# Physics 141.
# Review exam # 2.

**It's all physics!**

# Physics 141 Exam # 2.

- Exam # 2 will take place on Thursday 10/17 between 8 am and 9.20 am.
- Exam # 2 will cover the material of Chapters 4, 5, 6, and 7.

- General remarks:
  - You must answer question 11 and 12 in one blue booklet.
  - You must answer question 13 in the second blue booklet.
  - **If you answer all analytical questions in one blue booklet, question 13 will not be graded.**
  - You must enter your student ID in the appropriate place on the scantron form. **No ID on the form, no grade for the multiple-choice questions.**
  - If you arrive after 8.45 am, you will not be allowed to take the exam.
  - You cannot leave the exam before 8.45 am.

# Next week

- No recitations on Tuesday 10/15 (fall break).
- Regular office hours and recitations on Wednesday 10/16 to help you prepare for Exam # 2. Everyone can attend any of the two recitations on 10/16.
- No office hours on Thursday 10/17

# Surviving Phy 141 Exams.

- Time your work:
  - Exam has 10 MC + 3 analytical questions.
  - Work 15 minutes on the MC questions.
  - Work 15 minutes on each of the analytical questions (45 minutes total).
  - You now have 30 minutes left to finish those questions you did not finish in the first 15 minutes.
- Write neatly – you cannot earn credit if we cannot read what you wrote!
- Write enough so that we can see your line of thought – you cannot earn credit for what you are thinking!
- Know you student id # to identify your scantron form.

# Surviving Phy 141 Exams.

- Every problem should start with a diagram, showing all forces (direction and approximate magnitude) and dimensions. All forces and dimensions should be labeled with the variables that will be used in your solution.
- Indicate what variables are known and what variables are unknown.
- Indicate which variable needs to be determined.
- Indicate the principle(s) that you use to solve the problem.
- If you make any approximations, indicate them.
- Check your units!

# Surviving Phy 141 Exams.

- Look at the solutions to the homework assignments.
- Take the practice exam (I updated our practice exams to reflect the material covered on our exams this year).
- Look at the end-of-chapter problems.
- Be well rested when you come to the exam!

# Review Midterm Exam # 2.
# Chapter 4.

- The focus of this Chapter is the atomic nature of matter and the forces that act on our system and influences its motion.

- We discussed a model of a solid in terms of a lattice of atoms that are interconnected by springs. Many dynamic properties of a solid can be understood in terms of this simple model.

- We discussed various forces and types of motion:
  - Simple-harmonic motion are discussed and the force requirements for this type of motion.

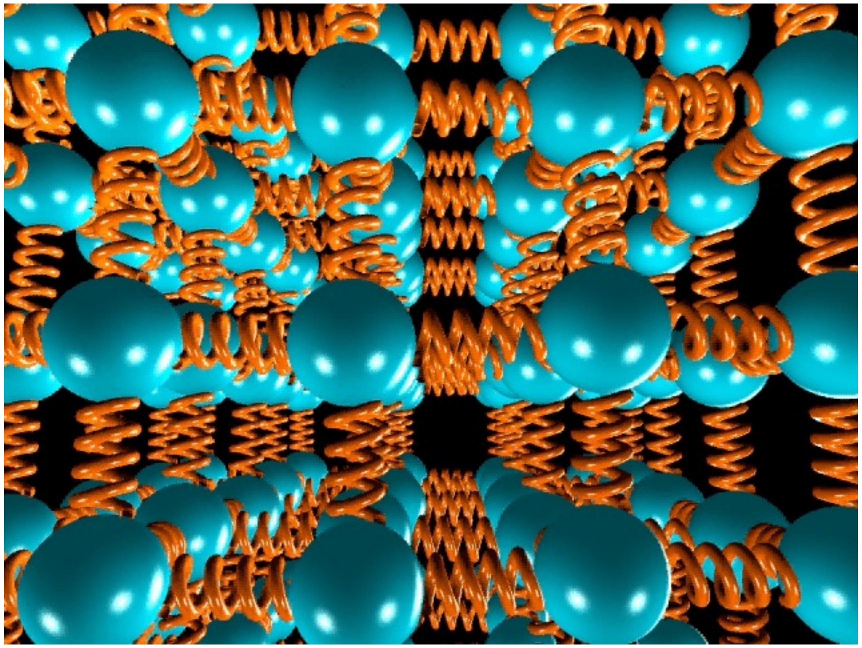
- Sections excluded: none (sorry).

# Review Midterm Exam # 2.
# Chapter 4.

- Terminology introduced:
    - The atomic model of a solid.
    - Tension.
    - Stress and strain.
    - Harmonic motion.

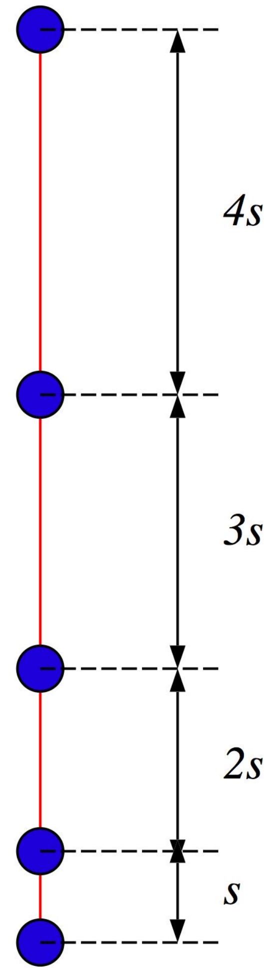
# Review Midterm Exam # 1. Chapter 4.

- We can visualize a solid as a collection of atoms of mass *m*, interconnected by springs.
- The atoms are not at rest in a sold, but continuously vibrate around an equilibrium position.
- The temperature of the solid is a measure of the kinetic energy associated with the motion of the atoms.
- This simple model can explain many important properties of matter, but many others can only be explained in terms of quantum mechanics.



# Review Chapter 4.
# The atomic model of a wire.

- A commonly used atomic model of a wire is a model in which the atoms are connected via springs of spring constant *k*.
- The inter-atomic separation will increase when we move up the wire.
- The assumption that the tension in the wire is constant is thus a poor approximation.
- When we connect a mass to the wire, there still will be a dependence of the spring force on position, but this dependence will be much smaller than it was before.

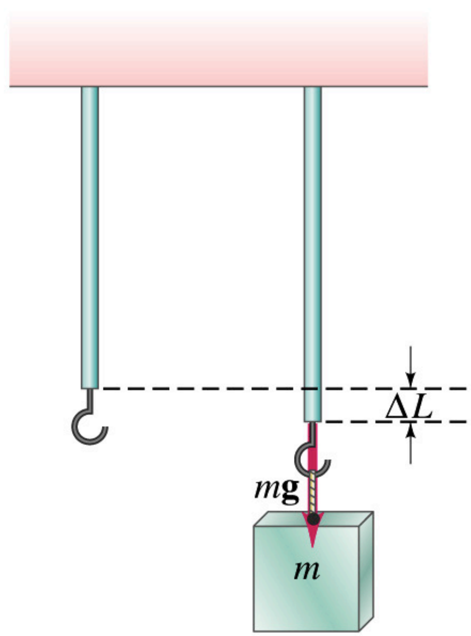


# Review Chapter 4. Stress and strain.

- When we apply a force to an object that is kept fixed at one end, its dimensions can change.
- If the force is below a maximum value, the change in dimension is proportional to the applied force. This is called **Hooke's law**:

$$F = k\Delta L$$

- This force region is called the elastic region.



# Review Chapter 4. Stress and strain.

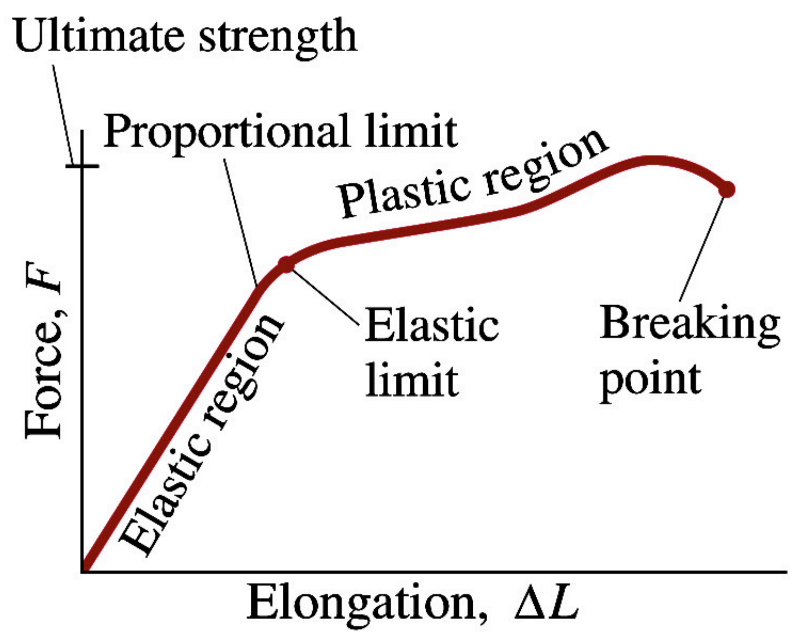
- The elongation $\Delta L$ in the elastic region can be specified as follows:

$$\Delta L = \frac{1}{Y}\frac{F}{A}L$$

where

$L$ = original length
$A$ = cross sectional area
$Y$ = Young's modulus

- **Stress** is defined as the force per unit area (= $F/A$).
- **Strain** is defined as the fractional change in length ($\Delta L/L$).




**Note: the ratio of stress to strain is equal to the Young's Modulus.**

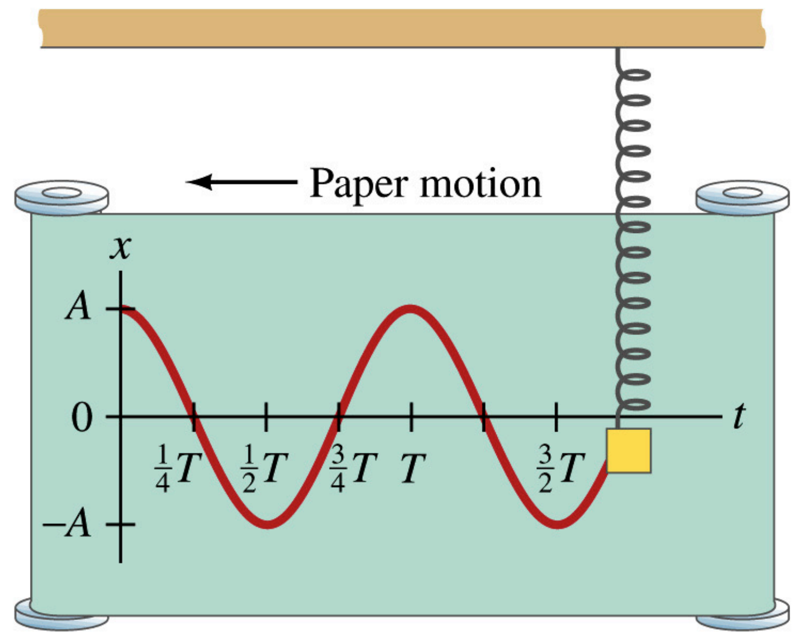
# Review Chapter 4.
# Simple harmonic motion (SHM).

Phase Constant

Amplitude

$$x(t) = A\cos(\omega t + \phi)$$

Angular Frequency



# Review Chapter 4.
# SHM: what forces are required?

- Consider we observe simple harmonic motion.
- The observation of the equation of motion can be used to determine the nature of the force that generates this type of motion.
- In order to do this, we need to determine the acceleration of the object carrying out the harmonic motion:

$$x(t) = A\cos(\omega t + \phi)$$

$$v(t) = \frac{dx}{dt} = -\omega A\sin(\omega t + \phi)$$

$$a(t) = \frac{dv}{dt} = -\omega^2 A\cos(\omega t + \phi) = -\omega^2 x(t)$$

# Review Chapter 4. What forces are required for SHM?

- Using Newton's second law we can determine the force responsible for the harmonic motion:

$$F = ma = -m\omega^2 x$$

- We conclude:

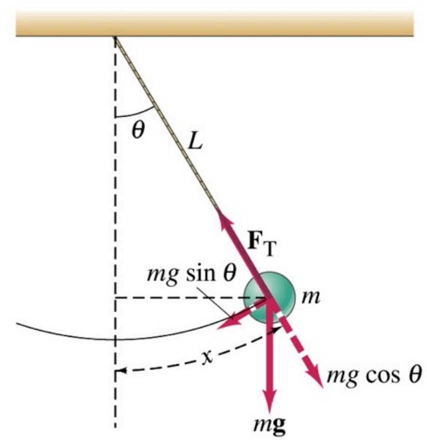
***Simple harmonic motion is the motion executed by a particle of mass m, subject to a force F that is proportional to the displacement of the particle, but opposite in sign.***

- Any force that satisfies this criterion **can** produce simple harmonic motion. If more than one force is present, you need to examine the net force, and make sure that the net force is proportional to the displacements, but opposite in sign.

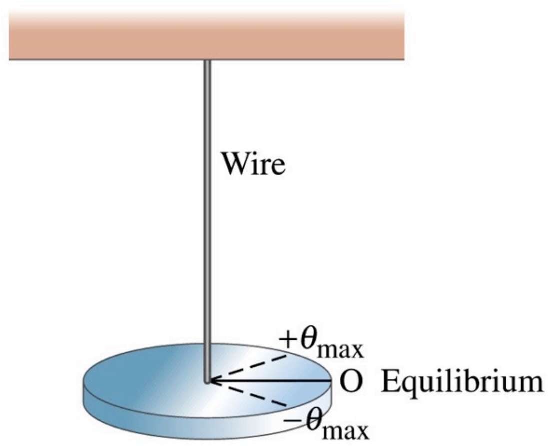
# Review Chapter 4.
# SHM: examples.

- The simple pendulum:
  - The pendulum will carry out SHM with an angular frequency $\omega = \sqrt{g/L}$.
  - The period of the pendulum is thus

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}}.$$




- The torsion pendulum:
  - The pendulum will carry out SHM with an angular frequency $\omega = \sqrt{K/I}$.
  - By measuring the period of the pendulum, we can determine the torsion constant $K$ of the wire.



# Review Chapter 4.
# Damped Harmonic Motion.

- If we add a damping force (such as the drag force) to the equation of motion we obtain:

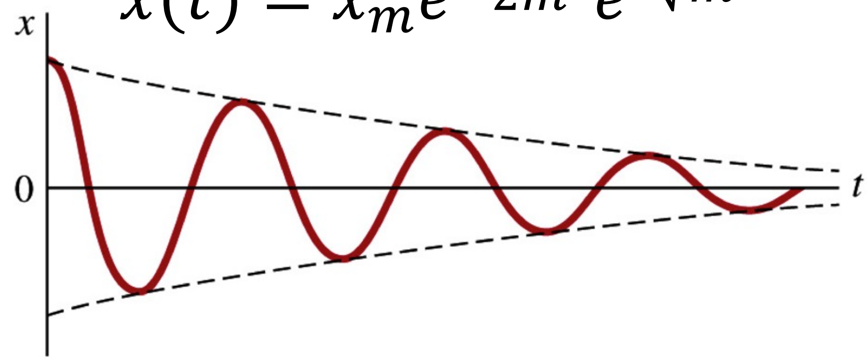
$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$

- The solution of this equation is:

$$x(t) \simeq x_m e^{-\frac{b}{2m}t} e^{i\sqrt{\frac{k}{m}}t}$$

Damping Term ↑ SHM Term ↑

$$x(t) \simeq x_m e^{-\frac{b}{2m}t} e^{i\sqrt{\frac{k}{m}}t}$$



# Review Chapter 4.
# Driven Harmonic Motion.

- When we apply a driving force to our system, the equation of motion becomes

$$\frac{d^2x}{dt^2} = -\omega_0^2 x + F_0 \sin(\omega t)$$

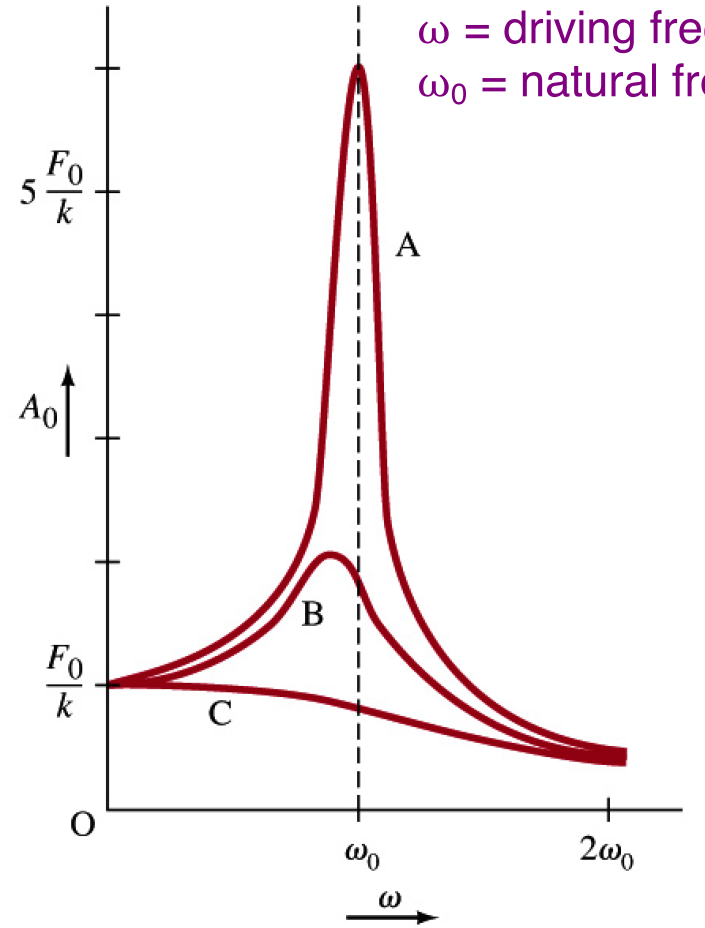
- The steady-state solution of this equation of motion is

$$x(t) = A\cos(\omega t + \phi)$$

- The amplitude $A$ depends on the natural and the driving frequencies:

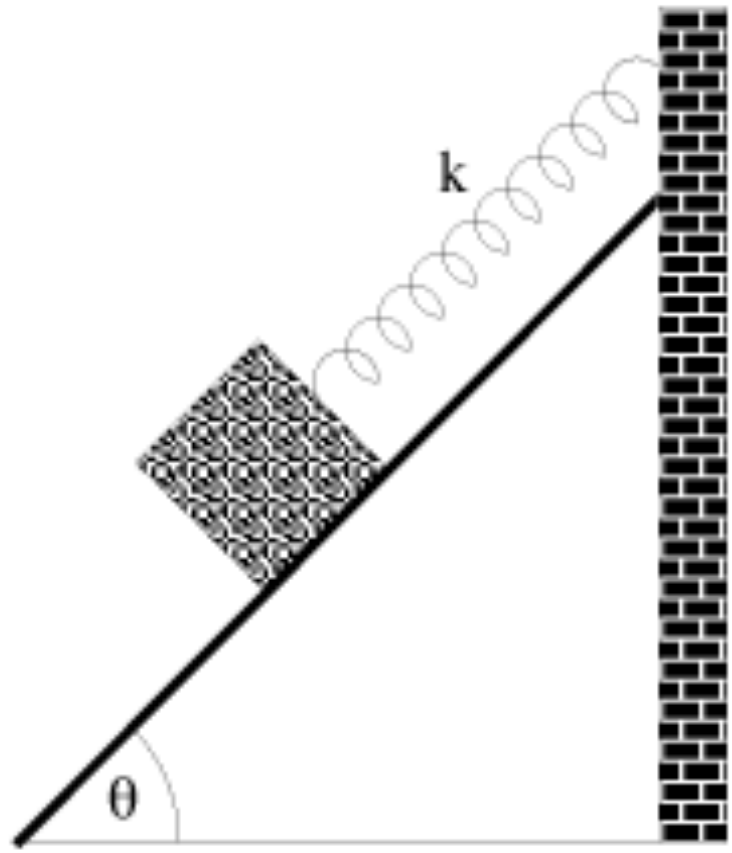
$$A = \frac{F_0}{\omega_0^2 - \omega^2}$$

Note:
$\omega$ = driving frequency
$\omega_0$ = natural frequency



# Another word of caution: make sure you know how to decompose your force(s).

- In many problems you need to decompose an external force into components that are parallel and perpendicular to a surface.
- Know how to do this!
  - Check that your decomposition makes sense.
  - The component of the gravitational force parallel to the inclined plane is $mg$ sin$\theta$. Does this make sense? What do you expect to get if $\theta = 0$?



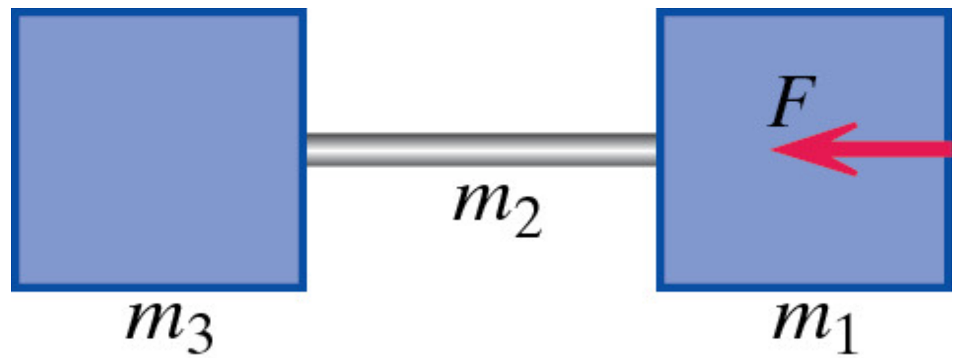
# Review Chapter 4.
# Analyzing Force Diagrams.

- When looking at complex systems:
  - Determine all external forces.
  - How do the components of the system move? If the components of the system carry out the same motion then the acceleration of the system is the ratio of the total external force divided by the total mass.
  - Now look at each component separately. Since we know its acceleration, we can determine the net force acting on it. The net force is the sum of the external and internal forces acting on this component. If some of these forces are not known, their properties can be determined in this way.

# Review Chapter 4.
# Sample problem: P41.

- Two blocks of mass $m_1$ and $m_3$, connected by a rod of mass $m_2$, are sitting on a low-friction surface. You push to the left on the right block with a constant force of magnitude $F$.

- What is the force exerted by the rod on mass $m_3$? Specify magnitude and direction.



# Review chapter 4.

End of Chapter 4

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# Review Midterm Exam # 1.
# Chapter 5.

- The focus of Chapter 5 are the forces that act on our system and influences its motion.

- We discussed various forces and types of motion:
  - Friction forces.
  - Normal forces, drag forces, and buoyant forces.

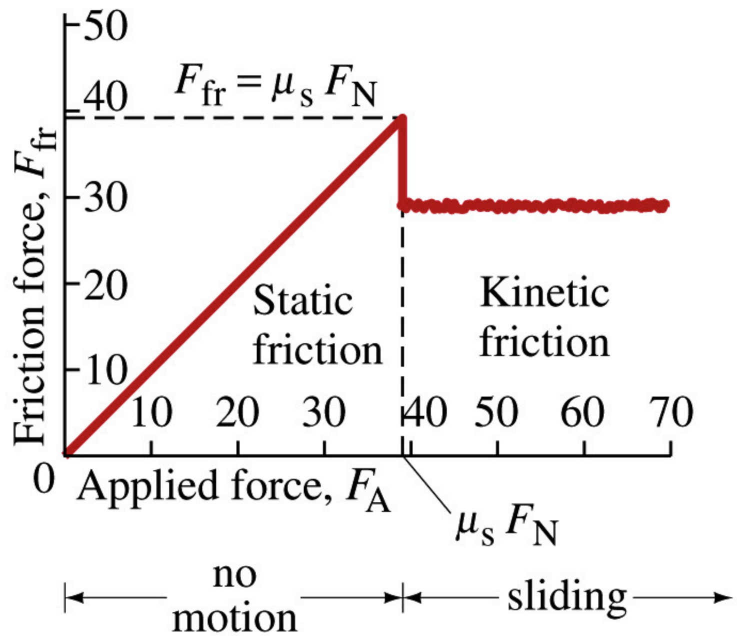
- Sections excluded: none (sorry).

# Review Midterm Exam # 2. Chapter 5.

- Terminology introduced:
  - The normal force.
  - Friction.
  - Buoyancy and pressure.

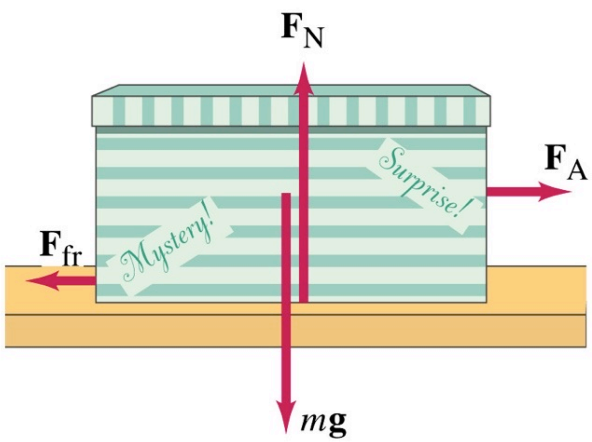
# Review chapter 5.
# Dissipative forces: friction.

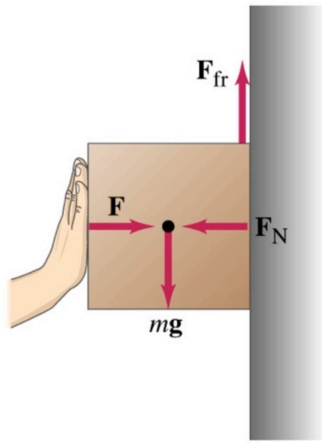
- Observations of the friction force show that :
  - There are two different friction forces: the **static friction** force (no motion) and the **kinetic friction** force (motion).
  - The static friction force increases with the applied force but has a maximum value.
  - The kinetic friction force is independent of the applied force, and has a magnitude that is less than the maximum static friction force.



# Review Chapter 5.
# Dissipative forces: friction.

- The maximum static friction force and the kinetic friction force are proportional to the normal force.
- Changes in the normal force will result in changes in the friction forces.
- **NOTES:**
  - The normal force will be always perpendicular to the surface.
  - The friction force will be always opposite to the direction of (potential) motion.
  - Static friction: $F_{fr} \leq \mu_s N$.
  - Kinetic friction: $F_{fr} = \mu_k N$.

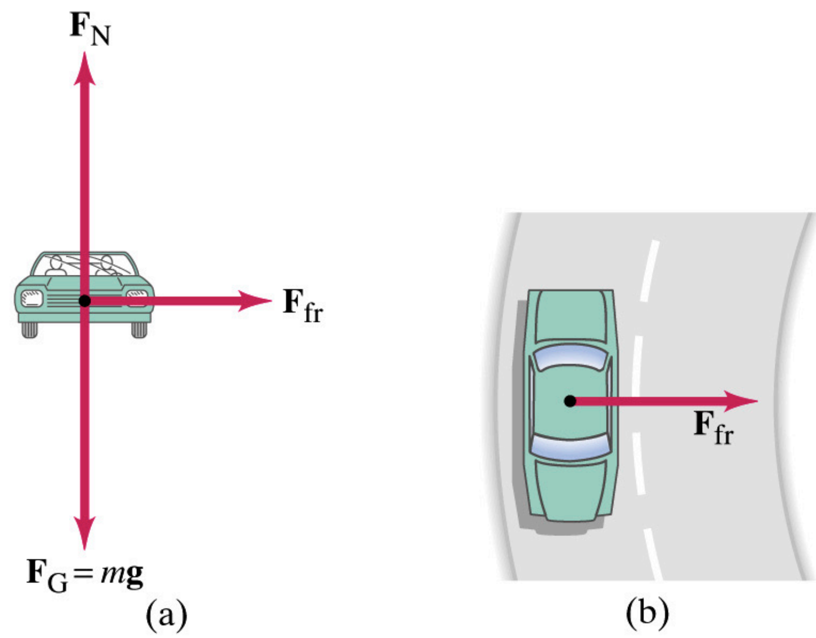


# Review Chapter 5.
# Dissipative forces: friction.

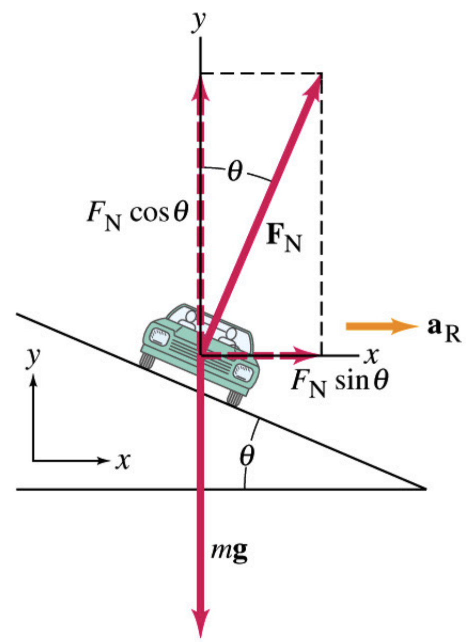
- When you drive your car around a corner you carry out circular motion.
- In order to be able to carry out this type of motion, there must be a force present that provides the required acceleration towards the center of the circle.
- This required force is provided by the friction force between the tires and the road.
- But remember ….. The friction force has a maximum value, and there is a maximum speed with which you can make the turn.

Required force = $Mv^2/r$.
If $v$ increases, the friction force must increase and/or the radius must increase.



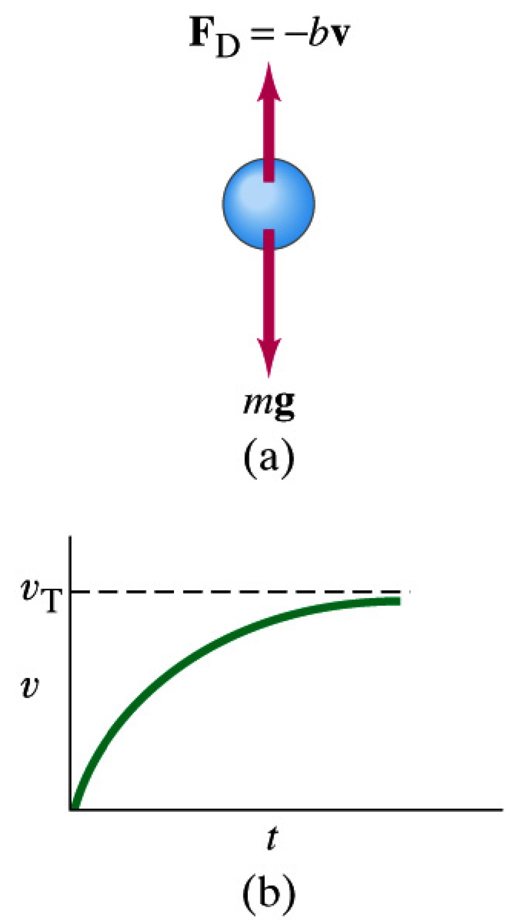
# Review Chapter 5.
# Dissipative forces: friction.

- Unless a friction force is present you can not turn a corner …… unless the curve is banked.
- A curve that is banked changes the direction of the normal force.
- The normal force, which is perpendicular to the surface of the road, can provide the force required for circular motion.
- In this way, you can round the curve even when there is no friction ……. but only if you drive with exactly the right speed (the posted speed).

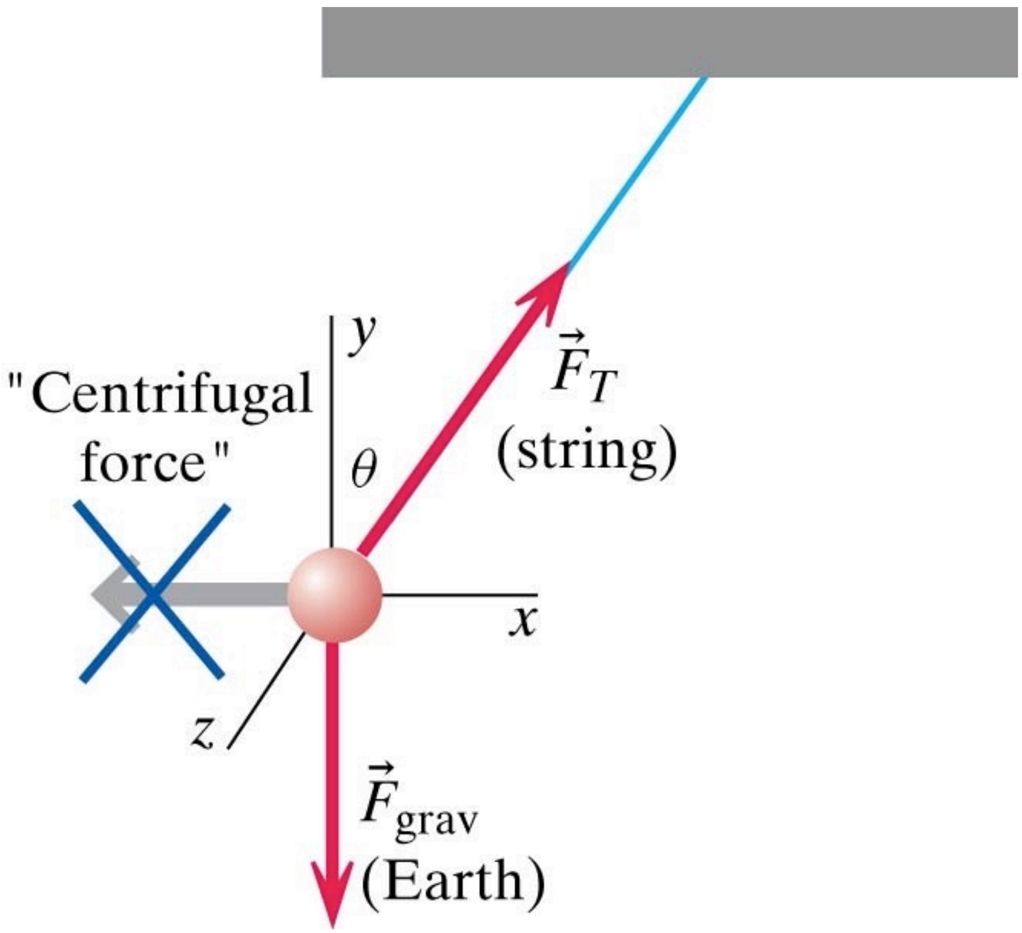


# Review chapter 5.
# Dissipative forces: drag.

- Objects that move through the air also experience a “friction” type force.
- The drag force has the following properties:
  - It is proportional to the cross-sectional area of the object.
  - It is proportional to the velocity of the object.
  - It is directed in a direction opposite to the direction of motion.
- The drag force is responsible for the object reaching a terminal velocity (when the drag force balances the gravitational force).



# One word of caution.
# Never draw a centrifugal force!



# Review Chapter 5.
# Sample problem: P45.

**5.P.59** A small block of mass $m$ is attached to a spring with stiffness $k_s$ and relaxed length $L$. The other end of the spring is fastened to a fixed point on a low-friction table. The block slides on the table in a circular path of radius $R > L$. How long does it take for the block to go around once?

# Review chapter 5.

End of Chapter 5

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# Review exam # 2.
# Chapter 6.

- The focus of Chapter 6 is conservation of energy.
- We firmly believe that the total energy is a conserved quantity: it can neither be created or destroyed.
- Energy can be converted from one form to another form (some of these transformations are reversible, some of them are irreversible).
- Sections excluded: sections 6.19 - 6.21 (except the results).

# Review exam # 2.
# Chapter 6.

- Terminology introduced:
  - Work
  - The energy principle (aka. the work-energy theorem)
  - Energy
  - Kinetic energy
  - Potential energy
  - Conservative and non-conservative forces

# The energy principle.

- The energy principle states that the change in energy of a system ($\Delta E_{\text{system}}$) is equal to the work done by the surroundings ($W_{\text{surr}}$) and the energy flow ($Q$) between the system and surroundings due to a difference in temperature:

$$\Delta E_{system} = W_{surr} + Q$$

- The work $W$ done by the force $F$ is defined as

$$W = \vec{F} \cdot \vec{d} = Fd\cos(\theta)$$

- If $Q > 0$ J, energy flows into the system (e.g. $T_{\text{sys}} < T_{\text{surr}}$). If $Q < 0$ J, energy flows out of the system (e.g. $T_{\text{sys}} > T_{\text{surr}}$).

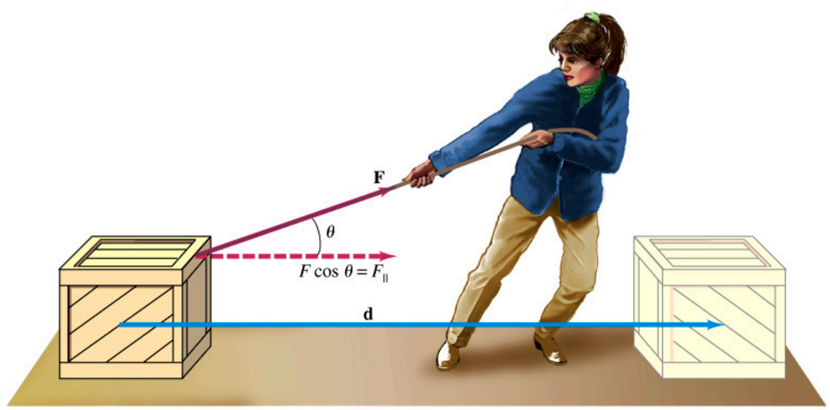
# Review chapter 6.
# Work.

- When a force $F$ is applied to an object, it may produce a displacement $d$.

- The work $W$ done by the force $F$ is defined as

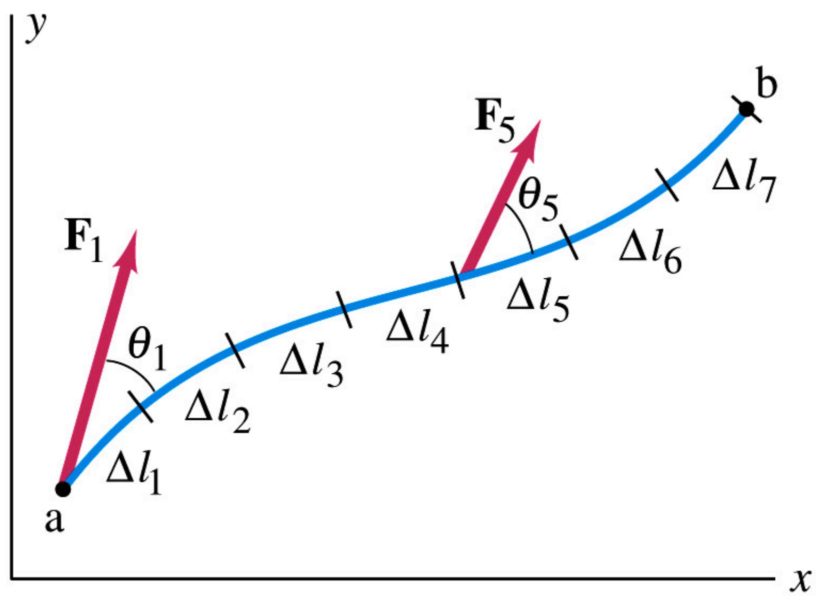
$$W = \vec{F} \cdot \vec{d} = Fd\cos(\theta)$$

where $\theta$ is the angle between the force $F$ and the displacement $d$.



# Review chapter 6.
# Work.

- In most realistic cases, we need to consider the work done when the force is varying (both in magnitude and direction) as function of time and/or position.
- In this case, we can still use the same approach as we just discussed by breaking up the motion into small intervals such that the path is linear and the force is constant during the intervals considered.



# Review chapter 6.
# The energy principle.

- In general, we expect that the change in the energy of a particle is related to the work done by all the forces acting on this particle:

$$\Delta E = W$$

- We take this to be the definition of the energy $E$.
- Consider that the particle, subjected to a force $F$, moves a distance $\Delta x$ along the $x$ axis. The change in energy as a result of this motion will be

$$\Delta E = \vec{F} \cdot d\vec{r} = F_x \Delta x = \left(\frac{\Delta p_x}{\Delta t}\right) \Delta x$$

# Review chapter 6.
# The energy principle.

- The work-energy theorem shows us that the energy of a particle of rest mass $m$, moving with velocity $v$, is equal to

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$$

- We note that even if the particle is not moving, it will have a non-zero energy, equal to $mc^2$. This energy is called the **rest energy** of the particle.
- When the particle is moving, its energy is larger than its rest energy, and this excess of energy is called the **kinetic energy *K*** of the particle (since it is associated with its motion):

$$K = E - mc^2 = mc^2\left(\frac{1}{\sqrt{1 - v^2/c^2}} - 1\right)$$

# Review chapter 6.
# The energy principle.

- In the non-relativistic limit, $v \ll c$, we find for $K$

$$K = mc^2\left(1 + \frac{1}{2}\frac{v^2}{c^2} - 1\right) = \frac{1}{2}mv^2$$

- The energy and the momentum of a particle are related according in the following manner:

$$E^2 - p^2c^2 = (mc^2)^2$$

- We conclude that $E^2 - p^2c^2$ is an invariant (the same in each reference frame).
- If the particle has no mass (e.g. a photon) then the right-hand side is zero, and we conclude that $E = pc$.

# Review chapter 6.
# The potential energy *U*.

- The work done by a force changes the energy of a particle (due to the change in the kinetic energy) and energy is thus not conserved.
- Mechanical energy, defined as the sum of the particle energy and its potential energy $U$, will be conserved if $\Delta U$ is defined as

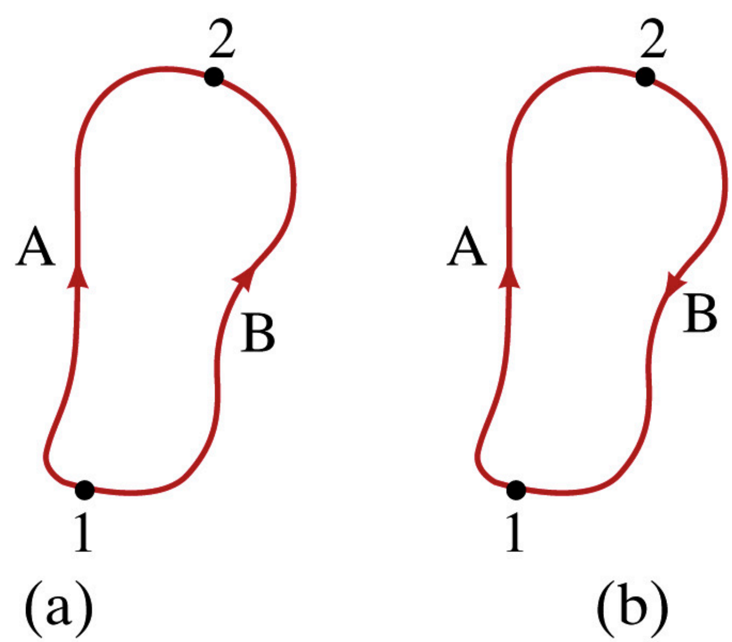
$$\Delta U = -W = -\int_{\vec{r}_0}^{\vec{r}} F(\vec{r}) \cdot d\vec{r}$$

- The potential energy at one position is related to the potential energy at a reference position

$$U(\vec{r}) = U(\vec{r}_0) + \Delta U = U(\vec{r}_0) - \int_{\vec{r}_0}^{\vec{r}} F(\vec{r}) \cdot d\vec{r}$$

# Review chapter 6.
# The potential energy *U*: path dependence.

- If the work is independent of the path and only depends on the initial and final position, then the work around any closed path will be equal to 0 J.
- A force for which the work is independent of the path is called a **conservative force**. With such forces we can associate a potential energy.
- A force for which the work depends on the path is called a **non-conservative force**.



# Review chapter 6.
# Calculating the potential energy.

- The potential energy of 1 spring:

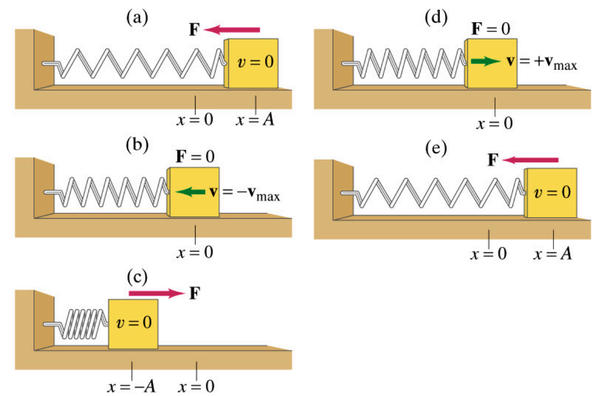
$$U(x) = -W = \frac{1}{2}kx^2$$

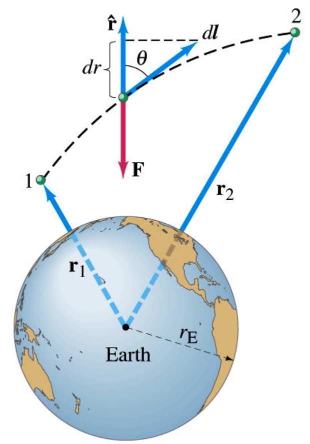
- The potential energy of the gravitational field, choosing our reference point at infinity and setting the potential energy at this position to 0 J:

$$U(\vec{r}) = -G\frac{mM}{r}$$

- The electric potential energy:

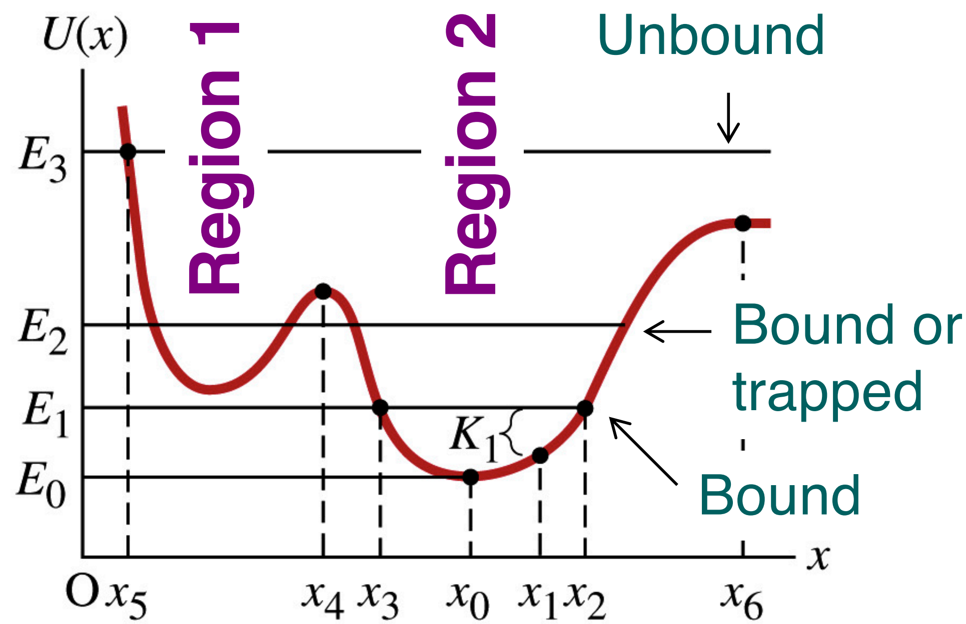
$$U_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$



# Review chapter 6.
# Potential energy distributions.

- Consider a particle that can move in a region where we know the potential energy:
  - If the energy of the particle is $E_1$ it can can move between $x_2$ and $x_3$.
  - If the energy of the particle is $E_3$, it can move in the entire $x > x_5$ region.
  - If the energy of the particle is $E_2$, its motion is restricted to two regions (region 1 and region 2) and no motion from region 1 to region 2, and vice-versa, is permitted.



# Problem 6.Q5.

**6.X.77** Figure 6.71 shows the path of a comet orbiting a star.

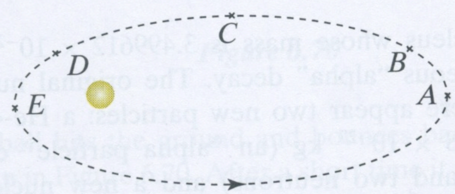



***Figure 6.71***

**(a)** Rank-order the locations on the path in terms of the magnitude of the comet's momentum at each location, starting with the location at which the magnitude of the momentum is the largest.

**(b)** Rank-order the locations on the path in terms of the comet's kinetic energy at each location, starting with the location at which the kinetic energy is the largest.

**(c)** Consider the system of the comet plus the star. Which of the following statements are correct?

A. External work must be done on the system to speed up the comet.

B. As the comet slows down, energy is lost from the system.

C. As the comet's kinetic energy increases, the gravitational potential energy of the system also increases.

D. As the comet slows down, the kinetic energy of the system decreases.

E. As the kinetic energy of the system increases, the gravitational potential energy of the system decreases.

**(d)** Still considering the system of the comet plus the star, which of the following statements are correct?

A. The sum of the kinetic energy of the system plus the gravitational potential energy of the system is a positive number.

B. At every location along the comet's path the gravitational potential energy of the system is negative.

C. The gravitational potential energy of the system is inversely proportional to the square of the distance between the comet and star.

D. The sum of the kinetic energy of the system plus the gravitational potential energy of the system is the same at every location along this path.

E. Along this path the gravitational potential energy of the system is never zero.

**(e)** Rank-order the locations on the path in terms of the potential energy of the system at each location, largest first. (Remember that $-3 > -5$).

# Problem 6.Q6.

**6.X.78** Figure 6.72 is a graph of the energy of a system of a planet interacting with a star. The gravitational potential energy $U_g$ is shown as the thick curve, and plotted along the vertical axis are various values of $K + U_g$.

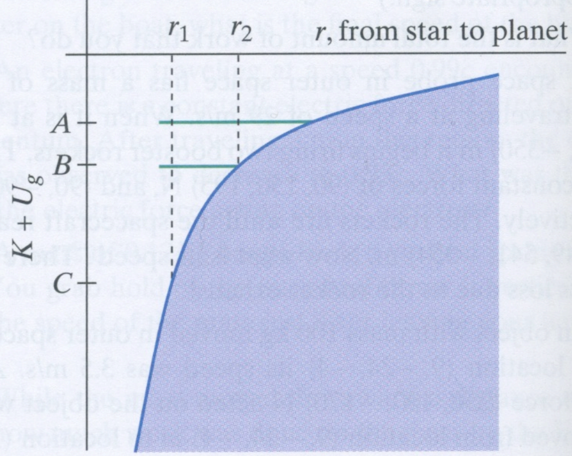



***Figure 6.72***

Suppose that $K + U_g$ of the system is $A$. Which of the following statements are true?

A. The potential energy of the system decreases as the planet moves from $r_1$ to $r_2$.

B. When the separation between the two bodies is $r_2$, the kinetic energy of the system is $(A - B)$.

C. The system is a bound system; the planet can never escape.

D. The planet will escape.

E. When the separation between the two bodies is $r_2$, the kinetic energy of the system is $(B - C)$.

F. The kinetic energy of the system is greater when the distance between the star and planet is $r_1$ than when the distance between the two bodies is $r_2$.

Suppose instead that $K + U_g$ of the system is $B$. Which of the following statements are true?

A. When the separation between the planet and star is $r_2$, the kinetic energy of the system is zero.

B. The planet and star cannot get farther apart than $r_2$.

C. This is not a bound system; the planet can escape.

D. When the separation between the planet and star is $r_2$, the potential energy of the system is zero.

# Review chapter 6.

End of Chapter 6.

# Review exam # 2.
# Chapter 7.

- Chapter 7 extends the discussion of Chapter 6 from one-particle systems to multi-particle systems.
- In this Chapter we learn how to apply conservation of total energy to systems in which various non-conservative forces act.
- The non-conservative forces discussed in this Chapter include static and kinetic friction, air resistance, and viscous friction.
- Sections excluded: none.

# Review exam # 2.
# Chapter 7.

- Terminology introduced:
  - Potential energy of multi-particle systems.
  - Thermal energy.
  - Energy accounting in open and closed systems.
  - Conservation of energy in the presence of non-conservative forces.
  - Friction and resistance.

# Review chapter 7.
# The energy principle.

- When we are dealing with multi-particle systems we have to separate the forces acting on the system into two groups:
  - Internal forces: forces that act between the particles that make up the system.
  - External force: forces that are generated due to interactions between the system and its surroundings.
- Thus

$$\sum_i \Delta E_i = W_{ext} + W_{int}$$

- The opposite of the work done by the internal forces on the system is called the **potential energy** of the system

$$\sum_i \Delta E_i - (W_{int}) = \sum_i \Delta E_i + \Delta U = W_{ext}$$

# Review chapter 7.
# The potential energy $U$.

- The potential energy $U$ of a system of particles is the energy associated with the interaction between the constituents of the system.

- The change in the potential energy of a pair of particles with an interaction force $F$ acting between them is given by

$$\Delta U = -\left(\vec{F}_{1,2} \cdot \Delta\vec{r}_1 + \vec{F}_{2,1} \cdot \Delta\vec{r}_2\right) = -\vec{F}_{2,1} \cdot (\Delta\vec{r}_2 - \Delta\vec{r}_1)$$

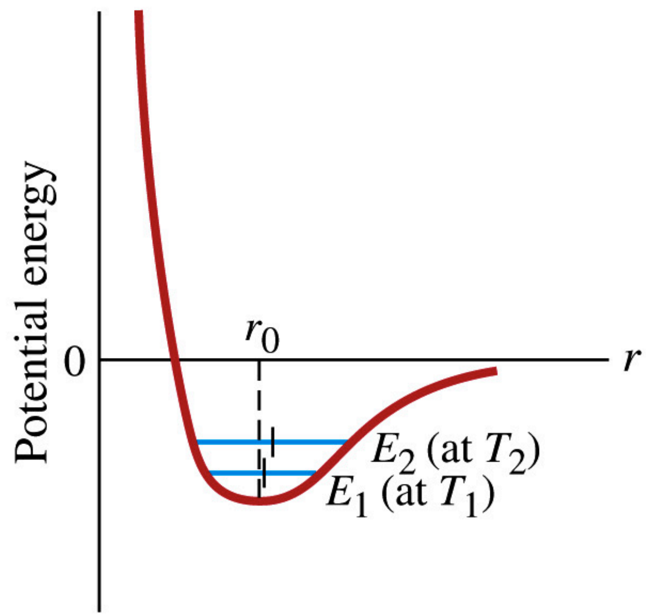
- If the configuration of the system does not change (e.g. a rigid object), its potential energy will also not change.

# Review chapter 7.
# Conservation of mechanical energy.

- When **dissipative forces**, such as friction forces, are present, the **mechanical energy of a system will no longer be conserved** and energy will be exchanged between the system and its surroundings.
- The amount of energy being exchanged will depend on the path along which the system evolved, and we can not assign a potential energy with these forces (nor will a motion along the path in opposite direction restore the energy that we moved from the system to its environment.
- The amount of energy dissipated by these non-conservative forces can be calculated if we know the magnitude and direction of these forces along the path followed by the object.

# Review chapter 7. Thermal energy.

- One form of energy that is frequently present in mechanics problems (but often ignored) is the thermal energy.
- Thermal energy is associated with the temperature of a system; a change in thermal energy correspond to a change in temperature.
- An increase in the temperature of a material will increase the amplitude of the inter-atomic vibrations, and increase the average distance between atoms (due to the fact that the potential energy is not symmetric around its minimum).



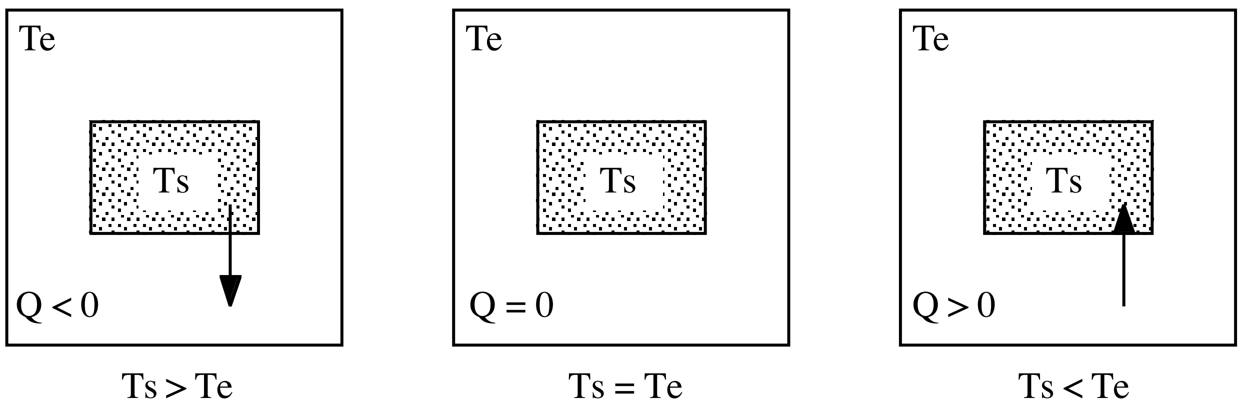
# Review chapter 7.
# Measuring temperature.

- In order to measure temperature we must:
  - Agree on a standard reference point to which we assign a certain temperature.
  - Agree on a unit.
  - Agree on a standard thermometer against which all other thermometers can be calibrated.
- The unit of temperature will be the Kelvin (K).
- The standard reference point is the triple point of water ($T$ = 273.16 K).

http://www.fluke.fr/common/prod_pages/pages/hart/products/tpw.htm

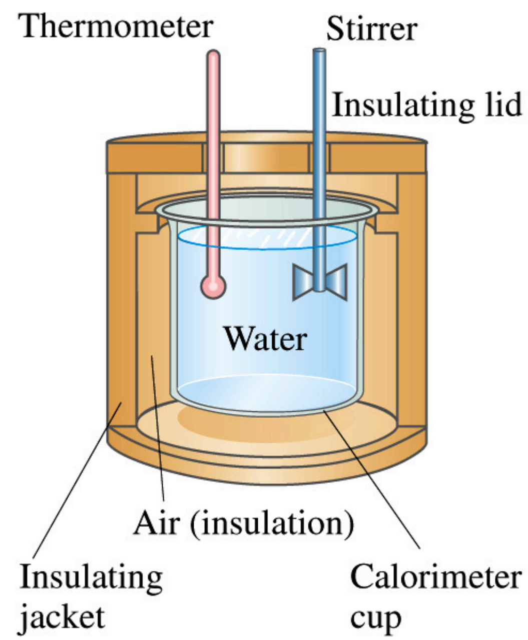
# Review chapter 7. Thermal energy and thermal equilibrium.

- When two objects are brought in thermal contact they can achieve thermal equilibrium (equal temperature) via an exchange of thermal energy.
- The exchange of thermal energy (heat, *Q*) will continue until the two objects have the same temperature.
- Thermal energy can also be exchanged if work is done.



# Review chapter 7.
# Heat and heat capacity.

- When heat is added to an object, its temperature will increase:
  $$Q = C(T_f - T_i)$$
- The coefficient $C$ is the heat capacity of the object. It depends on the type and the amount of material used.
- In order to remove the dependence on the amount of material, we prefer to use the heat capacity per unit mass $c$:
  $$Q = cm(T_f - T_i)$$



# Problem 7.X.28

**7.X.28** Refer to Figure 7.56. Calculate the change in electric energy along two different paths in moving charge $q$ away from charge $Q$ from $A$ to $B$ along a radial path, then to $C$ along a circle centered on $Q$, then to $D$ along a radial path. Also calculate the change in energy in going directly from $A$ to $D$ along a circle centered on $Q$. Specifically, what are $U_B - U_A$, $U_C - U_B$, $U_D - U_C$, and their sum? What is $U_D - U_A$? Also, calculate the round-trip difference in the electric energy when moving charge $q$ along the path from $A$ to $B$ to $C$ to $D$ to $A$.

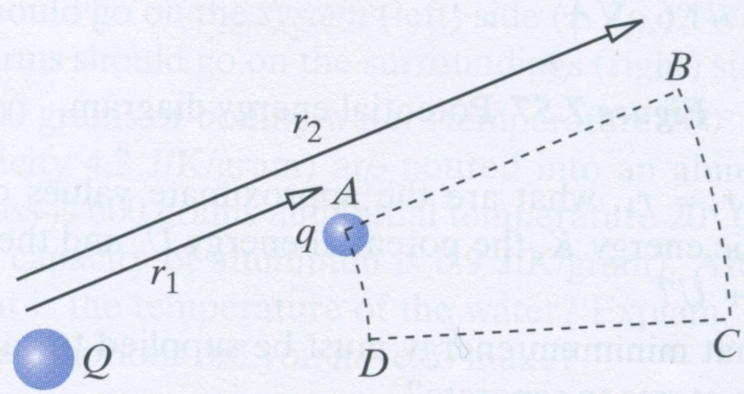



***Figure 7.56*** Change in electric energy along two different paths.

# Problem 7.P61

**7.P.61** Figure 7.58 is a portion of a graph of energy terms vs. time for a mass on a spring, subject to air resistance. Identify and label the three curves as to what kind of energy each represents. Explain briefly how you determined which curve represented which kind of energy.

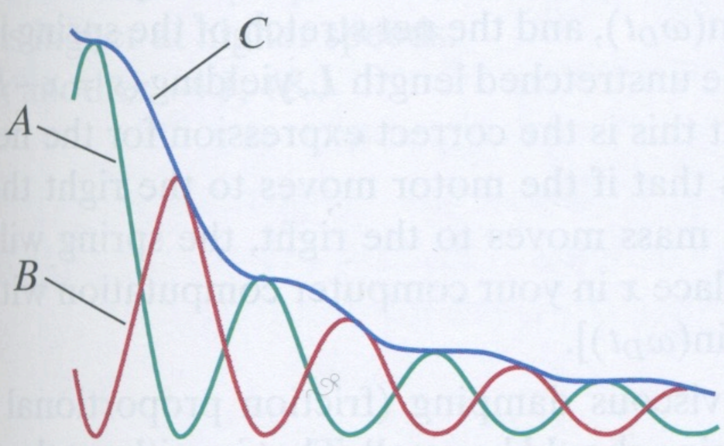



*Figure 7.58* Which curve represents which kind of energy?

# Review chapter 7.

End of Chapter 7.

# Review exam # 2.

The end!