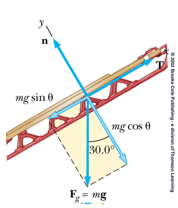


Incline Plane Diagram



Friction Example 4

- The mass of the sled shown is 20 kg. The coefficient of kinetic friction is .12. What is it's acceleration down the 30 degree hill with and without friction.



Alternative way to find μ

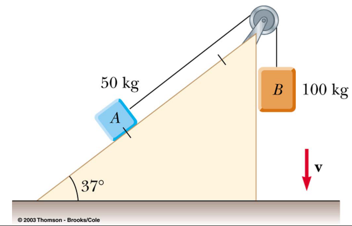
- Assume we have a block on an on an incline and we raise the incline until the block just starts to move at this point we would have:
  - Fp = Ff
  - Fw sin(θ)=μFw cos(θ)
  - Fw sin(θ) / Fw cos(θ) = μ
  - sin(θ) / cos(θ) = μ
  - tan (θ) = μ

Applied forces on an incline continued

- When forces are applied on an incline there angle is based on surface of the incline.
- Forces parallel to the incline are at 0 and 180 degrees.
- Forces that are perpendicular to the incline are 90 degrees
- The applied forces can add or subtract from the force normal, the force parallel, or both.
- Consider this in your calculations.
- If the applied force effects the force normal then the force of friction will change!

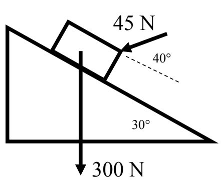
Applied Forces on an Incline Example 1

What is the acceleration of the System?
What is the velocity of block b when it hits the ground after dropping .5 meters?



Applied Forces on an Incline Example 2

What is the net normal force?
What is the acceleration of the System?



Problem Solving Strategies for solving ALL force problems

1. Draw a free body diagram of the situation

2. Determine the Fw of the object using the equation Fw=ma

Problem Solving Strategies for solving ALL force problems

3. Analyze the applied force. If there is none, Fapp=0. If there is one, how is related to the plane the object is lying on. Is it at 0 deg? 90 deg? Or some other value.
   1. Use the equation Fapp(parallel)=Fapp * cos (theta----APPLIED)
   2. Use the equation Fapp(normal)=Fapp * sin (theta----APPLIED)

Problem Solving Strategies for solving ALL force problems

4. If there is more then one force applied repeat step 3 until all the components are found. Add up all the like components to come up with the total force applied in the parallel and normal directions.

5. Determine the force normal. Fn=Fw * cos (thetaincline)

Problem Solving Strategies for solving ALL force problems

6. Fn (net) =Fn + Fapp (normal). (Make sure you use the correct sign for the direction)

7. Determine the Force parallel caused by gravity using the equation Fp:=Fw x sin (thetaincline)

8. Determine the force friction using the equation Ff:=Fn(net) * mu

Problem Solving Strategies for solving ALL force problems

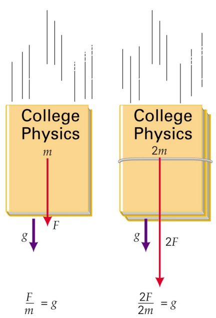
9. Now look at the Force net. Remember Fnet is what the outside observer sees. If you don’ t know anything you can look at the block and use a stop watch to determine it velocity. From that you can determine acceleration. If you know the mass of the object then you can use Fnet=ma. OR the total force can be given!

10. Now you have all of the variables. Plug them in to the following equation. Remember to use the proper signs for the proper direction.
    1. Fnet(along the parallel)= Fp + Fapp(parallel) + Ff

Free Fall

- Since a small mass need a small force to accelerate and a large mass needs a large mass to accelerate both F and M in both cases are proportional

- That is the Ratio of F to M is always 9.8



Air Resistance

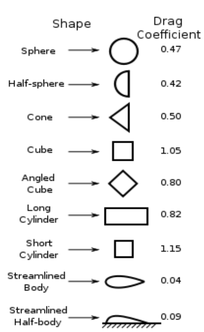
- Another type of friction is air resistance

- Air resistance is proportional to the speed of the object

Air Resistance

$$F_d = \frac{1}{2}\rho v^2 C_d A$$

- ρ=Air Density
- v=velocity
- Cd=Coefficent of Drag
- A= Surface area



Measured Drag Coefficients

Terminal Speed

- When the upward force of air resistance equals the downward force of gravity, the net force on the object is zero

$$mg - \frac{1}{2}\rho v^2 A C_d = 0\ .$$

- The constant speed of the object is the *terminal speed*

$$V_t = \sqrt{\frac{2mg}{\rho A C_d}}$$

Force Applied To Area
PRESSURE

- When force is applied to an area, we say that there is a pressure
- Pressure=Force/Area
- Pressure is measured in Pascals (Pa)
- Determine your pressure on the ground using graph paper

Hooke's Law

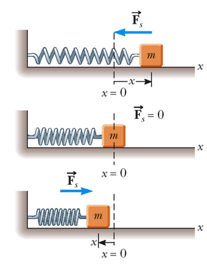
- $F_s = - k x$
  - F_s is the spring force
  - k is the spring constant
    - It is a measure of the stiffness of the spring
      - A large k indicates a stiff spring and a small k indicates a soft spring
  - x is the displacement of the object from its equilibrium position
    - x = 0 at the equilibrium position
  - The negative sign indicates that the force is always directed opposite to the displacement

Hooke's Law Force

- The force always acts toward the equilibrium position
  - It is called the *restoring force*
- The direction of the restoring force is such that the object is being either pushed or pulled toward the equilibrium position

Hooke's Law Applied to a Spring – Mass System

- When x is positive (to the right), F is negative (to the left)
- When x = 0 (at equilibrium), F is 0
- When x is negative (to the left), F is positive (to the right)



Deformation of Solids

- All objects are deformable
- It is possible to change the shape or size (or both) of an object through the application of external forces
- when the forces are removed, the object tends to its original shape
  - This is a deformation that exhibits *elastic behavior*

Elastic Properties

- *Stress* is the force per unit area causing the deformation
- *Strain* is a measure of the amount of deformation
- The *elastic modulus* is the constant of proportionality between stress and strain
  - For sufficiently small stresses, the stress is directly proportional to the strain
  - The constant of proportionality depends on the material being deformed and the nature of the deformation

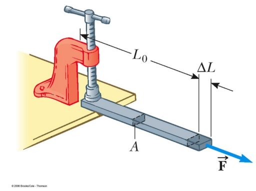
Elastic Modulus

- The elastic modulus can be thought of as the stiffness of the material
  - A material with a large elastic modulus is very stiff and difficult to deform
    - Analogous to the spring constant
  -

stress=Elastic modulus×strain

Young's Modulus: Elasticity in Length

- Tensile stress is the ratio of the external force to the cross-sectional area
  - Tensile is because the bar is under tension
- The elastic modulus is called *Young's modulus*



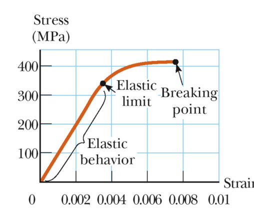
Young's Modulus, cont.

- SI units of stress are Pascals, Pa
  - 1 Pa = 1 N/m²
- The tensile strain is the ratio of the change in length to the original length
  - Strain is dimensionless

$$\frac{F}{A} = Y\frac{\Delta L}{L_o}$$

Young's Modulus, final

- Young's modulus applies to a stress of either tension or compression
- It is possible to exceed the *elastic limit* of the material
  - No longer directly proportional
  - Ordinarily does not return to its original length

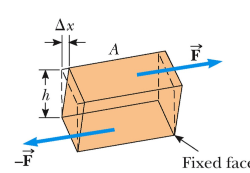


Breaking

- If stress continues, it surpasses its *ultimate strength*
  - The ultimate strength is the greatest stress the object can withstand without breaking
- The **breaking point**
  - For a brittle material, the breaking point is just beyond its ultimate strength
  - For a ductile material, after passing the ultimate strength the material thins and stretches at a lower stress level before breaking

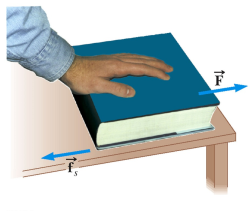
Shear Modulus: Elasticity of Shape

- Forces may be parallel to one of the object's faces
- The stress is called a *shear stress*
- The *shear strain* is the ratio of the horizontal displacement and the height of the object
- The shear modulus is S



Shear Modulus, final

- $$\text{shear stress} = \frac{F}{A}$$
  $$\text{shear strain} = \frac{\Delta x}{h}$$
  $$\frac{F}{A} = S\frac{\Delta x}{h}$$
- S is the shear modulus
- A material having a large shear modulus is difficult to bend

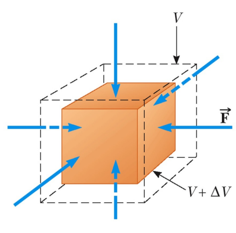


Bulk Modulus: Volume Elasticity

- Bulk modulus characterizes the response of an object to uniform squeezing
  - Suppose the forces are perpendicular to, and act on, all the surfaces
    - Example: when an object is immersed in a fluid
- The object undergoes a change in volume without a change in shape

Bulk Modulus, cont.

- Volume stress, ΔP, is the ratio of the force to the surface area
  - This is also the Pressure
- The volume strain is equal to the ratio of the change in volume to the original volume



Bulk Modulus, final

$$\Delta P = -B\frac{\Delta V}{V}$$

- A material with a large bulk modulus is difficult to compress
- The negative sign is included since an increase in pressure will produce a decrease in volume
  - B is always positive
- The *compressibility* is the reciprocal of the bulk modulus

Notes on Moduli

- Solids have Young' s, Bulk, and Shear moduli
- Liquids have only bulk moduli, they will not undergo a shearing or tensile stress
  - The liquid would flow instead

Ultimate Strength of Materials

- The *ultimate strength* of a material is the maximum force per unit area the material can withstand before it breaks or factures
- Some materials are stronger in compression than in tension