Getting harder, physics is. - Yoda

There are some killer opportunities for trick test questions from this material. Hopefully the test maker will be kind. [I try!]

How to use the graphs

What exactly IS potential energy? The prelecture gave us the equation for it, and defined it in terms of other equations and terms, but what is it in a real life sense? [“Stored” Energy, a potential for motion.]
90 Minutes. Covers Lectures 1-6.

No Hard “Work & Energy” on the exam.

{Maybe 1 simple question}

Exam review in class this Wednesday – we will work through the first hour exam from spring/2010

The old exams are a fantastic way to practice. We have put hundreds of great problems online (with formula sheet)…
Today's Concepts:

a) Energy and Friction
b) Potential energy & force

We will work out 3 HW problems in class today
“please explain all of the relationships between work, force, and potential energy.”

“force times distance”
integrating this just means taking tiny steps

\[ W = \Delta K \]

For springs & gravity

\[ -\Delta U = \Delta K \]

U decreases as much as K increases

K + U doesn’t change ➔ Energy conservation
“Can you please elaborate more on the topic macroscopic work? I am very confused.”

This is not a new idea – it’s the same “work” you are used to.

\[ W = \int_{a}^{b} \vec{F} \cdot dl \]

Applied to big (i.e. macroscopic) objects rather than point particles (picky detail)

We call it “macroscopic” to distinguish it from “microscopic”.

You will deal with this in Physics 213

Feel free to ignore this word for now...
Macroscopic Work done by Friction

Work-Kinetic Energy Theorem

\[ \Delta K = W_{Net} \]
\[ -\frac{1}{2}mv_o^2 = -\mu_k mg D \]

Macroscopic Work done by Friction

\[ f_k = \mu_k N \]
\[ mg \]

\[ D = \frac{v_o^2}{2 \mu_k g} \]

\[ v_f = 0 \]
Work-Kinetic Energy Theorem

$$\Delta K = W_{Net}$$

$$-\frac{1}{2}mv_o^2 = -\mu_k mgD$$

Macroscopic work done by friction force.
“Heat” is just the kinetic energy of the atoms!

Do spinning Heat Demo
\[ \Delta K = W_{tot} = W_{gravity} + W_{friction} \]

\[ 0 = W_{gravity} + W_{friction} \]

\[ 0 = mgH + W_{friction} \]

must be negative

“...give more examples of work done by kinetic friction.”
A block of mass $m$, initially held at rest on a frictionless ramp a vertical distance $H$ above the floor, slides down the ramp and onto a floor where friction causes it to stop a distance $D$ from the bottom of the ramp. The coefficient of kinetic friction between the box and the floor is $\mu_k$. What is the macroscopic work done on the block by friction during this process?

A) $mgH$  
B) $-mgH$  
C) $\mu_kmgD$  
D) 0
What is the macroscopic work done on the block by friction during this process?

A) $mgH$  
B) $-mgH$  
C) $\mu_k mgD$  
D) 0

B) At the beginning there is potential energy of $mgH$ and at the end there is no potential or kinetic energy. This means the work done by friction must be $-mgH$.

C) $\text{work} = \text{force} \times \text{distance}$. 

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CheckPoint

You can ignore this word…it just tells us we don’t need to worry about individual atoms.
What is the total macroscopic work done on the block by all forces during this process?

A) $mgH$  
B) $-mgH$  
C) $\mu_k mgD$  
D) 0

\[ \Delta K = W_{tot} \]
Potential Energy vs. Force

Didnt understand the math derivation of the derivative of Potential energy

\[ U(x) = \frac{1}{2} kx^2 \]

\[ F(x) = -\frac{dU(x)}{dx} = -kx \]
What does an upside down delta sign mean? Do we need to know how to use this for anything?

Force from the Potential Energy

\[ F(x) = -\frac{dU(x)}{dx} \]  

\[ \vec{F} = -\nabla U \]

Please elaborate/explain how the statement that says that objects move to minimize their potential energy is the same as saying that objects accelerate in the direction of the net force. Please explain how these are equivalent.
Potential Energy vs. Force

\[ W = \int_{a}^{b} \mathbf{F} \cdot dl = -\Delta U \]

\[ F(x) = -\frac{dU(x)}{dx} \]

<table>
<thead>
<tr>
<th>P.E. Function</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity (Near Earth)</td>
<td>( mgh + U_o )</td>
</tr>
<tr>
<td>Gravity (General Expression)</td>
<td>(-G \frac{m_1 m_2}{r} + U_o )</td>
</tr>
<tr>
<td>Spring</td>
<td>( \frac{1}{2} kx^2 + U_o )</td>
</tr>
</tbody>
</table>
Suppose the potential energy of some object $U$ as a function of $x$ looks like the plot shown below.

Where is the force on the object zero?

A) (a)  
B) (b)  
C) (c)  
D) (d)

$$F(x) = -\frac{dU(x)}{dx}$$
Suppose the potential energy of some object $U$ as a function of $x$ looks like the plot shown below.

Where is the force on the object in the $+x$ direction?

A) To the left of (b)  
B) To the right of (b)  
C) Nowhere

$$F(x) = -\frac{dU(x)}{dx}$$
Suppose the potential energy of some object $U$ as a function of $x$ looks like the plot shown below.

Where is the force on the object biggest in the $-x$ direction?

A) (a)  B) (b)  C) (c)  D) (d)

$F(x) = -\frac{dU(x)}{dx}$
What is the gravitational potential energy for the block at the top of the incline?

Write down the answer in terms of these variables:

- \( m \) = mass
- \( g \) = acceleration of gravity
- \( x \) = amount the spring is compressed by
- \( d \) = distance between the spring and block
- \( k \) = spring constant
- \( \theta \) = angle of incline

Gravitational Potential Energy = 
\[ m * g * (d + x) * \sin(\theta) \]
\[ U_g = mg(d + x) \sin \theta \]

\[ U_s = \frac{1}{2} kx^2 \]

\[ \frac{1}{2} kx^2 = mg(d + x) \sin \theta \]

\[ \frac{1}{2} kx^2 - mg \sin \theta x - mgd \sin \theta = 0 \]

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
A mass $m = 5.8$ kg hangs on the end of a massless rope $L = 1.97$ m long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? \[ \text{m/s} \]
A mass \( m = 5.8 \text{ kg} \) hangs on the end of a massless rope \( L = 1.97 \text{ m} \) long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? \( \boxed{\text{m/s}} \)  

2) What is the magnitude of the tension in the string at the bottom of the path? \( \boxed{\text{N}} \)  

Will the tension be (A) bigger or (B) smaller than \( mg \)?
A mass $m = 5.8$ kg hangs on the end of a massless rope $L = 1.97$ m long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? $\text{m/s}$

2) What is the magnitude of the tension in the string at the bottom of the path? $\text{N}$

$$v = \sqrt{2gL}$$

$$mg = \frac{1}{2}mv^2$$

$$T - mg = \frac{mv^2}{L} \quad \Rightarrow \quad T = mg + \frac{mv^2}{L}$$
A mass $m = 5.8 \text{ kg}$ hangs on the end of a massless rope $L = 1.97 \text{ m}$ long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? $\text{m/s}$

2) What is the magnitude of the tension in the string at the bottom of the path?

3) If the maximum tension the string can take without breaking is $T_{\text{max}} = 500 \text{ N}$, what is the maximum mass that can be used? (Assuming that the mass is still released from the horizontal and swings down to its lowest point.) $\text{kg}$

\[
T = mg + \frac{mv^2}{L} = mg + \frac{m(2gL)}{L} = 3mg
\]

\[
m_{\text{max}} = \frac{T_{\text{max}}}{3g}
\]
Now a peg is placed $4/5$ of the way down the pendulum's path so that when the mass falls to its vertical position it hits and wraps around the peg. As it wraps around the peg and attains its maximum height it ends a distance of $3/5 \ L$ below its starting point (or $2/5 \ L$ from its lowest point).

How fast is the mass moving at the top of its new path (directly above the peg)?

$m/s$  
Submit

Conserve Energy from initial to final position
4) Now a peg is placed 4/5 of the way down the pendulum’s path so that when the mass falls to its vertical position it hits and wraps around the peg. As it wraps around the peg and attains its maximum height it ends a distance of 3/5 L below its starting point (or 2/5 L from its lowest point).

How fast is the mass moving at the top of its new path (directly above the peg)?

5) Using the original mass of \( m = 5.8 \text{ kg} \), what is the magnitude of the tension in the string at the top of the new path (directly above the peg)?
A mass $m = 85$ kg slides on a frictionless track that has a drop, followed by a loop-the-loop with radius $R = 19.8$ m and finally a flat straight section at the same height as the center of the loop ($19.8$ m off the ground). Since the mass would not make it around the loop if released from the height of the top of the loop (do you know why?) it must be released above the top of the loop-the-loop height. (Assume the mass never leaves the smooth track at any point on its path.)

1) What is the minimum speed the block must have at the top of the loop to make it around the loop-the-loop without leaving the track? $\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. m/s$

Just barely making it means $N = 0$

$$mg = \frac{mv^2}{r} \quad v = \sqrt{Rg}$$
A mass $m = 85$ kg slides on a frictionless track that has a drop, followed by a loop-the-loop with radius $R = 19.8$ m and finally a flat straight section at the same height as the center of the loop (19.8 m off the ground). Since the mass would not make it around the loop if released from the height of the top of the loop (do you know why?) it must be released above the top of the loop-the-loop height. (Assume the mass never leaves the smooth track at any point on its path.)

1) What is the minimum speed the block must have at the top of the loop to make it around the loop-the-loop without leaving the track? $v$ m/s

2) What height above the ground must the mass begin to make it around the loop-the-loop? $h$ m