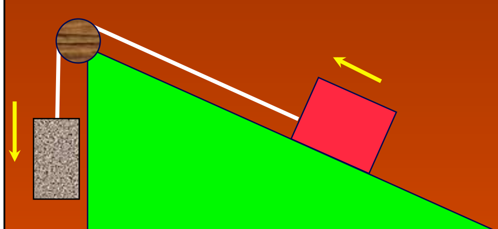
Physics 1021

Spring 2012 Ch.10b-11

ConcepTest 10b.1 Force and Work

A box is being pulled up a rough incline by a rope connected to a pulley. How many forces are doing work on the box?

1) one force
2) two forces
3) three forces
4) four forces
5) no forces are doing work



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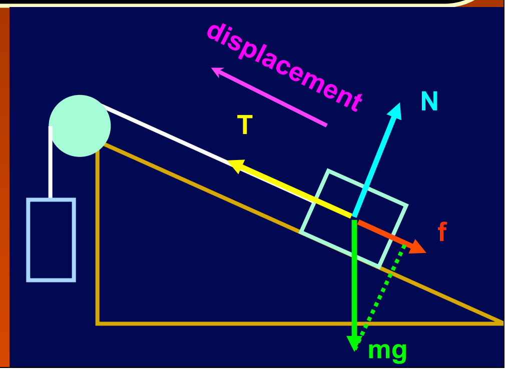
Any force not perpendicular to the motion will do work:

N does *no work*
T does positive work
f does negative work
mg does negative work



Springs!

New Topic

- Other examples of potential energy? ***Spring!***
  - For you to stretch a spring, apply force.
- The spring pulls back with a
- *restoring force*: $F_{spring} = -k\,x$

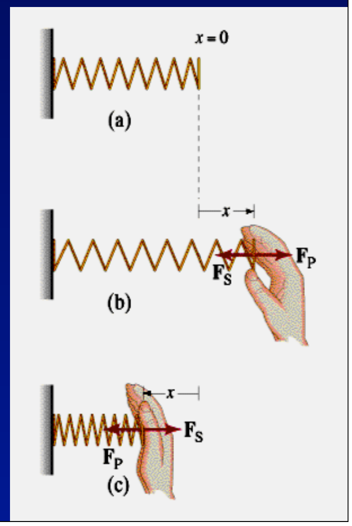
Hooke's Law

- Work due to external force gives the *elastic potential energy:*

$$\boxed{\Delta U = \frac{1}{2} k x^2}$$

Notice

F = -dU/dx



Example: Hanging Spring

A mass hangs from a spring which is attached to the ceiling. The spring will stretch when the weight is hung from it. What is the new equilibrium position in terms of *d*, k_0, *m*, and *g*?

Tangible: 2 Hanging Springs

A mass hangs from two springs which are linked end to end, each of which has a rest length *d* and a spring constant k_0. As in the example, the springs will stretch when the weight is hung from it. What are the new spring constant and equilibrium position in terms of k_0, *d, m*, and *g*. What if the springs are hung in parallel (side by side) from the ceiling? Use rubber bands and weights as proxies for the springs to verify your answer.

Work

New Topic

Definition of Work

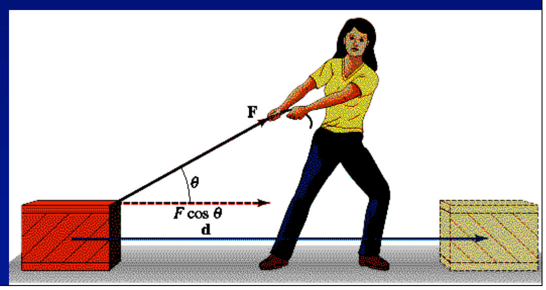
Work: change in energy of a system due to a force that acts over a distance

Work = force applied in direction of displacement × displacement

$$W = \int_a^b \vec{F} \circ d\vec{s}$$

- Work is a *scalar,*
- Units = N · m ≡ Joule (J)

If a crate is pulled along the floor, only the force component *parallel* to the *displacement d* contributes to the work!



Dot product or scalar product

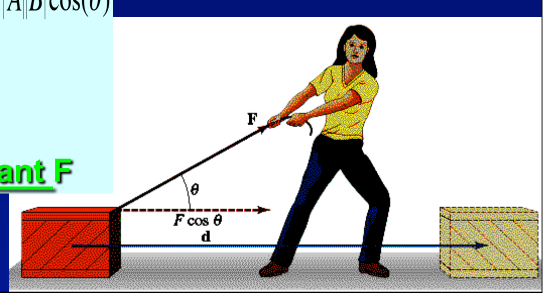
Vectors can be multiplied together (like Force and displacement. One way to do this is to multiply the components together to form a scalar

$$W = \int_a^b \vec{F} \circ d\vec{s}$$

$$C = \vec{A} \circ \vec{B} = A_x B_x + A_y B_y + A_z B_z = |A||B|\cos(\theta)$$

$$W = \int_a^b F_x dx$$

$$W = F(b - a)$$ For constant F



If you do work....

<u>Something will happen:</u>

❖Kinetic energy changes

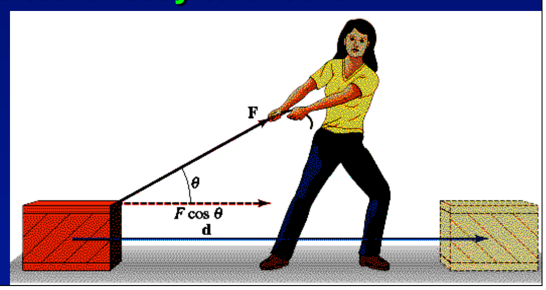
❖Potential energy changes

❖Heat is generated

Work energy theorem:

$W = \Delta K + \Delta U + F_{friction}\, d$

❖… the work is converted directly to another form of energy



Example: Skier

A skier traveling 11.4 m/s reaches the foot of a steady upward 18.4° incline and glides 11.2 m up along this slope before coming to rest. What was the average coefficient of friction?

Ponderable: Skier

A skier traveling 11.4 m/s reaches the foot of a steady upward 18.4° incline and glides 11.2 m up along this slope before coming to rest. What was the average coefficient of friction?

The skier turns right around and glides down the slope. What will be her speed at the bottom?

Ponderable: Spring

- **User LoggerPro to draw an energy diagram for the spring.**
- **Download the movie and insert it into LoggerPro http://www.gwu.edu/~phy21bio/Ponderables/spring.mov**
- **Use the point capture feature to plot x and v_xInsert new calculated columns which calculate the potential and the kinetic energy and the total energy.**
- **Make a plot of PE, KE, TE as a function of x.**
- **What is the spring constant ?**
- **What is the maximum potential energy?**
- **What is the maximum kinetic energy?**
- **What is the maximum position, also called the turning point?**

Power

New Topic

Power

- We have seen that $W = F \Delta x$
  - This does not depend on time !
- Time does matter for power :
  - Power is the "rate of doing work"

$$\boxed{\text{Power} = \frac{dW}{dt}}$$

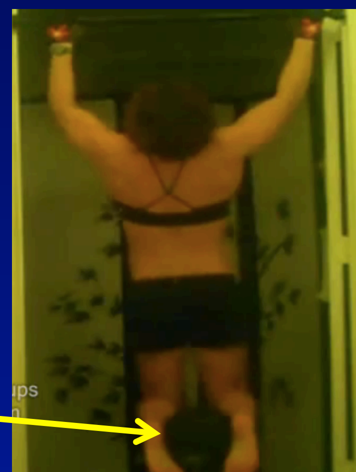
Stronger muscles do work faster, generate more power

- Units of power: *J/sec = Watts*

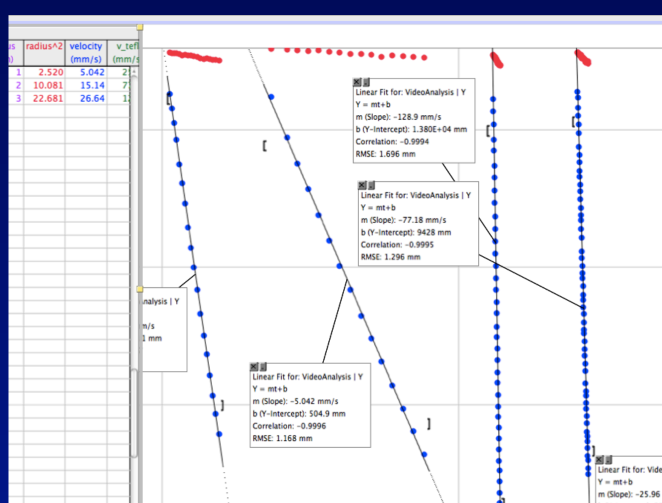
old unit: horsepower (hp)

Example: Alicia Weber

Alicia Weber has held a number of strength /endurance world records, including the most pullups in 1 min (31), in 30 mins. (345), and in 60 mins (560). What was the power output of her muscles in setting those records?

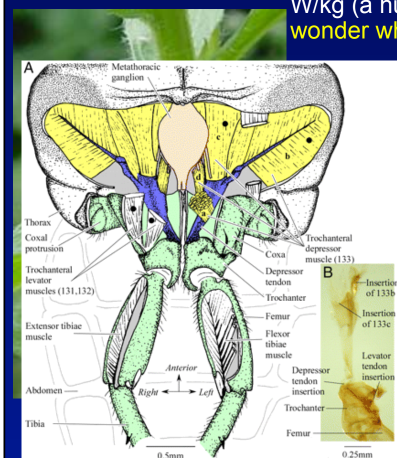


Note the 10 lb medicine ball !!



Ponderable: Powerful Frog Hoppers

A frog hopper is a 6 mm long insect that is the world high jump champion. This 12.3 mg insect can jump 700 mm or 100 times its length, but the power required to do this is quite large. A frog hopper launches itself with an initial velocity of 4.7 m/s in 1 ms. How much energy is lost to air resistance? What is the power needed to do this per kg of muscle (weight of muscle)? The maximum power that can be generated by muscle is 250 W/kg (a human athlete generates about 10 W/kg). Do you wonder what the Reynold's number is?



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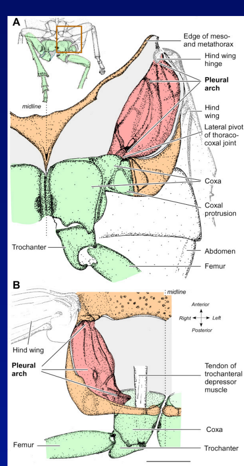
Ponderable: Springs in Frog Hoppers

A frog hopper launches itself with an initial velocity of 4.7 m/s. We want to test if the elastic parts of its pleural arch can store enough energy needed to launch it like a catapault, If its mass is 12.3 mg, and the arch is bent by 0.1 mm, how large must the spring constant be?



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ConcepTest 6.4 Going Bowling I

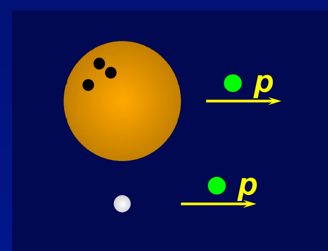
A bowling ball and a ping-pong ball are rolling towards you with the **same momentum**. If you exert the **same force** to stop each one, which takes a **longer time** to bring to rest?

1) the bowling ball
2) same time for both
3) the ping-pong ball
4) impossible to say

We know: $F_{av} = \dfrac{\Delta p}{\Delta t}$ so $\Delta p = F_{av} \Delta t$

Here, F and Δp are the *same* for both balls!

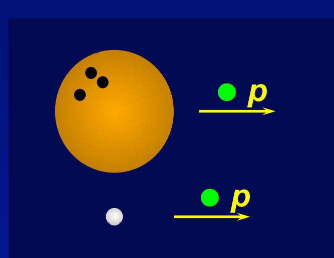
It will take the *same amount of time* to stop them.



ConcepTest 10b.2 Going Bowling II

A bowling ball and a ping-pong ball are rolling towards you with the same momentum. If you exert the same force to stop each one, for which is the stopping distance greater?

1) the bowling ball
2) same distance for both
3) the ping-pong ball
4) impossible to say

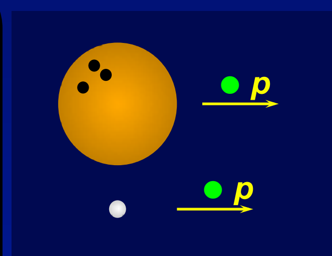


ConcepTest 10b.2 Going Bowling II

A bowling ball and a ping-pong ball are rolling towards you with the same momentum. If you exert the same force to stop each one, for which is the *stopping distance* greater?

1) the bowling ball
2) same distance for both
3) the ping-pong ball
4) impossible to say

Use the work-energy theorem: $W = \Delta KE$. The ball with less mass has the greater speed (why?), and thus the greater KE (why again?). In order to remove that KE, work must be done, where $W = Fd$. Since the force is the *same* in both cases, the distance needed to stop the less massive ball must be *bigger*.



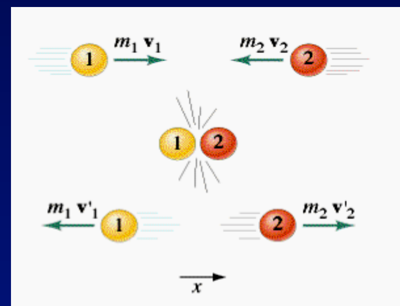
Elastic Collisions

New Topic

Momentum conservation

Initial: $\mathbf{p}_i = m_1\mathbf{v}_1 + m_2\mathbf{v}_2$

Final: $\mathbf{p}_f = m_1\mathbf{v}'_1 + m_2\mathbf{v}'_2$

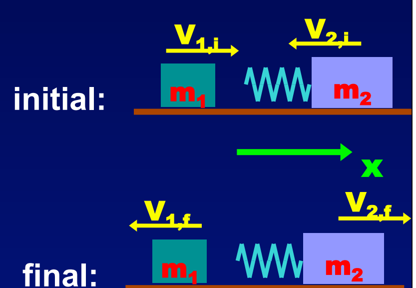


- Momentum conservation: initial momentum = final momentum

$$\boxed{m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = m_1\mathbf{v}'_1 + m_2\mathbf{v}'_2}$$

  - Note that this is a vector equation !!

Elastic Collision in 1-D



- Conserve momentum p_x:

  $m_1v_{1,i} + m_2v_{2,i} = m_1v_{1,f} + m_2v_{2,f}$

- Conserve kinetic energy:

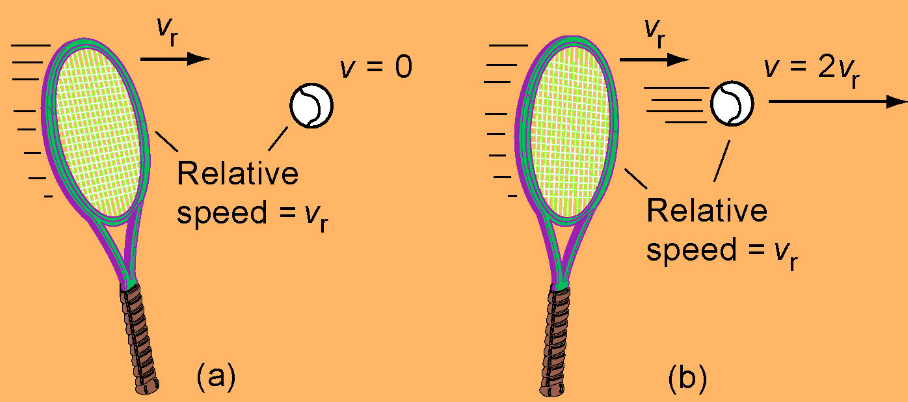
  $\frac{1}{2}\, m_1v^2_{1,i} + \frac{1}{2}\, m_2v^2_{2,i} = \frac{1}{2}\, m_1v^2_{1,f} + \frac{1}{2}\, m_2v^2_{2,f}$

- After some algebra, one can show a general result:

$$\boxed{v_{1,i} - v_{2,i} = -(v_{1,f} - v_{2,f})}$$

+ means *approach*
– means *receding*

The ***relative velocity*** before the collision is equal and opposite to the relative velocity after the collision



- A perfectly elastic collision is one where the relative speed afterward is equal to the relative speed before … the relative velocity is equal and opposite.

ConcepTest 10b.3 Elastic Collisions I

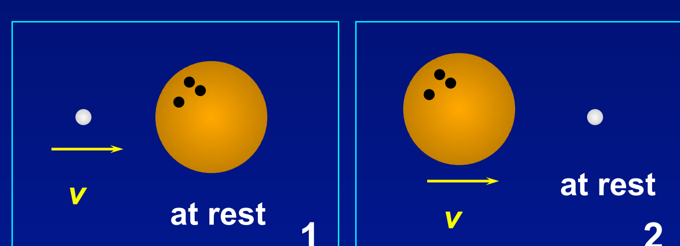
Consider two elastic collisions:

1) a golf ball with speed v hits a stationary bowling ball head-on.

2) a bowling ball with speed v hits a stationary golf ball head-on.

In which case does the golf ball have the greater speed after the collision?

1) situation 1
2) situation 2
3) both the same



ConcepTest 10b.3 Elastic Collisions I

Consider two elastic collisions:

1) a golf ball with speed *v* hits a stationary bowling ball head-on.

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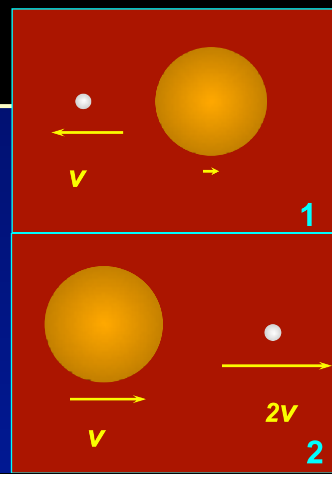


Remember that the magnitude of the *relative velocity* has to be equal before and after the collision!

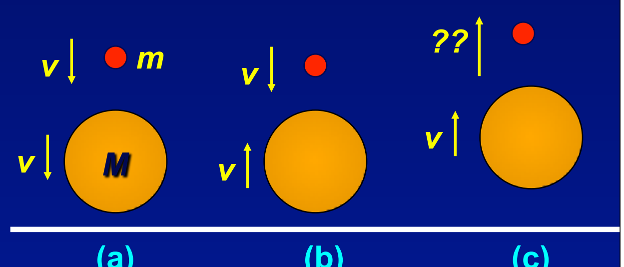
In case 1 the bowling ball will almost remain at rest, and the golf ball will bounce back with speed close to *v*.

In case 2 the bowling ball will keep going with speed close to *v*, hence the golf ball will rebound with speed close to 2*v*.

ConcepTest 10b.4 Elastic collisions II

Carefully place a small rubber ball (mass *m*) on top of a much bigger basketball (mass *M*) and drop these from some height. What is the velocity of the smaller ball after the basketball hits the ground and collides with small rubber ball?

1) zero
2) v
3) 2v
4) 3v
5) 4v



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(1) zero

(2) v

(3) 2v

(4) 3v

(5) 4v

Remember that ***relative velocity*** has to be equal before and after collision! Before the collision, the basketball bounces up with *v* and the rubber ball is coming down with *v*, so their *relative* velocity is *–2v*. After the collision, it therefore has to be *+2v*!!