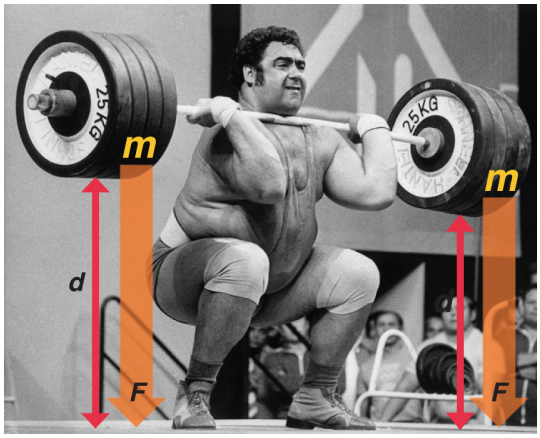
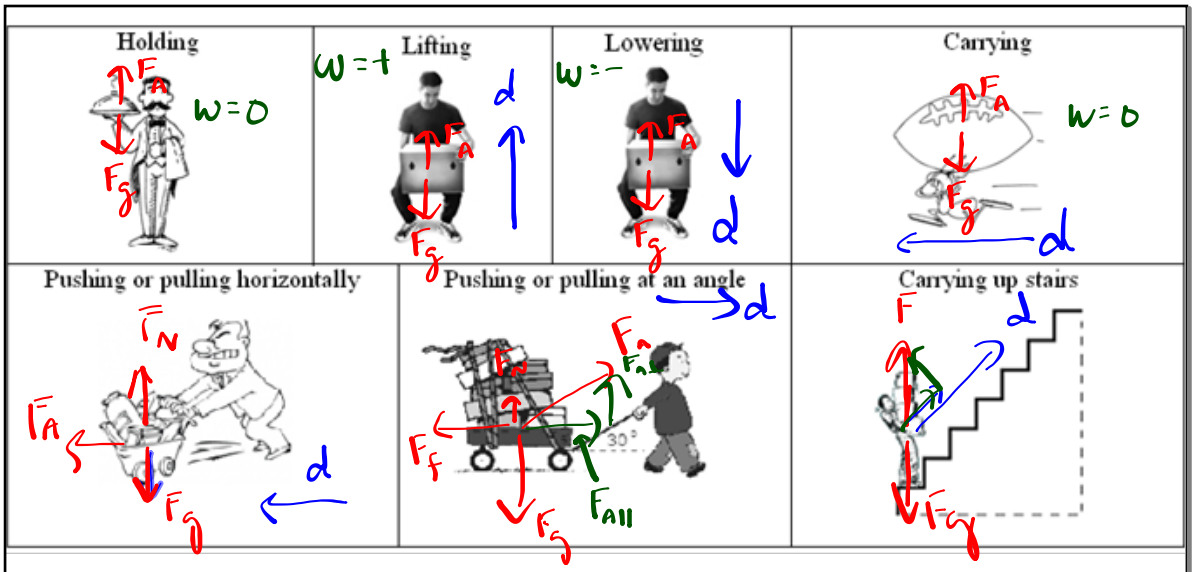
Work and Energy





Work:

1) Product of a force and the component of the displacement in the direction of the force.

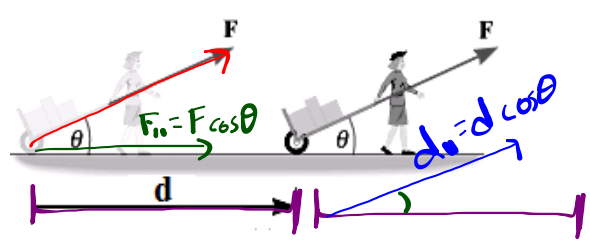
2) Product of a displacement and the component of the force in the direction of the displacement.

$\times$

$\cdot$

Formula:

$$W = \vec{F} \cdot \vec{d}$$
$$= F_{\parallel} d$$
$$= F \cdot d \cdot \cos\theta$$



W	F	d	θ
work	force	displacement	angle between F and d
[N·m] = [J]	[N]	[m]	
scalar	vector	vector	

1. Work is a scalar but it can be positive or negative. Explain.

Positive Work:

force and displacement are in same direction
($\theta = 0^o$) $\cos 0^\circ = 1$

Negative Work:

force and displacement are in opposite directions
($\theta = 180^o$) $\cos 180^\circ = -1$

2. Express the units for work in terms of fundamental units.

$$W = F \cdot d$$
$$= m \cdot a \cdot d$$
$$[kg]\left[\frac{m}{s^2}\right][m] = \left[kg\,\frac{m^2}{s^2}\right]$$

Power:

a) the rate at which work is done

b) the rate at which energy is transferred or transformed

Formula:

Alternate Formula:

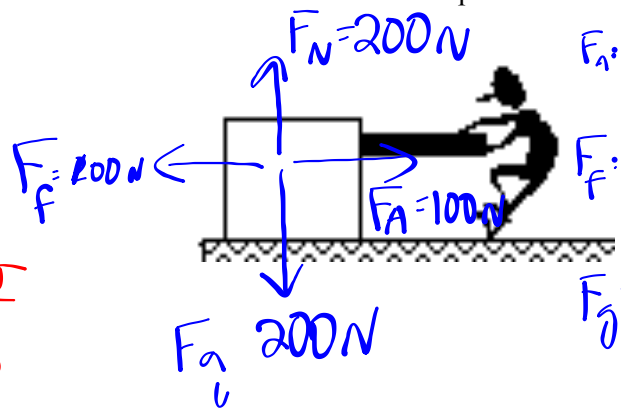
$$P = \frac{W}{t} = \frac{F \cdot d}{t} = F \cdot v_{avg}$$

P	W	t
power	work	time
$[J/s] = [W]$ watt	$[J]$	$[s]$
scalar	scalar	scalar

1. Express the units for power in terms of fundamental units.

$$[W] = [J/s] = \left[\frac{Nm}{s}\right] = \left[\frac{kg\, m/s^2 \cdot m}{s}\right] = \left[kg \frac{m^2}{s^3}\right]$$

2. A student drags a 20.0 kg box horizontally across the floor at a constant speed for a distance of 3.00 meters by applying a force of 100. newtons for 8.0 seconds. Calculate how much work the student did and how much power was dissipated.



F_A: $W = F_{\parallel} \cdot d = 100N \cdot 3m = 300J$

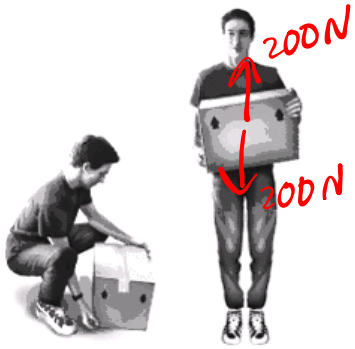
F_f: $W = F_{\parallel} \cdot d = -100N \cdot 3m = -300J$

F_g: $W = F_{\parallel} \cdot d = 0 \cdot 3m = 0$

$P = \frac{W}{t} = \frac{300J}{8s} = 38W$

3. The student then lifts the same 20.0 kilogram box 1.50 meters straight up in the air in 4.0 seconds at a constant speed.

a) Calculate the work he did and the power he used.



$F \cdot d$

$W_{by\ STU} = 300J$

$W_{by\ grav} = -300J$

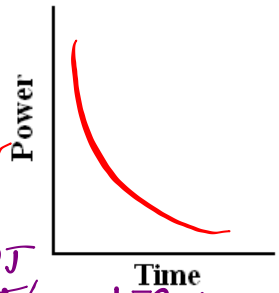
$P = 75W$

NOTE: When lifting or lowering an object at a constant speed . . .

The applied force is equal to the force of gravity (weight) of the object.

b) A second student lifted the same box to the same height at a constant speed but in only 2.0 seconds. Compare the work she did and the power she generated to those of the first student.

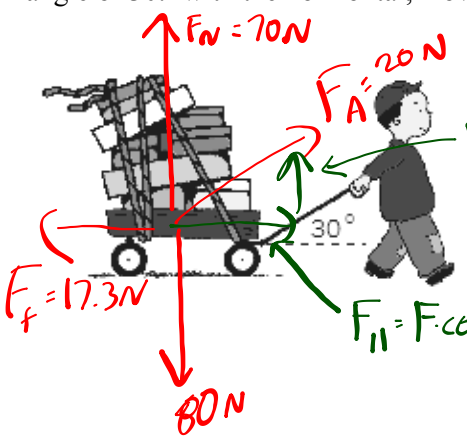
½t → same W
→ 2x power



$P \propto t^{-1}$

2s → $W = F \cdot d = 300J$
$P = W/t = 300J/2s = 150W$

4. If a child drags a 8.0 kilogram wagon for 10. meters by using a force of 20. newtons at an angle of 30.º with the horizontal, how much work does he do?



$F_N = 70N$
$F_A = 20N$
$F_{A\perp} = F \cdot \sin\theta = 20 \sin 30 = 10N$
$F_f = 17.3N$
$F_{\parallel} = F \cdot \cos\theta = 17.3N$
80N

$W = F_{\parallel} \cdot d = F \cdot d \cos\theta$
$= 17.3N \cdot 10m = 20N \cdot 10m \cdot \cos 30°$
173J

5. A student carries 150. newtons worth of books 10. meters up a flight of stairs which are inclined at an angle of 30^0 from the horizontal. How much work does he do?