**Exam solutions are posted on the class website:**
**[http://faculty.washington.edu/storm/121C/](http://faculty.washington.edu/storm/121C/)**

**Expect to return graded exams Friday.**

**Homework assignment – lighter than usual.**
**Was posted Monday afternoon on Tycho.**
**Now due Friday before midnight.**

**Beware problem about c.m. Tycho wants 3 significant figures.**

**Office hours today: 5:15 – 6:00…**

**Exam grades posted on Tycho. If there is a "_" entered for a question, that means you didn't put your name on the page or didn't hand it in. See Helen Gribble in PAB C136 to identify your page.**

## Chapter 6.2 and 6.3 Work

**By a variable force in a straight line**

$W = F_x \Delta x$ **becomes** $W = \int_{x_0}^{x_f} F_x(x)\,dx$

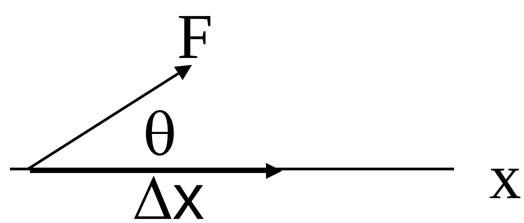
**Spring example. Work by spring on a thing:**

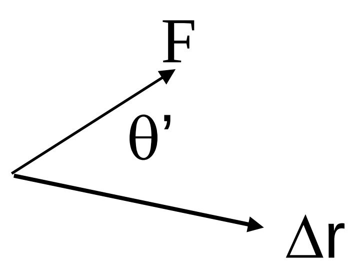
$F_x = -kx$, **and integral gives** $W = -\frac{1}{2} k x_f^2 + \frac{1}{2} k x_i^2$
**If the spring does negative work on the thing the thing does positive work on the spring.**

**Scalar product** $F_x = F\cos(\theta)$

$F_x \Delta x = F\cos(\theta)\,\Delta x$

**If motion in some other direction,** $\Delta\vec{r}$ **get component of** $\vec{F}$ **along** $\Delta\vec{r}$. $W = F\,\Delta r\cos(\theta')$




**Scalar product of** $\vec{A}, \vec{B}$

$\vec{A} \bullet \vec{B} = AB\cos(\theta)$

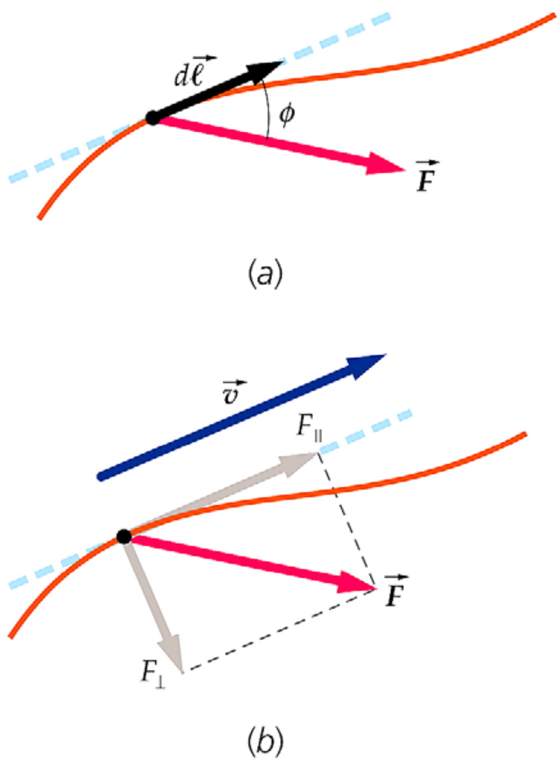
**also** $A_x B_x + A_y B_y + A_z B_z$

**so** $W = \vec{F} \bullet \Delta\vec{r}$ **for constant** $\vec{F}$

**Special unit: Joule (work, kinetic energy…)**
**Abbreviation: J**

**For variable force on general path:**

$$W = \int_{\vec{r}_0}^{\vec{r}_f} \vec{F}(\vec{r})\bullet d\vec{\ell}$$ **integral is along given path.**




**POWER**    **Work per unit time.**

$d\vec{\ell} = \vec{v}dt$   **so** $P = \vec{F}\bullet d\vec{\ell}\,/\,dt = \vec{F}\bullet\vec{v}$

**special unit: Watt = J/s**

**"English Units"   Work:  Foot-pound.**

**Power: Horse-power:  550 Ft-lb/sec**

**Note 1 Horse-Power = ¾ kW  (approx).**

**Power from motor – example.**

**Demo**    **then clicker**

Power $P$ is required to lift a body a distance $d$ at a constant speed $v$.

What power is required to lift the body a distance $2d$ at constant speed $3v$?

*A. P* *B. 2P* *C. 3P* *D. 6P* *E. 3P/2*

## Section 6.4

**Change in kinetic energy:**

$$\frac{d}{dt}K = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = \frac{m}{2}\frac{d}{dt}(v^2)$$

$$\frac{d}{dt}(v^2) = \frac{d}{dt}\vec{v}\bullet\vec{v} = 2\vec{v}\bullet\frac{d}{dt}\vec{v} = 2\vec{v}\bullet\vec{a}$$

**so** $\frac{d}{dt}K = m\vec{v}\bullet\vec{a} = \vec{F}_{net}\bullet\vec{v} = P_{net}$

**Integrate over time, get Work Energy theorem in a more general sense than for straight line motion.**

$$\Delta K = \int_{t_1}^{t_2} P_{net}dt = W_{net}$$

**Work is independent of path for constant force:**

**Gravity:** $\vec{F}_g = 0\hat{i} - mg\hat{j}$

**and so work by gravity is**

$$dW = \vec{F}_g\bullet d\vec{\ell} = (0\ dx - mg\ dy)$$

**integrate to get**

$$W = -mg\Delta y$$

**regardless of the path overall – just the ends**

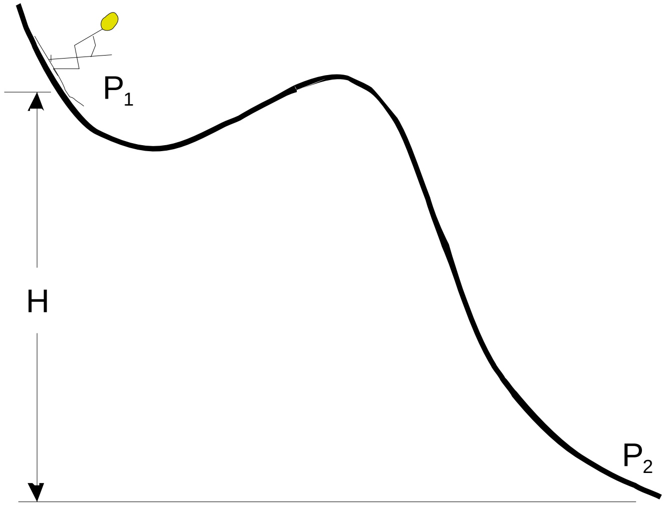
**Example**

**– sliding down ramp (frictionless) vs falling.**

**Clicker #2.**

**Demo**

A skier of mass 50 kg is moving at speed 10 m/s at point $P_1$ down a ski slope with negligible friction. What is the skier's kinetic energy when she is at point $P_2$, 20 m below $P_1$?




A. 2500 J B. 9800 J C. 12300 J D. 13100 J E. 15000 J

## Section 6.5 Center of Mass Work

For a system we had $\vec{F}_{\text{net,ext}} = M\vec{a}_{cm}$

same analysis we did for a particle, gives

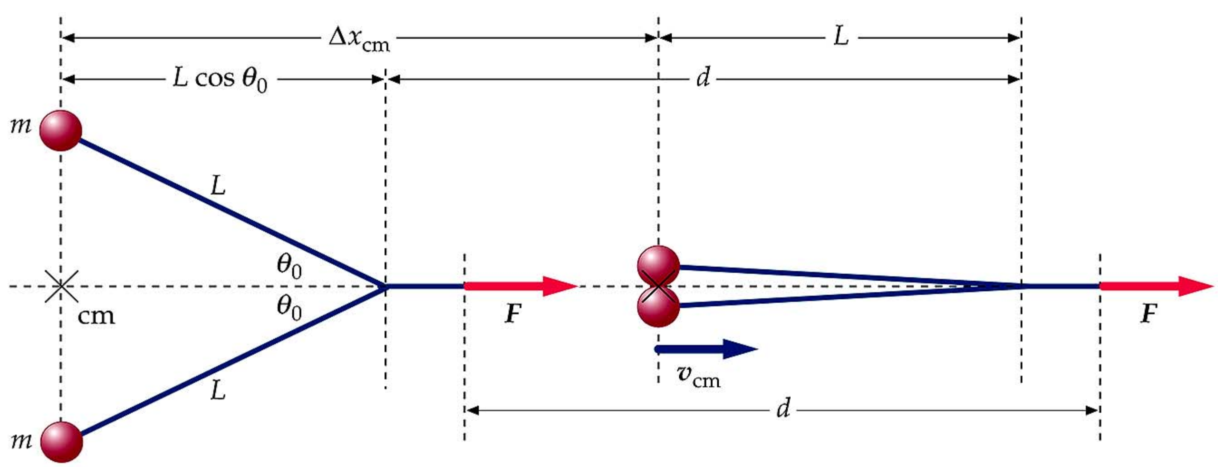
$$\Delta K_{\text{trans}} = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F}_{\text{net,ext}} \bullet d\vec{\ell}_{\text{cm}}$$

The c.m. Translational Kinetic Energy equals the c.m. work done on the system.

**Big thing to note:** The distance the CM goes may differ from the distance the point the force is applied goes.

- Work applied may go into CM motion and other stuff.
- CM work done on the system may not be total work done.

Example: 2 pucks and a string (in text)




Qualitative example, translational & rotational motion.

## Chapter 7.1 Potential Energy

**Example:**

**Do work on a spring with a mass on it**
**Later on, release it, spring moves mass**
**Spring force makes K**

**Work potential energy -> kinetic energy.**
**Work may be against dissipative force (friction)**
**or may be against conservative force**

**Conservative forces associated with potential E**

**Examples:**

**(perfect) spring,** $U(x) = +kx^2$ **(why +?)**
**Gravity** $U(h) = mgh$ **(near Earth)**
**Gravity in general, we will see later.**
**Electric forces**

**Conservative vs Nonconservative Forces**

**Con: work independent of path between 2 pts.**
**Noncon: work depends on path.**
**For closed path, work not zero.**

**Examples of Nonconservative force:**
**friction**
**river.**

## Potential energy functions:

$$\Delta U = -W = -\int_{\vec{r}_1}^{\vec{r}_2} \vec{F}(\vec{r}) \bullet d\vec{\ell}$$

**Work done by the force. Is opposite sign from work done on the source of the force.**

**e.g. spring, gravity.**
**Reason: *U* is like a bank balance. You reduce it to draw energy out and make *K* or do work on something.**

## Setting Zero

**Only $\Delta U$ matters, but desire function $U(\vec{r})$. Pick place where $U=U_0$ and value for $U_0$**
**Analogous to picking an origin for coordinates.**

**convenient settings:**

**spring: at equilibrium point, $x=0$, $U=0$**
**local gravity: at $y=0$, $U=0$.**
**astronomical gravity: at $y=\infty$ $U=0$ !!**