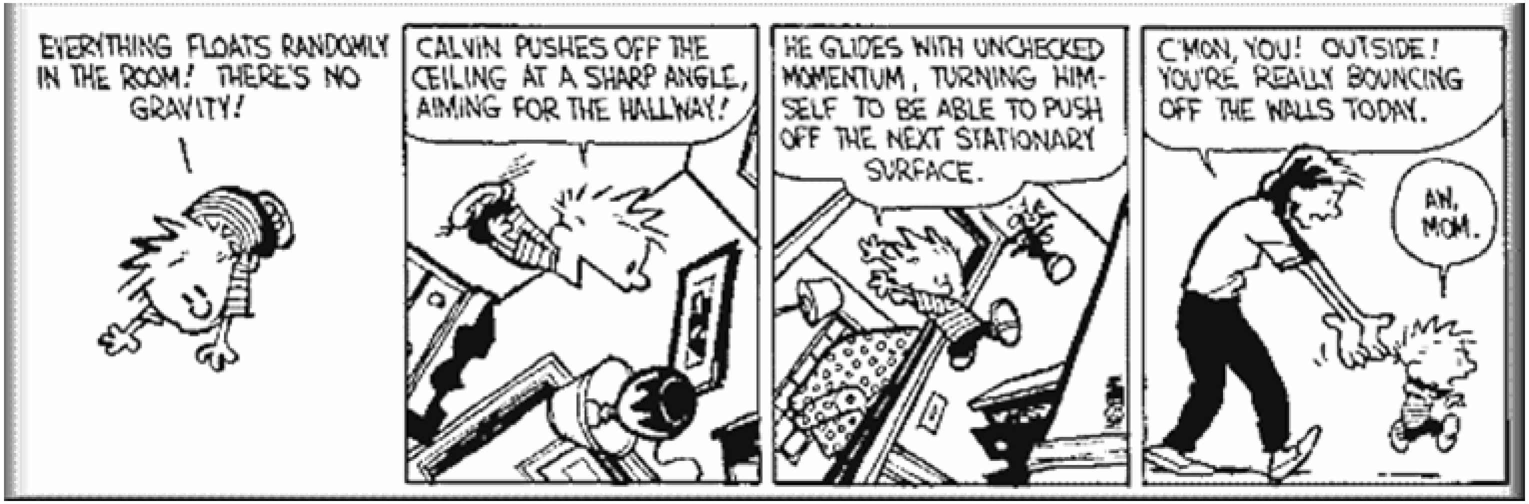
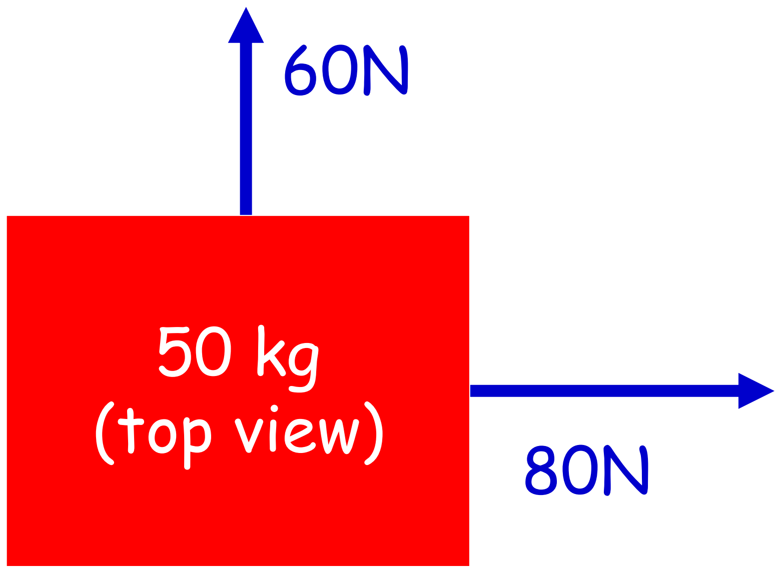
PHYSICS 231
Lecture 10: Too much work!





Two persons are dragging a box over a floor. Assuming there is no friction, what is the acceleration of the crate?

a) 1.2 m/s^2
b) 1.6 m/s^2
c) 2.0 m/s^2
d) 2.8 m/s^2
e) no acceleration whatsoever

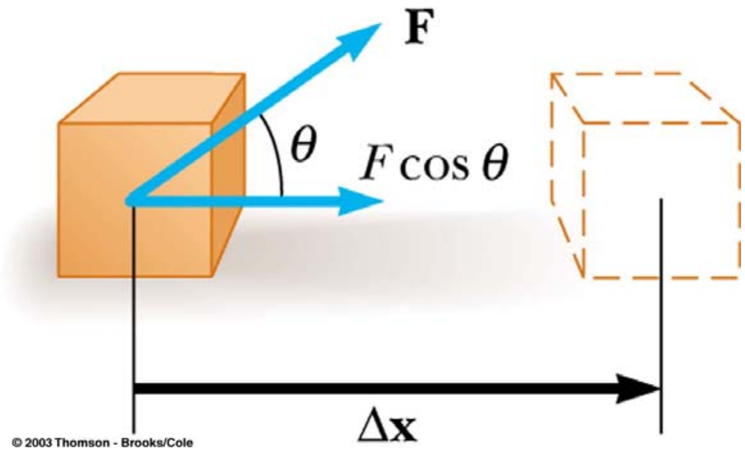
WORK

Work: 'Transfer of energy'

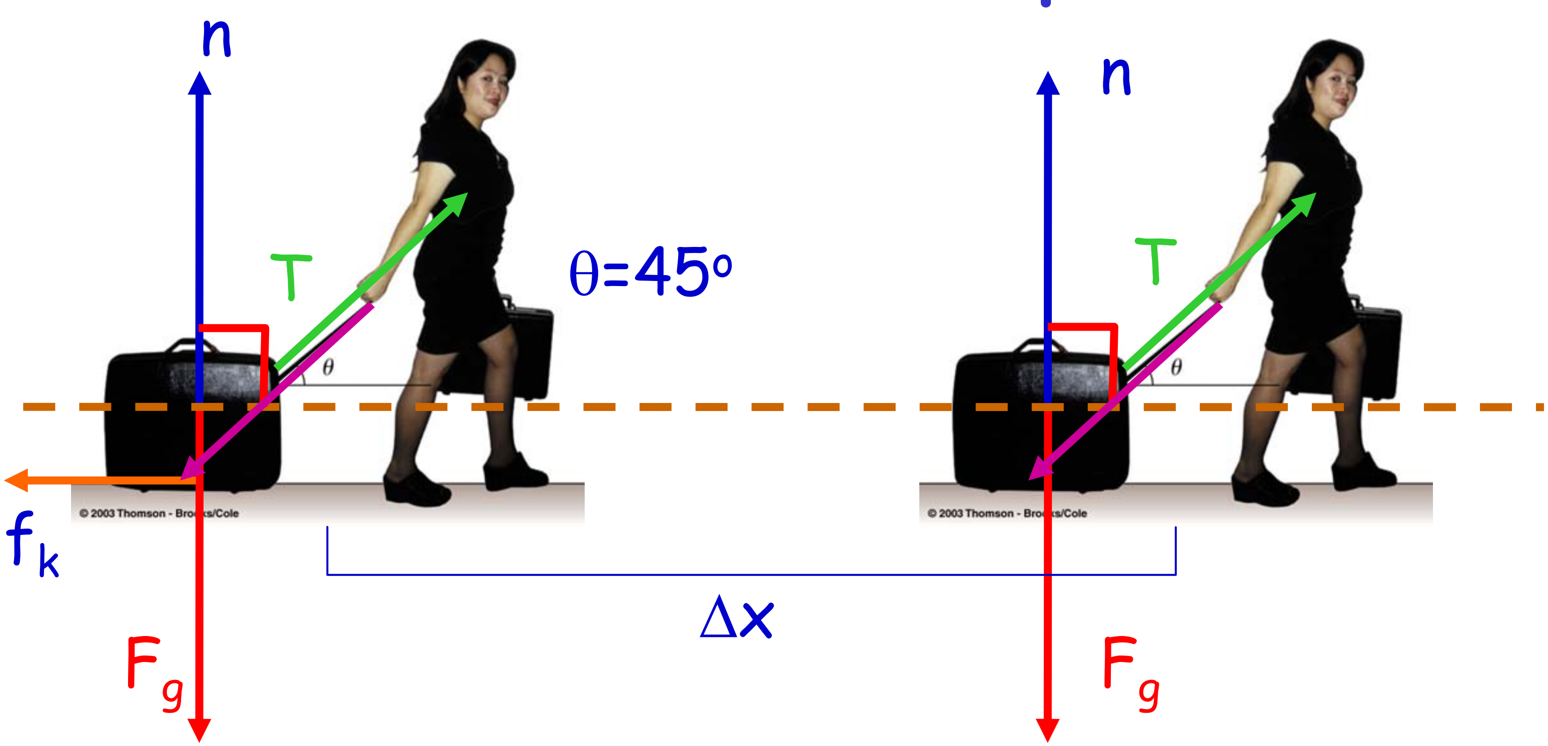
Quantitatively: The work W done by a constant force on an object is the product of the force along the direction of displacement and the magnitude of displacement.

$W=(F\cos\theta)\Delta x$

Units: =N m=Joule



An example



The work done by the person on the suitcase: $W=(T\cos 45^o)\Delta x$

The work done by F_g on the suitcase: $W=(F_g\cos 270^o)\Delta x=0$

The work done by n on the suitcase: $W=(F_g\cos 90^o)\Delta x=0$

The work done by friction on the suitcase: $W=(f_k\cos 180^o)\Delta x=-u_k n\Delta x$

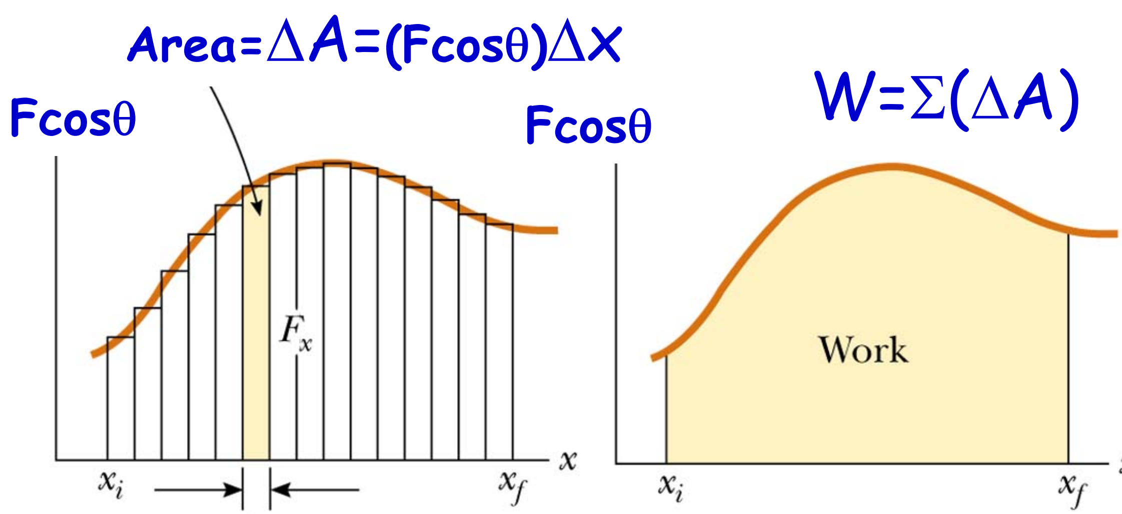
The work done by the suitcase on the person: $W=(T\cos 225^o)\Delta x$

opposite

Non-constant force

$W=(F\cos\theta)\Delta x$: what if $F\cos\theta$ not constant while covering Δx?

Example: what if θ changes while dragging the suitcase?



The work done is the same as the area under the graph of $F\cos\theta$ versus x

Power: The rate of energy transfer

Work (the amount of energy transfer) is independent of time.

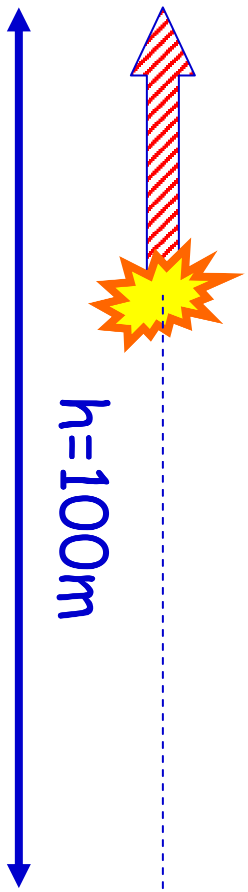
$W=(F\cos\theta)\Delta x$ … no time in here!

To measure how fast we transfer the energy we define:

Power(P)=$W/\Delta t$ (J/s=Watt) (think about horsepower etc).

$P = (F\cos\theta)\Delta x/\Delta t = (F\cos\theta)v_{average}$

Example



A toy-rocket of 5.0 kg, after the initial acceleration stage, travels 100 m in 2 seconds.
What is the work done by the engine?
What is the power of the engine?

$W=(F\cos\theta)\Delta h=m_{rocket}g\ \Delta h=4905\ J$

(Force by engine must balance gravity!)

$P=W/\Delta t=4905/2=2453\ W$ (=3.3 horsepower)

Or

1 hp = 750 W

$P=(F\cos\theta)v=mgv=5.0\ 9.81\ 100/2=2453\ W$

Potential Energy

Potential energy (PE): energy associated with the position of an object within some system.

Gravitational potential energy: Consider the work done by the gravity in case of the rocket:

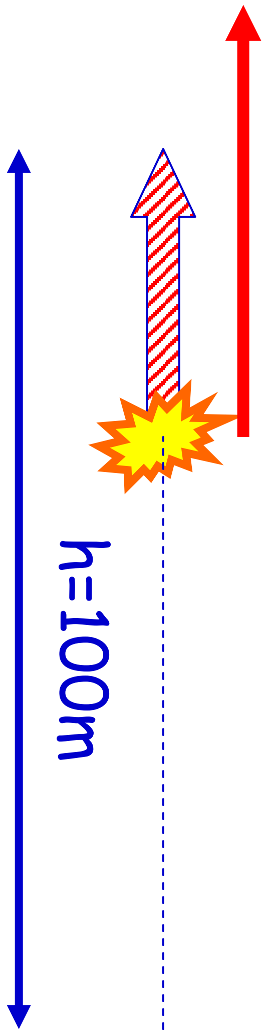
$$W_{gravity}=F_g\cos(180^o)\Delta h=-mg\Delta h=-(mgh_f-mgh_i)=mgh_i-mgh_f$$
$$=PE_i-PE_f$$

The 'system' is the gravitational field of the earth.

$$PE=mgh$$

Since we are usually interested in the change in gravitational potential energy, we can choose the ground level (h=0) in a convenient way.

Another rocket



A toy rocket (5kg) is launched from rest and reaches a height of 100 m within 2 seconds. What is the work done by the engine during acceleration?

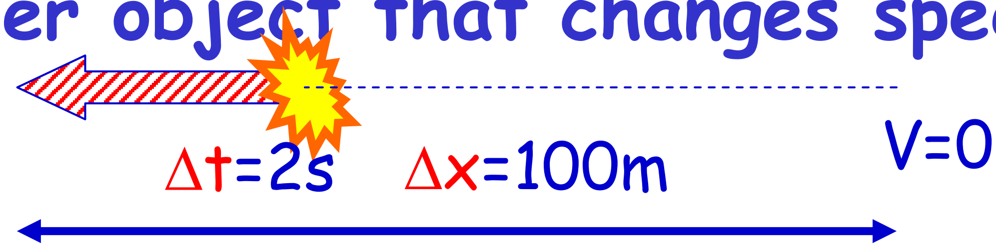
$h(t)=h(0)+v_0t+0.5at^2$ $100=0.5a2^2$ so $a=50\ m/s^2$
$V(t)=V(0)+at$ $V(2)=0+50*2=100\ m/s$
Force by engine=$(50+9.81)m=59.81*5=299.05$ N
($9.81\ m/s^2$ due to balancing of gravitation)
$W=F\Delta h=299.05*100=29905$ J

Change in potential energy:
$PE_f-PE_i=mgh(2s)-mgh(0)=4905-0=4905$ J
Where did all the work (29905-4905=25000 J)go?

Into the acceleration: energy of motion (kinetic energy)

Kinetic energy

Consider object that changes speed only



a) $W=F\Delta x=(ma)\Delta x$ … used Newton's second law

b) $v=v_0+at$ so $t=(v-v_0)/a$

c) $x=x_0+v_0t+0.5at^2$ so $x-x_0=\Delta x=v_0t+0.5at^2$

Combine b) & c)

d) $a\Delta x=(v^2-v_0^2)/2$

Combine a) & d)

$$W=\tfrac{1}{2}m(v^2-v_0^2)$$

Rocket:

$W=\tfrac{1}{2}5(100^2-0^2)$

$=25000$ J!!

That was missing!

Kinetic energy: $KE=\tfrac{1}{2}mv^2$

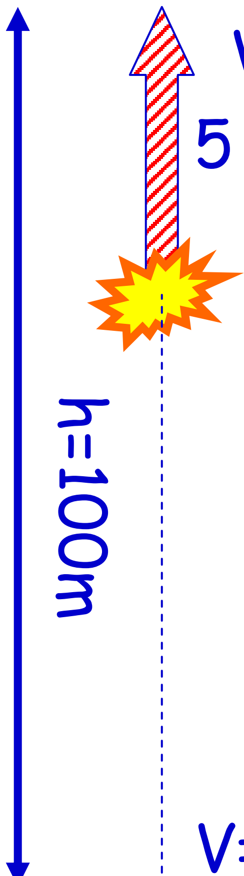
When work is done on an object and the only change is its speed: The work done is equal to the change in KE:

$$W=KE_{final}-KE_{initial}$$

Conservation of mechanical energy

Mechanical energy = potential energy + kinetic energy

In a closed system, mechanical energy is conserved*



$ME=mgh+\frac{1}{2}mv^2=\text{constant}$

What about the accelerating rocket?

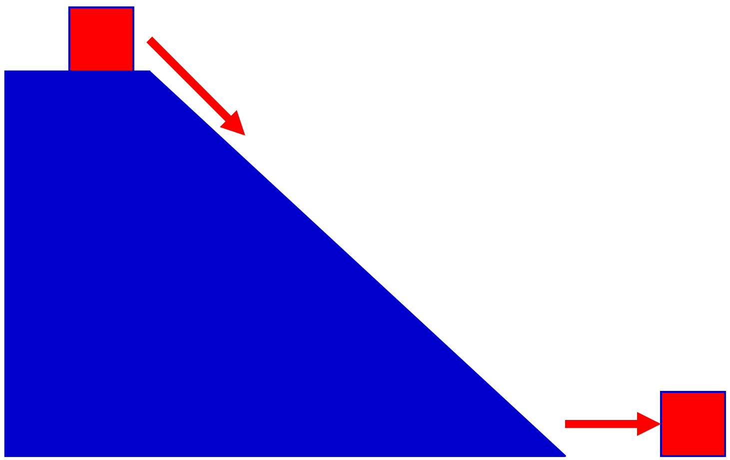
At launch: $ME=5*9.81*0+\frac{1}{2}5*0^2=0$

At 100 m height: $ME=5*9.81*100+\frac{1}{2}5*100^2=29905$

We did not consider a closed system! (Fuel burning)

* There is an additional condition, see next lecture

question



In the absence of friction, which energy-time diagram is correct?

potential energy

total energy

kinetic energy

C