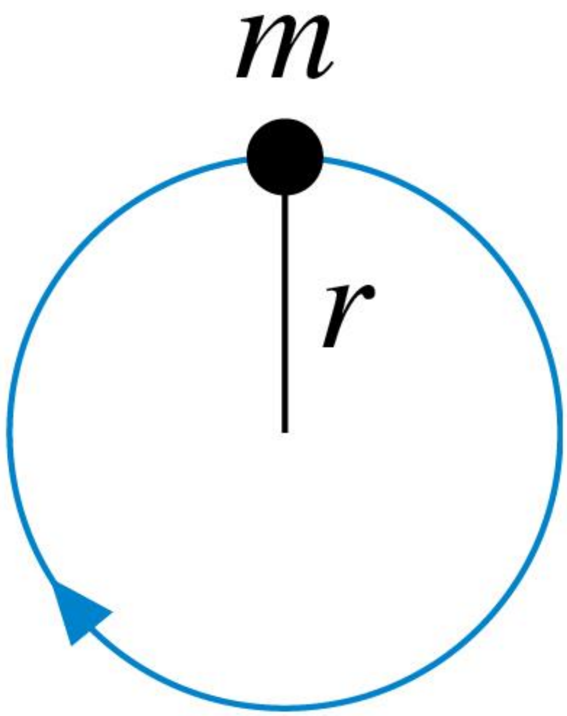
A mass tied to a string spins around in a vertical circle. How much work is done by (a) the string and (b) gravity when it goes from the top to the bottom?



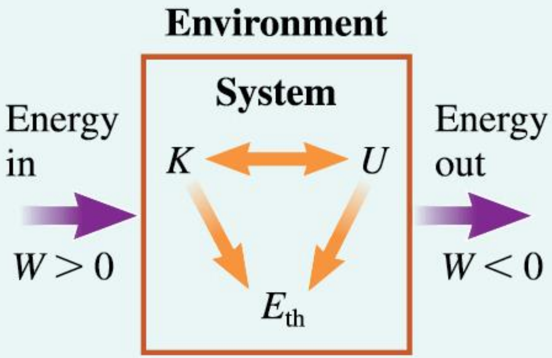
Chapter 9 – Work and Kinetic Energy

- Energy and systems
- Work
- Thermal energy
- Power

MODEL 9.1

Basic energy model

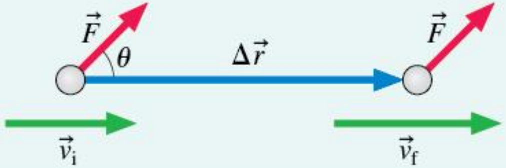
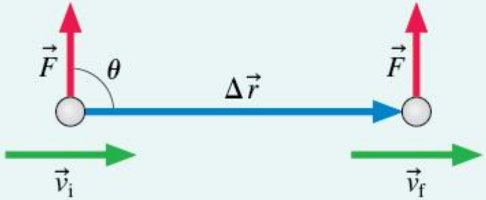
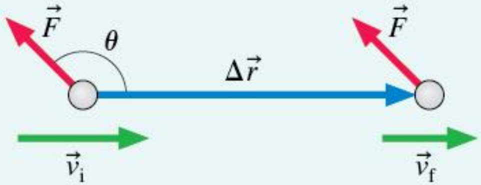
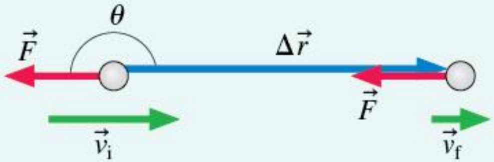
Energy is a property of the system.



- Energy is *transformed* within the system without loss.
- Energy is *transferred* to and from the system by forces from the environment.
  - The forces do *work* on the system.
  - $W > 0$ for energy added.
  - $W < 0$ for energy removed.
- The energy of an *isolated system*—one that doesn't interact with its environment—does not change. We say it is *conserved*.
- The energy principle is $\Delta E_{sys} = W_{ext}$.
- Limitations: Model fails if there is energy transfer via thermal processes (heat).

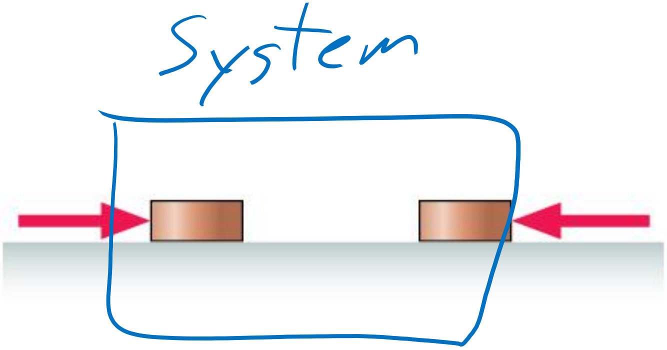
Exercise 1

Calculating the work done by a constant force

Force and displacement	θ	Work W	Sign of W	Energy transfer
	$0°$	$F(\Delta r)$	+	Energy is transferred into the system. The particle speeds up. K increases.
	$< 90°$	$F(\Delta r)\cos\theta$	+	
	$90°$	0	0	No energy is transferred. Speed and K are constant.
	$> 90°$	$F(\Delta r)\cos\theta$	–	Energy is transferred out of the system. The particle slows down. K decreases.
	$180°$	$-F(\Delta r)$	–	

Team Up Questions

STOP TO THINK 9.3 Two equal-mass pucks on frictionless ice are pushed toward each other by two equal but opposite forces. Let the system be both pucks. Is the total work done on the system positive, negative, or zero?



K increasing

E increasing

$W > 0$

Team Up Questions

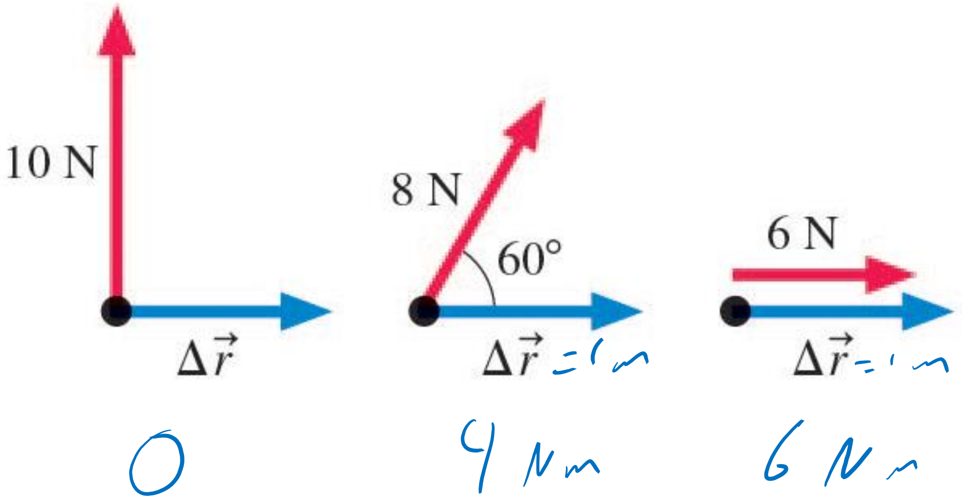
STOP TO THINK 9.4 A crane uses a single cable to lower a steel girder into place. The girder moves with constant speed. The cable tension does work W_T and gravity does work W_G. Which statement is true?

a. W_T is positive and W_G is positive.
b. W_T is positive and W_G is negative.
c. W_T is negative and W_G is positive.
d. W_T is negative and W_G is negative.
e. W_T and W_G are both zero.

Team Up Questions

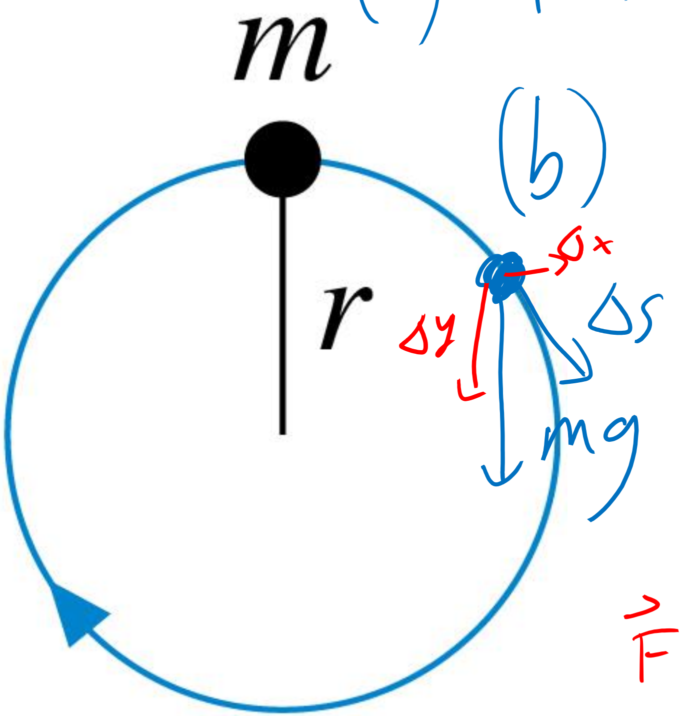
STOP TO THINK 9.5 Which force does the most work as a particle undergoes displacement $\Delta\vec{r}$?

a. The 10 N force.
b. The 8 N force.
c. The 6 N force.
d. They all do the same amount of work.



A mass tied to a string spins around in a vertical circle. How much work is done by (a) the string and (b) gravity when it goes from the top to the bottom?

(a) $\vec{T} \perp \vec{\Delta s} \rightarrow W = 0$



(b) $W = \int_{s_i}^{s_f} \vec{F} \cdot d\vec{s} = \int_{y_i}^{y_f} mg\,dy$

$= mg\Delta y$

$= mg(y_f - y_i)$

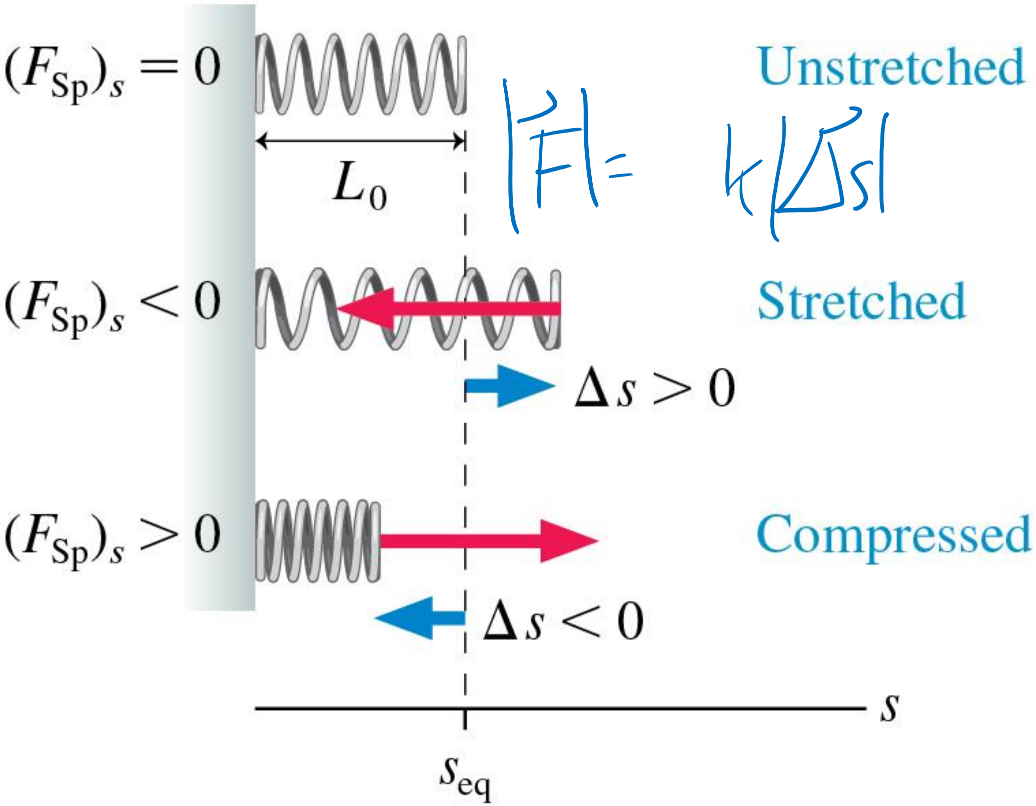
$\vec{\Delta s} = \Delta x\,\hat{i} + \Delta y\,\hat{j}$

$\vec{F} = mg\,\hat{j}$

$\vec{F} \cdot \vec{\Delta s} = 0\,\hat{i}\cdot\hat{i} + mg\Delta y\,\hat{j}\cdot\hat{j}$

$\hat{i}\cdot\hat{j} = 0$

A spring which is compressed a distance Δs from equilibrium exerts a force of magnitude $F_{sp} = k\,\Delta s$. How much work is done compressing the spring?



$|\vec{F}| = k|\Delta s|$

$$W = \int_{s_{eq}}^{s_f} \vec{F} \cdot d\vec{s}$$

$$= \int k(s - s_{eq})\,ds$$

$$= \frac{1}{2}k(s - s_{eq})^2 \Big|_{s_{eq}}^{s_f}$$

$$= \frac{1}{2}k(s_f - s_{eq})^2 - 0 = \frac{1}{2}k(\Delta s)^2$$