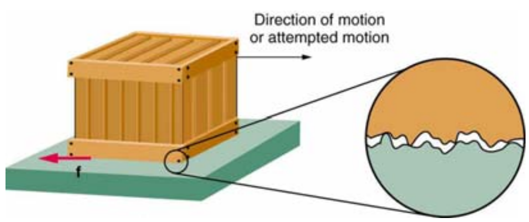
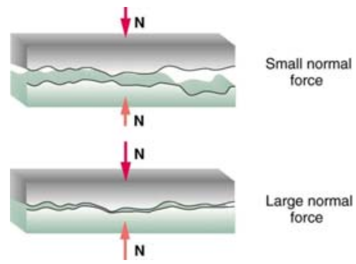
# Chap. 5 Applications: Friction, Drag, and Elasticity

**The frictional force is a force at the interface between two objects in contact. This force is parallel to the interface and acts in a direction to impede or slow down the relative motion between the two objects. The magnitude of this force is proportional to the magnitude of the normal force between the two objects.**



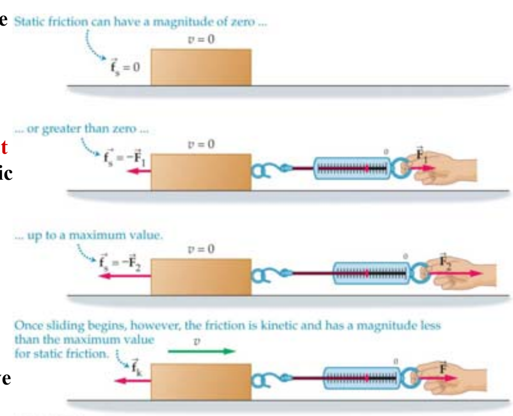




# Static Frictional Forces

**The static frictional force refers to situations where there is no relative movement between the two objects/surfaces. This frictional force can have any value from zero to a maximum value of $f_{S,\max}$ , depending on the applied force. The static frictional force opposes (prevents) applied external force parallel to the surface from causing a relative movement between the two objects. The maximum static friction is**

$$f_{S,\max} = \mu_S n \qquad ,$$

**where $\mu_S$ is known as the coefficient of static friction. The static friction becomes irrelevant when the two objects begin to move with respect to each other.**



## Kinetic Frictional Force

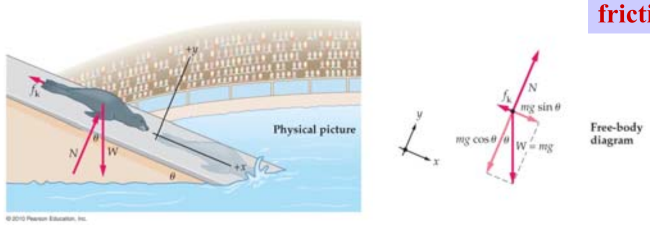
Once two surfaces begin sliding over one another, their motion is impeded by a drag force known as the kinetic frictional force, $f_k$. This force always acts **in a direction to slow down the relative motion**. The magnitude of $f_k$ is given by

$$f_k = \mu_k\, n \quad ,$$

Static and kinetic frictional forces

where $\mu_k$ is known as the coefficient of kinetic friction.

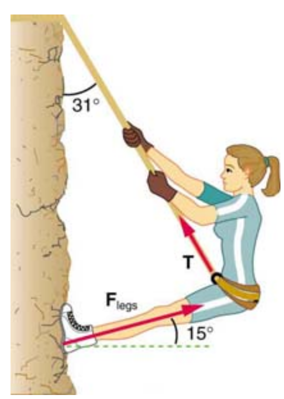
direction of frictional force




example

## Example

17. Consider the 52.0-kg mountain climber in the Figure. (a) Find the tension in the rope and the force that the mountain climber must exert with her feet on the vertical rock face to remain stationary. Assume that the force is exerted parallel to her legs. Also, assume negligible force exerted by herarms (b) What is the minimum coefficient of friction between her shoes and the cliff?



## Drag Force

Drag Force

density of medium

$$F_D = \tfrac{1}{2} C \rho A v^2$$

drag coefficient

cross section

Table 5.2 Drag Coefficient Values **Typical values of drag coefficient $C$.**

| Object | C |
|---|---|
| Airfoil | 0.05 |
| Toyota Camry | 0.28 |
| Ford Focus | 0.32 |
| Honda Civic | 0.36 |
| Ferrari Testarossa | 0.37 |
| Dodge Ram pickup | 0.43 |
| Sphere | 0.45 |
| Hummer H2 SUV | 0.64 |
| Skydiver (feet first) | 0.70 |
| Bicycle | 0.90 |
| Skydiver (horizontal) | 1.0 |
| Circular flat plate | 1.12 |

Upon reaching constant velocity in free fall:

$$mg = F_D = \tfrac{1}{2} C \rho A v_t^2$$

$v_t$ : terminal velocity.

$$v_t = \sqrt{\frac{mg}{2C\rho A}}$$

$\rho_{air}$ 1.21 kg/m$^3$

## Example

**25. Calculate the speed a spherical rain drop would achieve falling from 5.00 km (a) in the absence of air drag (b) with air drag. Take the size across of the drop to be 4 mm, the density to be 1.00 x 10$^3$ kg/m$^3$, and the surface area to be $\pi r^2$.**

## Solids and Elastic Deformation

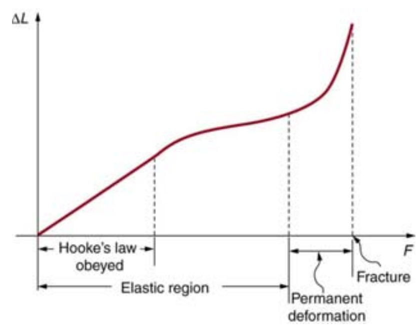
$$\text{Elastic modulus} = \frac{\text{stress}}{\text{strain}}$$

Stress: force per unit area

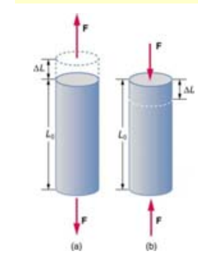
Strain: fractional deformation

Unit of stress: $N/m^2$ = pascal (Pa)

Stress: force per unit area




## Elastic Deformation: Young's And Shear Moduli



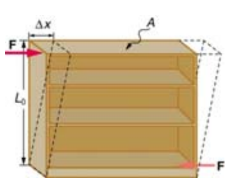

"uniaxial strain"

$$F = Y\left(\frac{\Delta L}{L_o}\right)A$$

Young's modulus

**Young's modulus**

shear strain




$$F = S\left(\frac{\Delta X}{L_0}\right)A$$

shear modulus

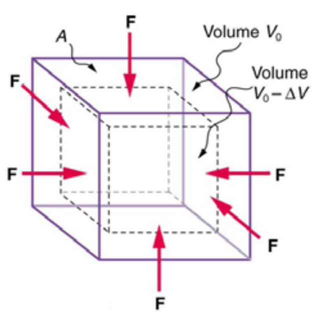
**shear modulus**

unit of modulus: $N/m^2$ (= pascal, Pa)

## Example

**34. A 20-0-m tall hollow aluminum flagpole is equivalent in stiffness to a solid cylinder 4.00 cm in diameter. A strong wind bends the pole much as a horizontal force of 900 N exerted at the top would. How far to the side does the top of the pole flex?**

## Bulk Modulus




**isotropic pressure**

$$F = B\left(\frac{\Delta V}{V}\right)A$$

**bulk modulus**

**bulk modulus**

**unit of modulus: N/m$^2$ (= pascal, Pa)**

## Springs and Hooke’s Law (Preview)

### Hooke’s Law:

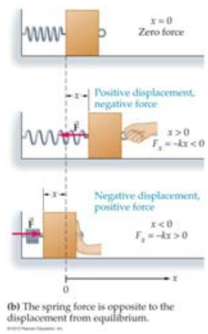
**The restoring force of an ideal spring is**

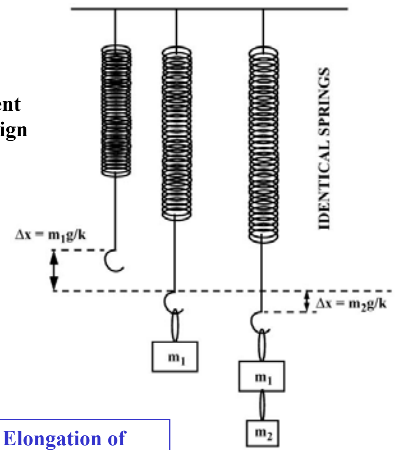
$$F = - k\,x$$

**where k is the spring constant and x is the displacement of the spring from its unstrained length. The minus sign indicates that the restoring force always points in a direction opposite to the displacement of the spring.**

**Unit of k: N/m**

**spring**



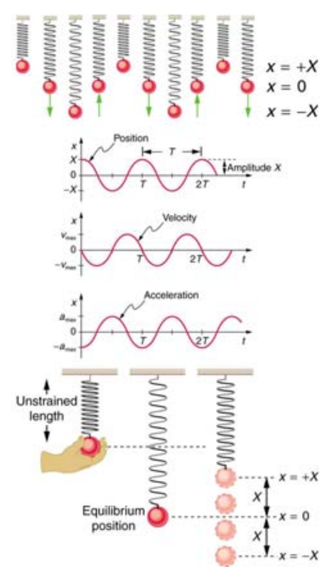

**Note: Elongation of spring is additive.**

## Simple Harmonic Motion (Preview)

### Mass on a spring

$$\omega = \sqrt{\frac{k}{m}}$$ **Angular velocity**

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$$ **Period of Oscillation**



## Chap. 5 Summary

**Friction:**

$$f_{S,\max} = \mu_S n$$

$$f_k = \mu_k n$$

**Drag Force:**

$$F_D = \tfrac{1}{2} C \rho A v^2$$

**Elasticity: Stress and Strain**

**Hooke's Law**

**Young's Modulus: uniaxial stress**

**Shear Modulus: shear stress**

**Bulk Modulus: hydrostatic pressure**

$$F = Y\left(\frac{\Delta L}{L_o}\right) A$$