Physics 221, February 9

Key Concepts:

- Work
- Energy
- Conservation of energy
- Power

Definition of Work:

Work is done by a force.

The work done by a force on an object is equal to the magnitude of the force, multiplied by the distance the object moves **in the direction** of the force.

$$W = \mathbf{F} \cdot \mathbf{d}$$

In one dimension:

Work done on an object by a **constant force**:

$W = F_x (x_f - x_i)$

Work done on an object by a **variable force**:

$W = \Sigma_{xi}^{xf} F_x \Delta x$, as Δx becomes infinitesimally small.

Work is a scalar, a number with units.

Work can be positive or negative.

External work done lifting an object near the surface of Earth:

$W_{ext} = mgh$

Work done by the gravitational force during this process:

$W_g = -mgh$

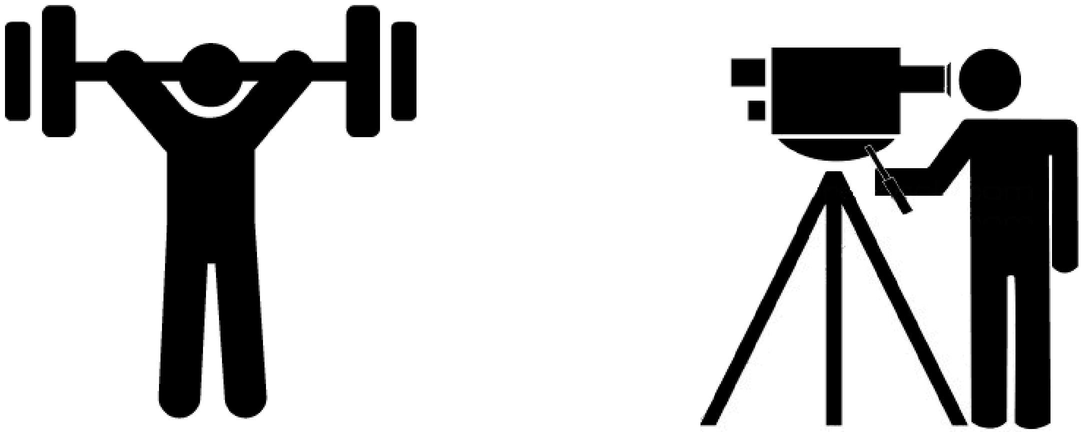
External work done stretching a spring from equilibrium:

$W_{ext} = (1/2)kx^2$

Work done by the spring during this process:

$W_{spring} = -(1/2)kx^2$

Your friend asks you to stand perfectly still holding up a weight bar with weights while he takes a picture. Are you doing work during this time?



Hint:
W = **F·d**
What does that mean?

1. Yes
2. No

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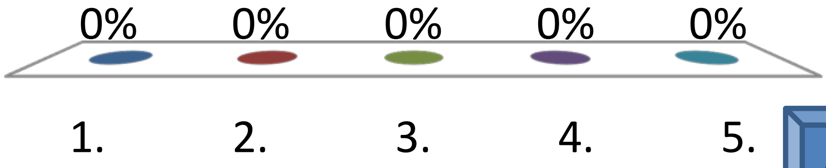
A junior lifter lifts his 80 kg weight bar three times straight up off the ground a distance of 1.6 m before releasing it. How much work does he do?

1. 128 J
2. 284 J
3. 4234 J
4. 3763 J
5. 1253 J



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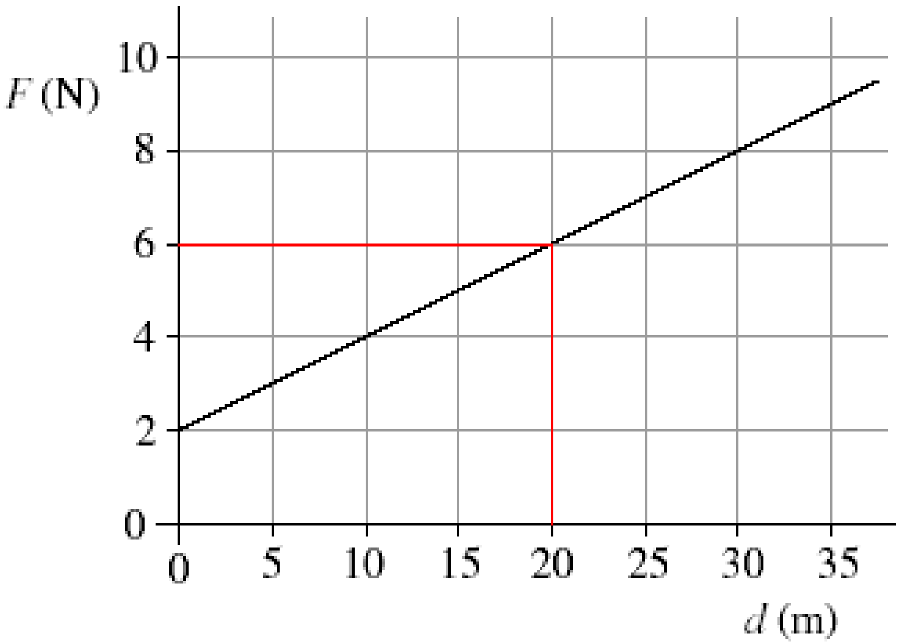
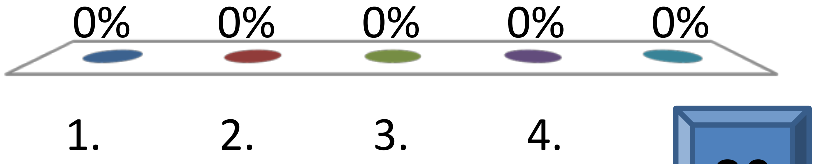
A non-constant force is applied to a 40 kg object over a distance of 20 m. (See diagram.) How much work does the force do?



Hint:
For a non-constant force
$W = F_{avg} * d$.

1. 80 J
2. 40 J
3. 120 J
4. 1600 J
5. 0



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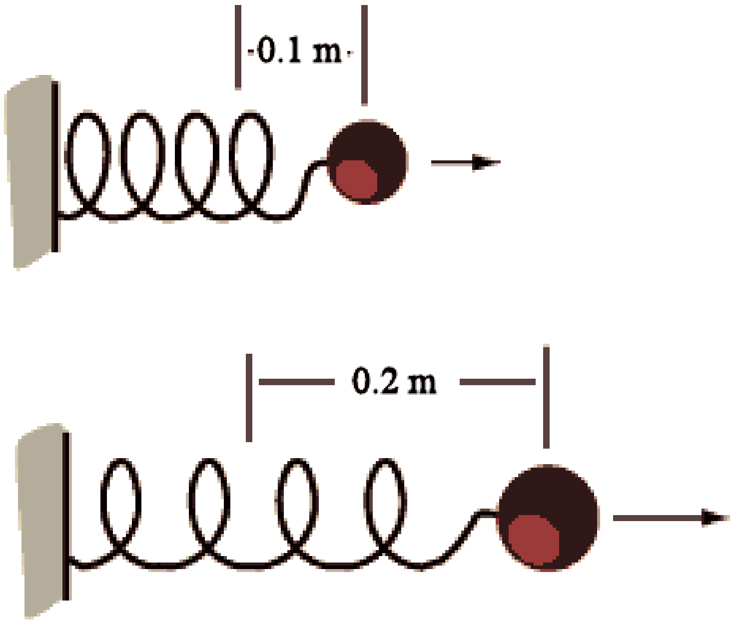
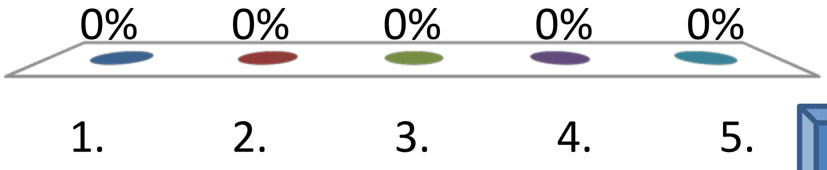
An ideal spring has a spring constant of 20 N/m. How much work must an external force do to stretch the spring from 0.1 m to 0.2 m?



Hint:
Find the difference
$W_{2m} - W_{1m}$.

1. 2 J
2. 0.6 J
3. 0.8 J
4. 0.3 J
5. 0.2 J



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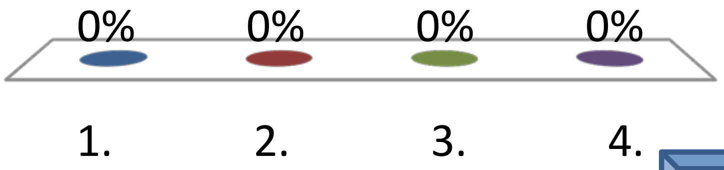
When you fly a kite, there is a time when you must do positive work on the kite.

1. It is the time when you let the kite out.
2. It is the time when you pull the kite in.
3. It is the time when you let the kite out and when you pull it in.
4. You never must do positive work.



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Forms of energy

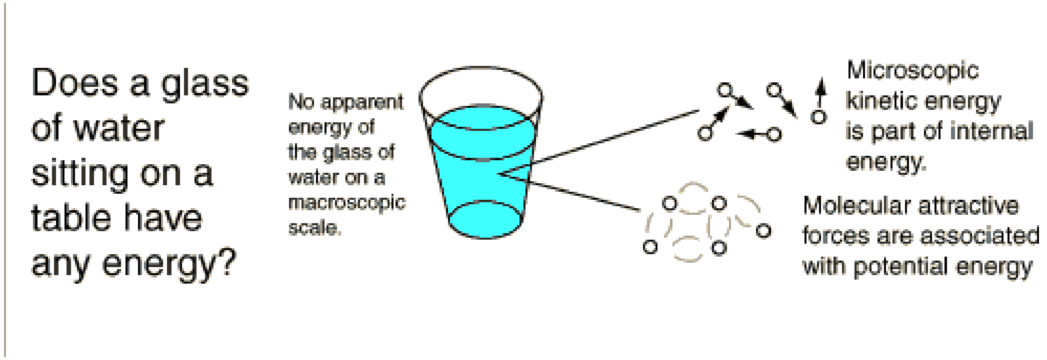
In an given inertial reference frame:

An object has **kinetic energy** (KE) because it moves. $KE = \frac{1}{2} mv^2$

An object has **potential energy** (PE) because of where it is located with respect to everything that interacts with it.

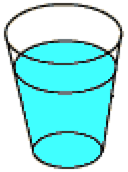
Potential energy is a function of position and is defined with respect to a reference position.

Microscopically all energy is some form of kinetic or potential Energy.



Energy conservation for an isolated system: $\Delta(KE) + \Delta(PE) = 0$

On a macroscopic scale we distinguish between **ordered** and **disordered** energy.



The glass of water, as a whole, can have ordered kinetic energy if it moves or ordered potential energy, if, for example, it is lifted or made to hang from a spring near the surface of Earth. This type of ordered energy is called **mechanical energy**.

The disordered kinetic and potential energy of the individual molecules is called **thermal energy**.

Energy is always conserved for an isolated system.

Mechanical energy is only conserved if no ordered energy is converted to thermal energy.

Work results in the conversion of one form of energy into another form of energy.

If the force doing the work does not convert ordered into disordered energy, we call it a **conservative force**.

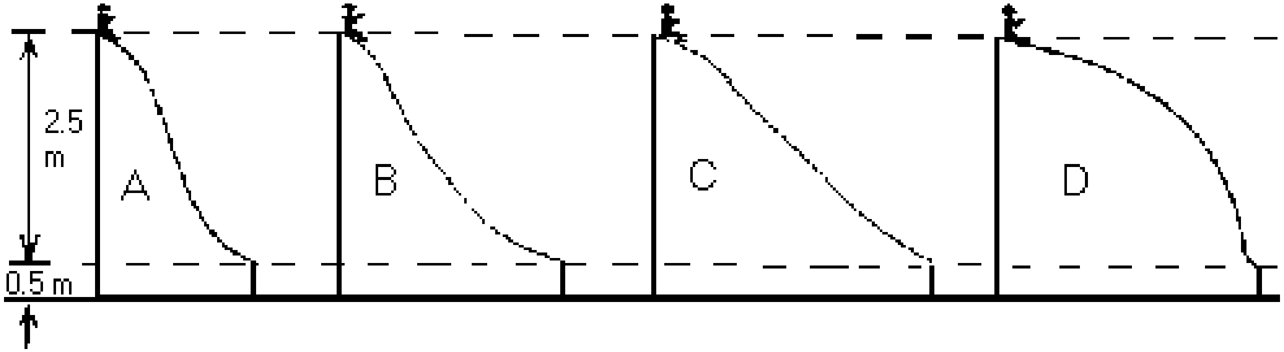
Formulas for forms of energy you should be familiar with:

Translational kinetic energy: $K = (1/2)mv^2$.

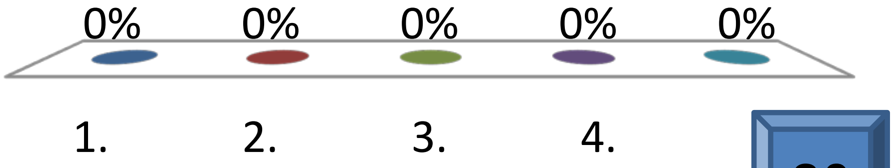
Gravitational potential energy: $U_g = mgh$.

Elastic potential energy: $U_s = (1/2)kx^2$.

A young girl wishes to select one of the frictionless playground slides illustrated above to give her the greatest possible speed when she reaches the bottom of the slide. Which of the slides illustrated in the diagram should she choose?



1. A
2. B
3. C
4. D
5. It does not matter, her speed would be the same for each.



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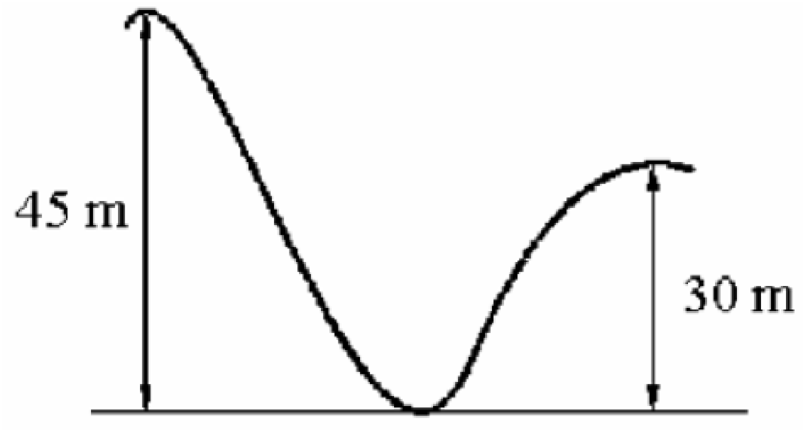
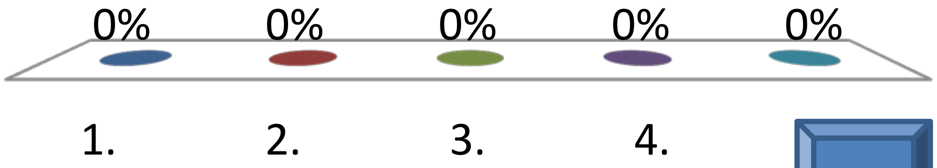
A 300 kg roller coaster cart starts from rest at a point 45 m above the bottom of a dip. Neglect friction. What will be its kinetic energy at the top of the next hill, which is 30 m above the bottom of the dip?
Let $g = 10\ m/s^2$.



1. 0
2. 135000 J
3. 90000 J
4. 13500 J
5. 45000 J



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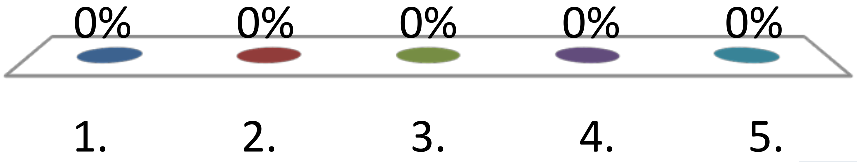
A person is dropping a ball.

Let us keep track of the energy!

A 750 kg car is traveling horizontally with speed 10.0 m/s. To triple is speed to 30 m/s , how much net work must be done on the car?

1. 112500 J
2. 337500 J
3. [✓ 300000 J]
4. 112500 J
5. 75000 J



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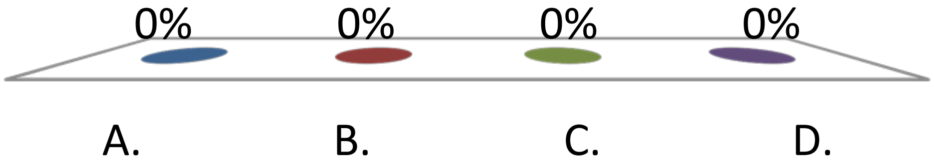
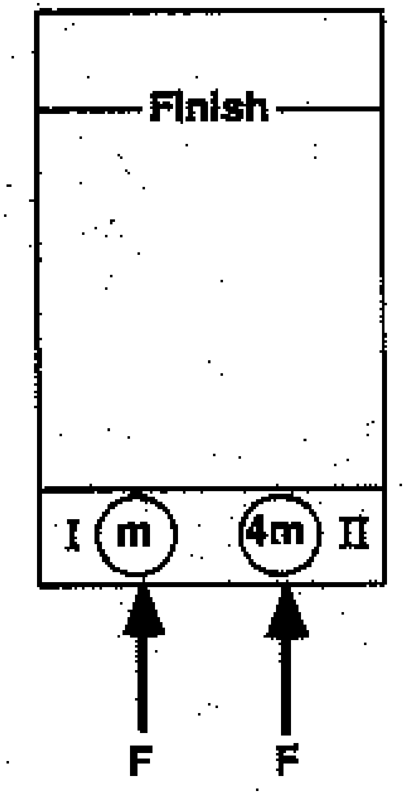
The diagram below depicts two pucks on a frictionless table.
Puck II is four times as massive as puck I.
Starting from rest, the pucks are pushed across the table from the start to the finish line by two **equal** forces.
Which puck will have the greater kinetic energy upon reaching the finish line?

A. I
B. II
C. They both have the same kinetic energy.
D. There is too little information to answer the question.





Solution:

Work = force times distance

The work done is the same for both blocks.

The work is converted into kinetic energy.

Power

Power is a measure of how quickly work is done, it is the rate at which work is done.

$P = \Delta W/\Delta t$ = average power

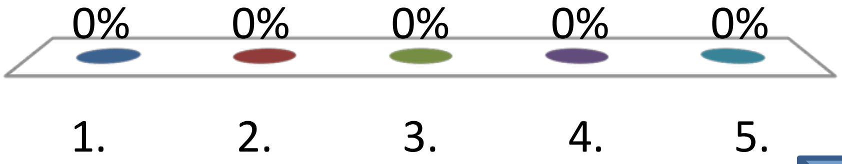
Power * time = energy transferred

We can also write:

$P = F\Delta x/\Delta t = Fv$

A crane lifts a 100 kg object to a height of 10 m in 5 s. What is its power output?

1. 200 W
2. 1960 W
3. 3920 W
4. 19600 W
5. 98000 W



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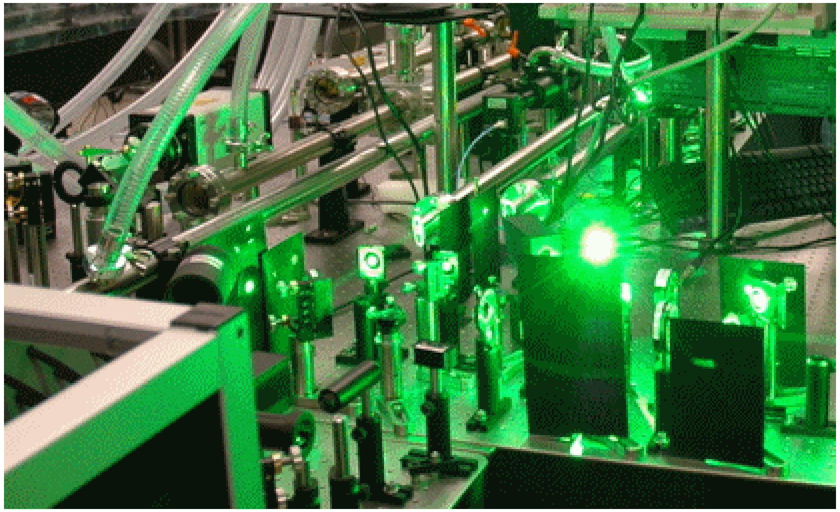
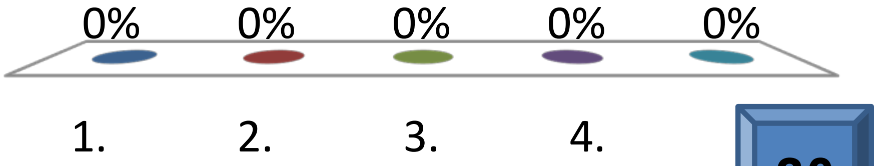
A fast pulsed laser emits a series of brief ps (10^{-12} s) pulses of light, one pulse per microsecond (10^{-6} s). If the average power of the laser is 50 W, what is the energy per pulse?



Hint:
W = J/s
How much light energy is emitted per second?
How many pulses are emitted per second?

1. $5*10^{-5}$ J
2. $5*10^{-6}$ J
3. $5*10^{7}$ J
4. $5*10^{11}$ J
5. 50 J



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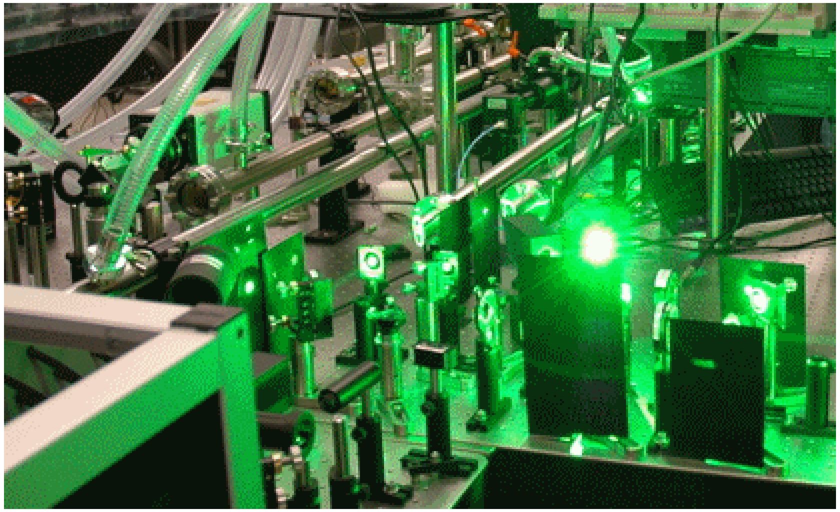
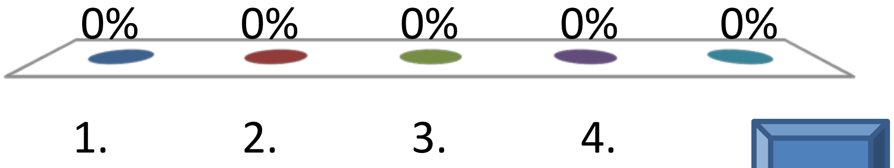
A fast pulsed laser emits a series of brief ps (10^{-12} s) pulses of light, one pulse per microsecond (10^{-6} s). If the energy per pulse is $5*10^{-5}$ J, what is the power of a pulse?



Hint:
pulse power
= pulse energy/pulse duration

1. $5*10^{-5}$ W
2. $5*10^{-17}$ W
3. $5*10^{7}$ W
4. $5*10^{11}$ W
5. 50 W



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