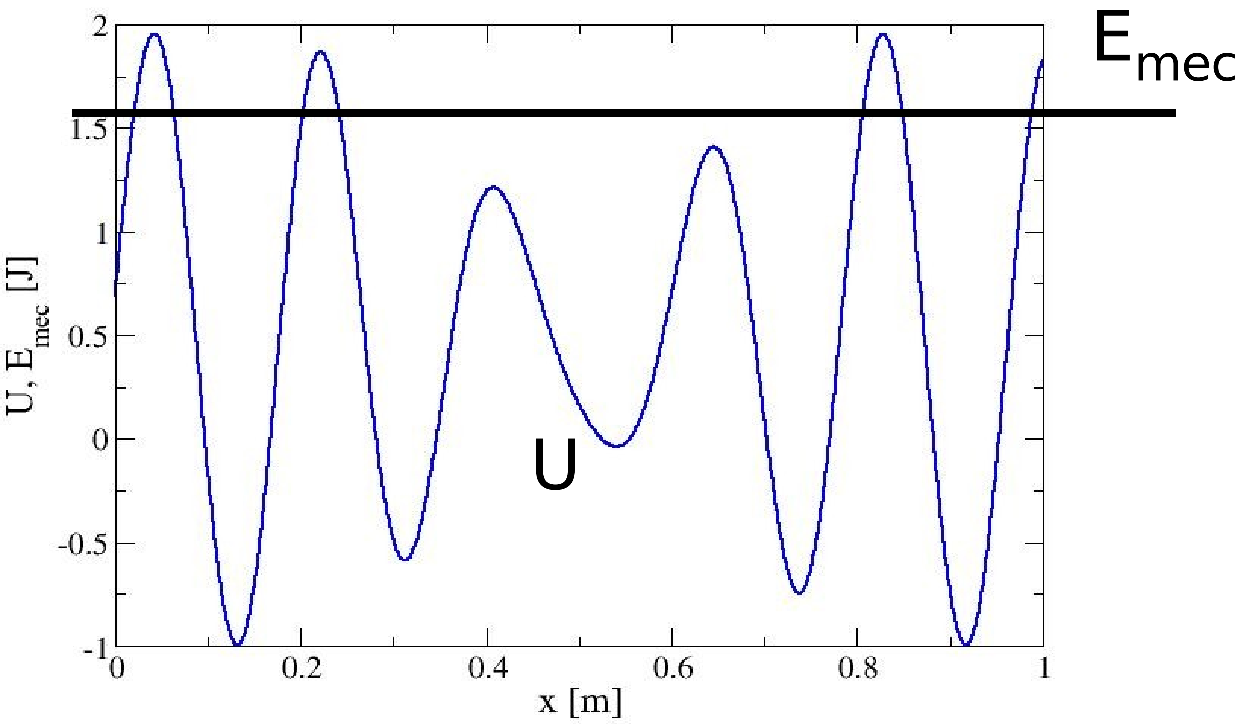
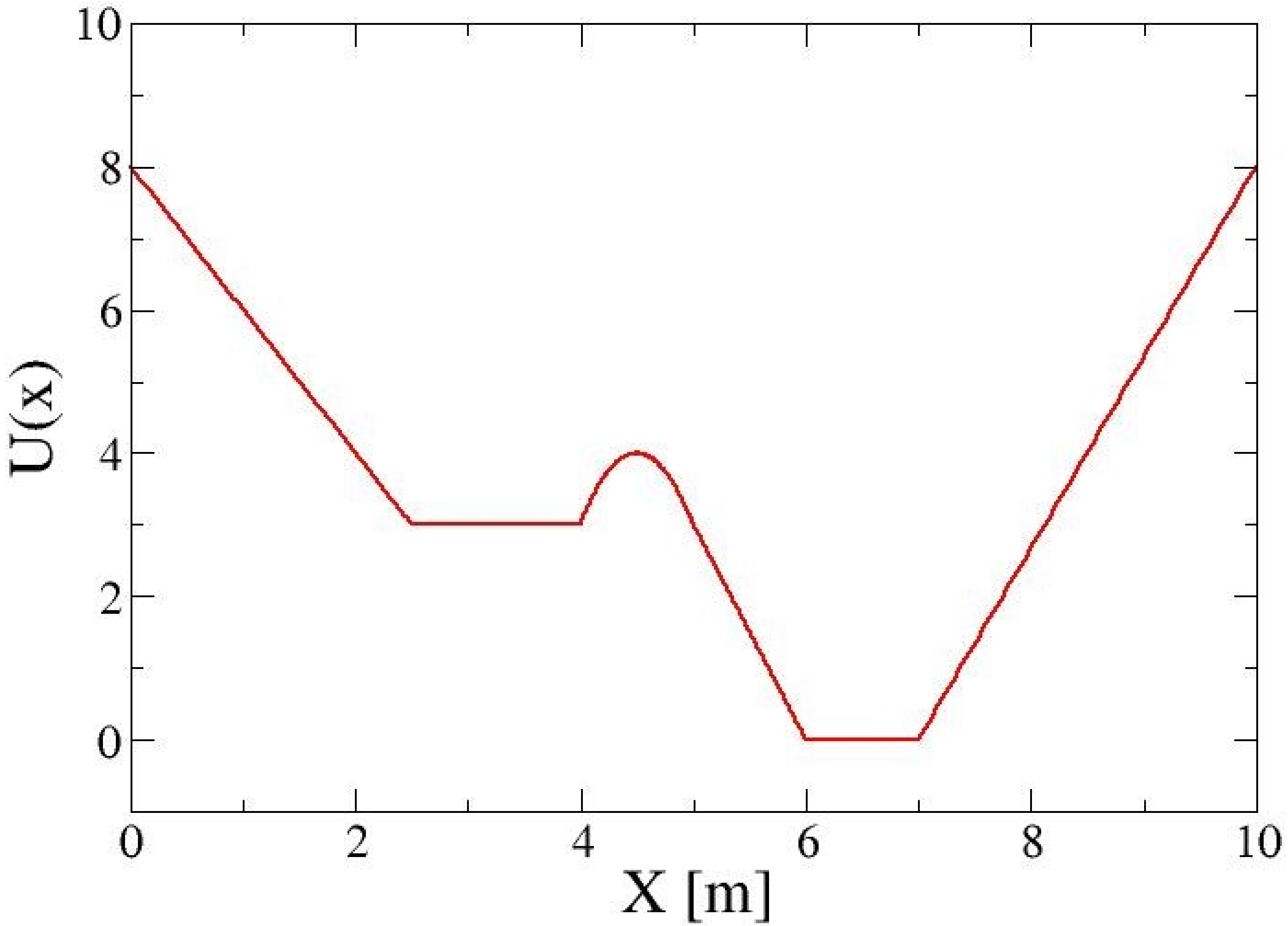
Review: Potential Energy Curves



Imagine this is a (frictionless) roller coaster and you release a marble at one location!

Example: Potential Energy Curves



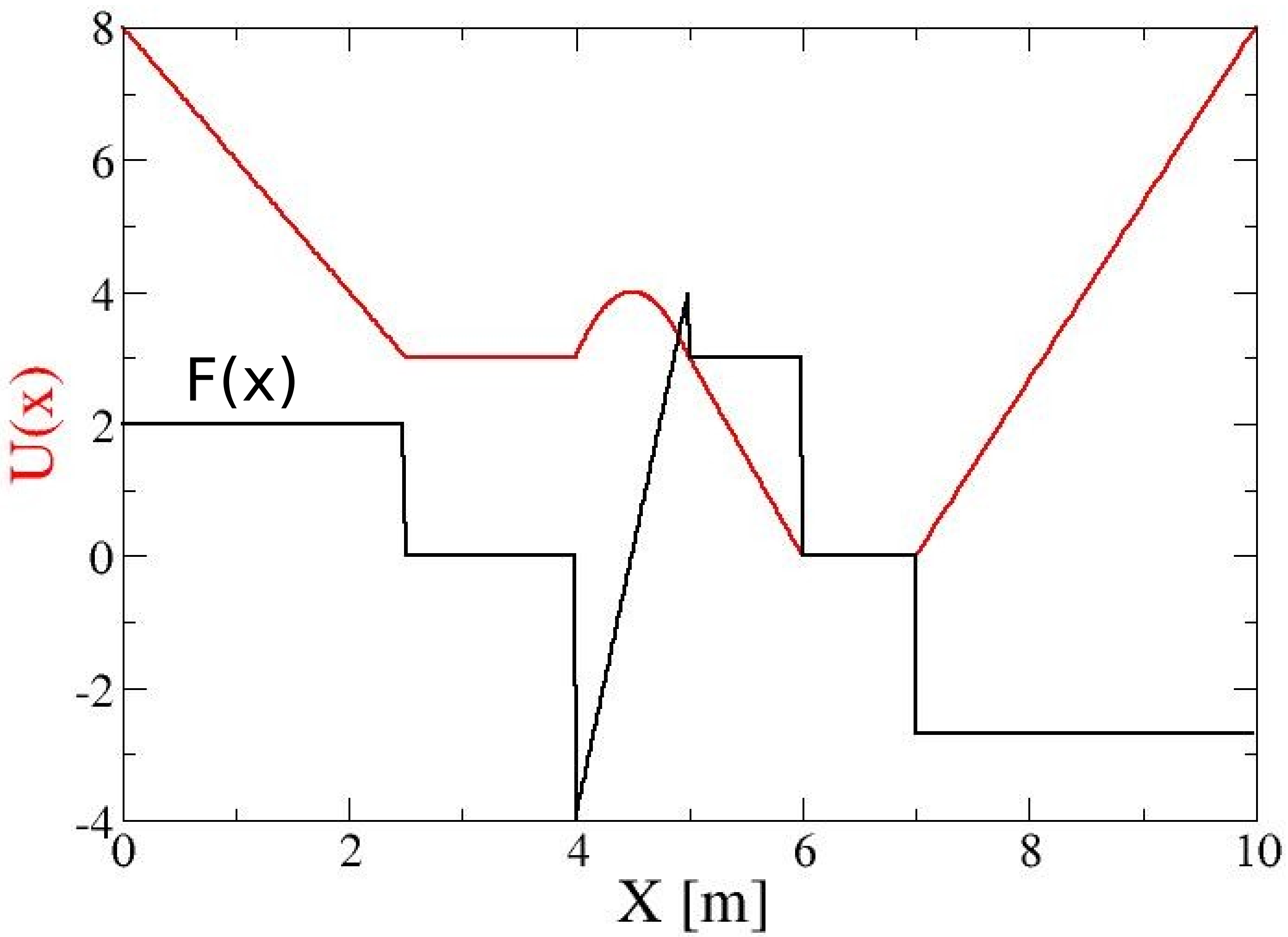
How large is F(x)?

$F(x) = -dU/dx$

Negative Force:
Pulls to lower x

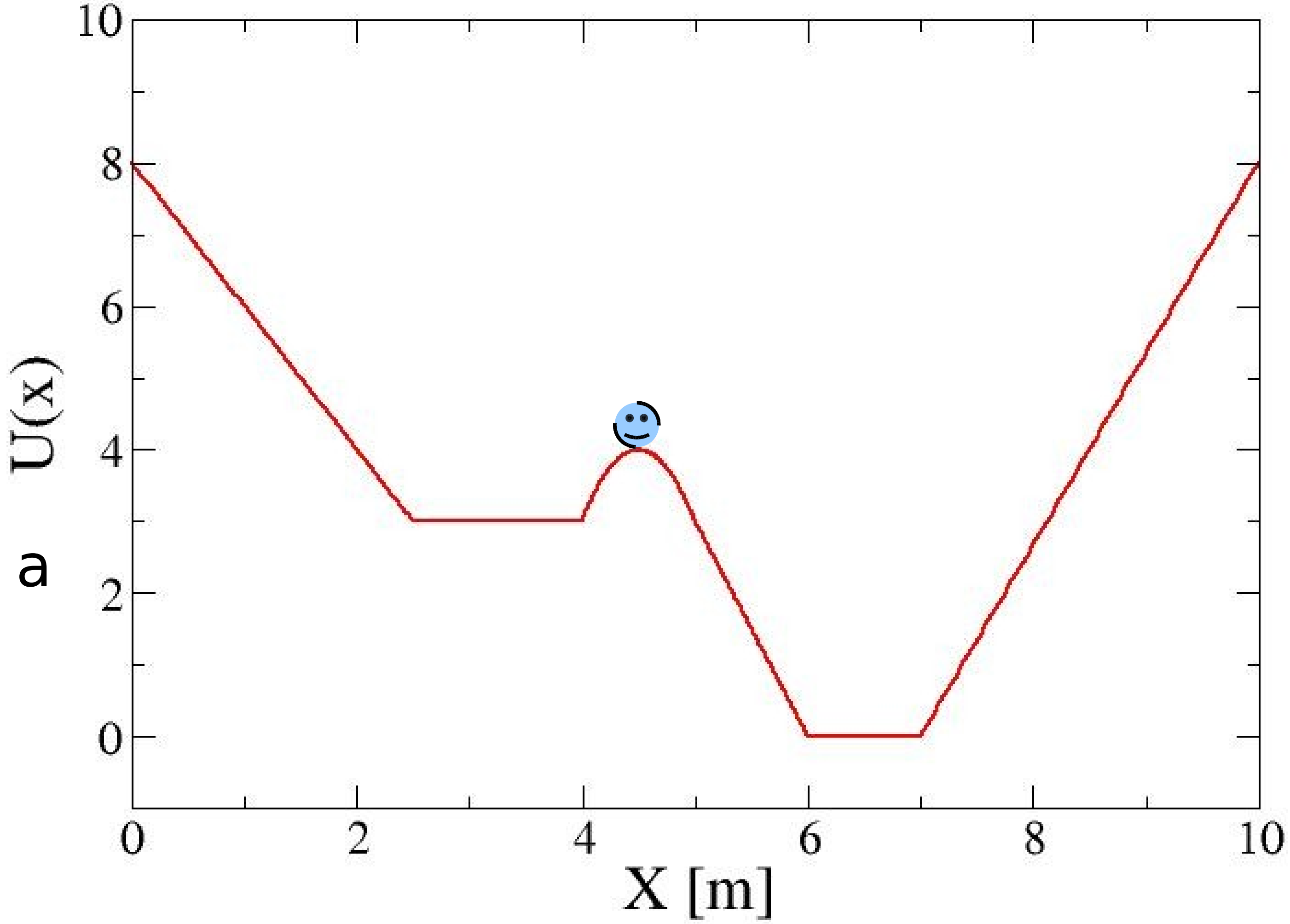
Positive Force:
Pushes to higher x

Example: Potential Energy Curves



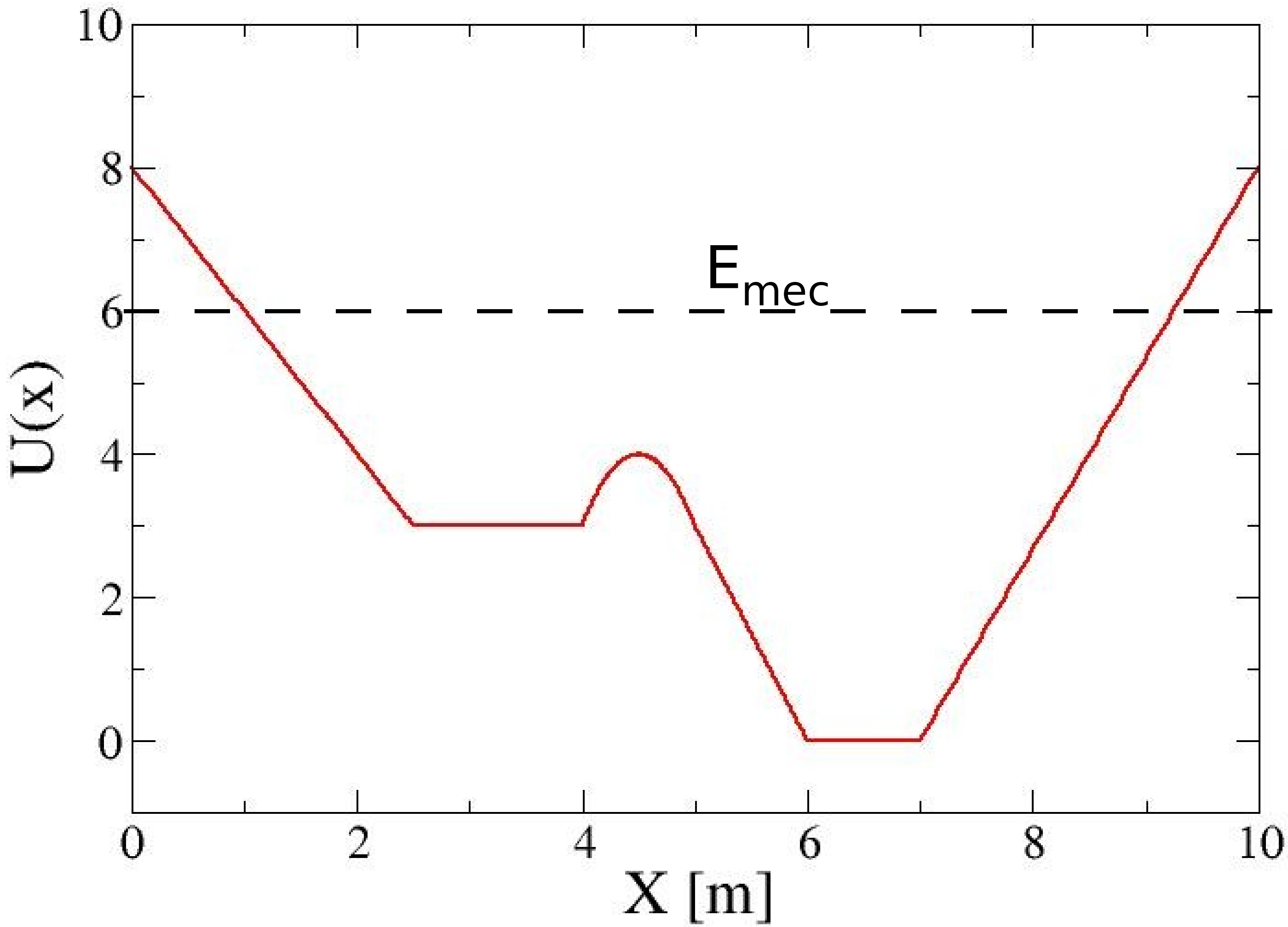
Example: Potential Energy Curves

Lets assume we release a particle of mass m=1kg at x=4.5m with a kinetic energy of 2J.



What is the speed of the particle at x=3m, x=6m?
Where are the turning points?

Example: Potential Energy Curves



E_{mec}=6J

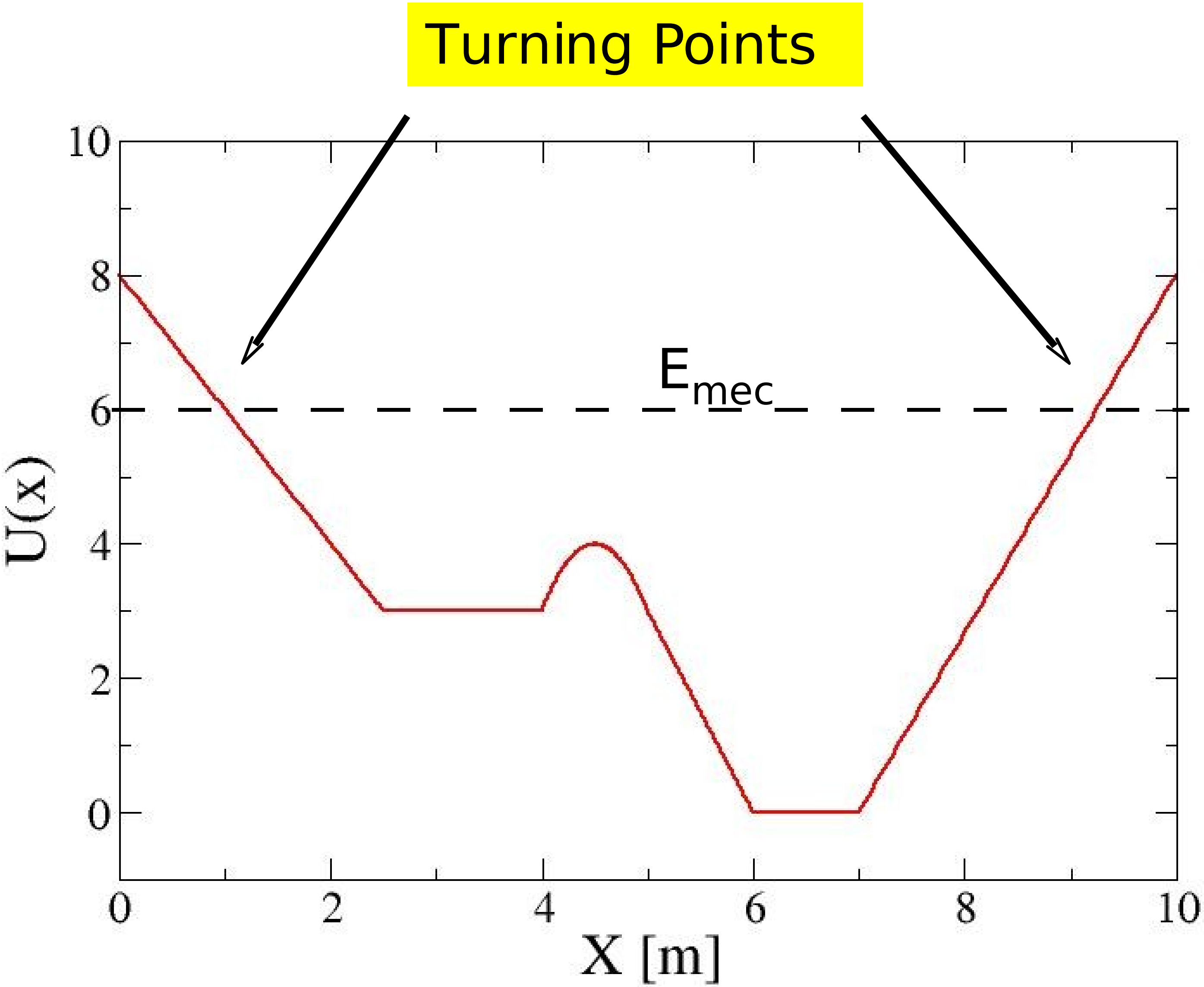
at x=3m:
U=3J
K=6J-U=3J

$v=(2K/m)^{1/2}$
=2.45m/s

at x=6m:
U=0J
K=6J-U=6J

$v=(2K/m)^{1/2}$
=3.46m/s

Example: Potential Energy Curves



Example: Potential Energy Curves

The potential energy of a diatomic molecule like H_2 or O_2 is given by:

$$U = \frac{A}{r^{12}} - \frac{B}{r^6}$$

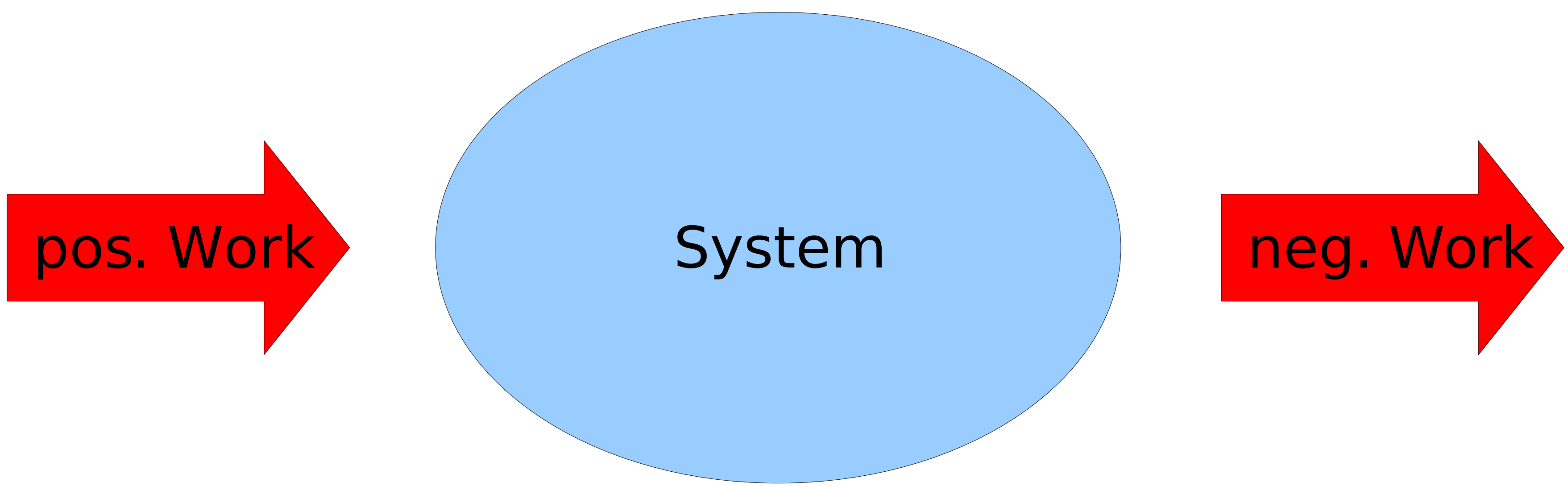
What is the equilibrium distance between the atoms?

Equilibrium: F=0 <-> U at minimum

$$\frac{dU}{dr} = -12\frac{A}{r^{13}} + 6\frac{B}{r^7} = 0 \quad \Rightarrow \quad r = (2A/B)^{1/6}$$

External Forces

Work is energy transferred to or from a system
by means of an external force acting on that system



Increases or decreases Energy of the system

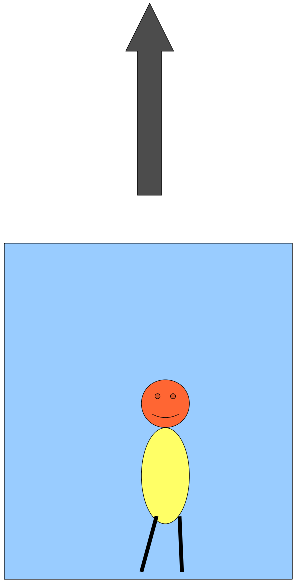
$$W = \Delta K + \Delta U = \Delta E_{mec}$$

Again: Total Energy is conserved

External Forces

Example: Elevator

Increases
your potential
energy
(and also your
kinetic energy
while moving)



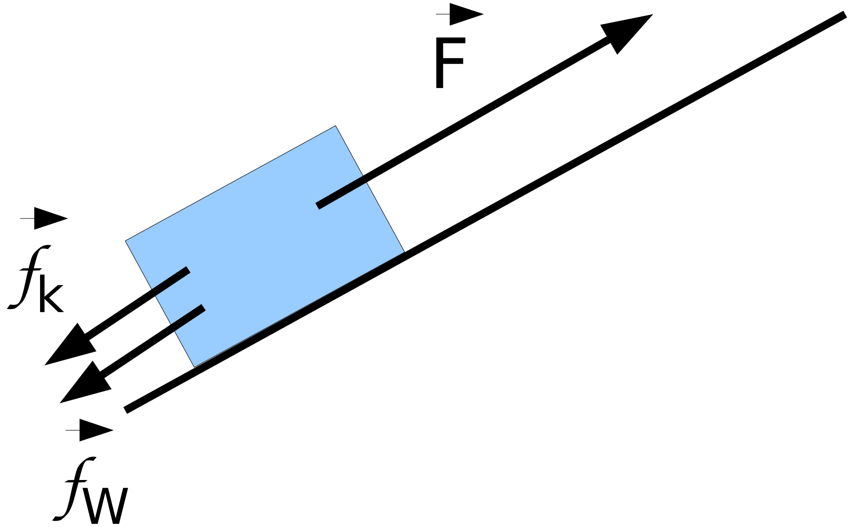
The motor of the
elevator provides
the energy.

Friction

Recall

- A force between two sliding objects
- Static friction: $f_{s,max} = \mu_s F_N$
  - Prevent things from sliding when applied force < $f_{s,max}$
- Kinetic friction: $f_k = \mu_k F_N$
  - Works against applied force
  - Reduces acceleration of pushed object
  - Objects heat up, increases thermal energy (New)

Friction



$f_W = mg \sin\theta$ Weight

$f_k = \mu_k mg \cos\theta$ Friction

One-dimension motion:

$F - f_k - f_W = ma$

Constant acceleration:

$$v^2 = v_0^2 + 2ad$$

$$ma = m(v^2 - v_0^2)/2d$$

$$Fd = f_k d + f_W d + m(v^2 - v_0^2)/2$$

ΔK

ΔU

Loss due to friction = increase in E_{th}

Applied positive Work

Friction

$$W = \Delta U + \Delta K + \Delta E_{th}$$

$$W = \Delta E_{mech} + \Delta E_{th}$$

Work done on a system increases its mechanical Energy and its thermal energy if friction is involved

Conservation of Energy

The total energy E of an **isolated** system cannot change.

In an isolated system energy can only be transformed between different forms.

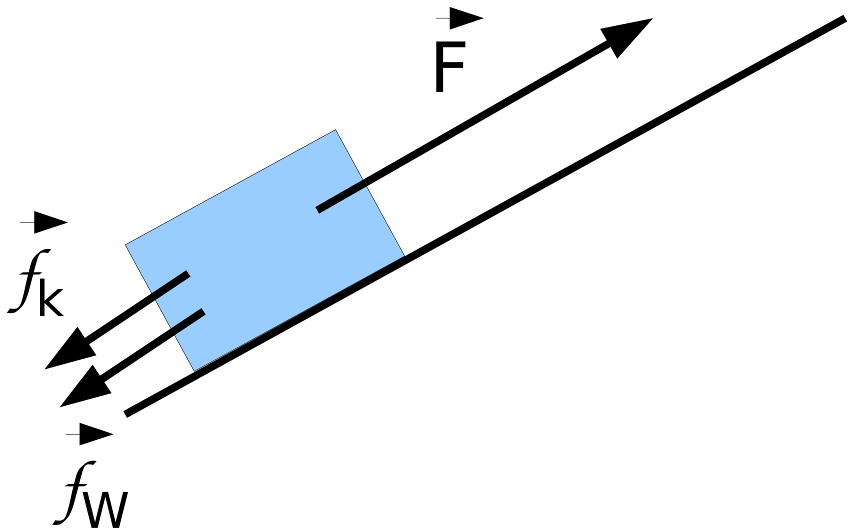
In an isolated system, we can relate the total energy at one instant with the total energy at another instant without considering the energies at intermediate times.

Conservation of Energy

The total energy E of a **non-isolated** system changes by the work put into or extracted from the system.

It also changes by the amount of thermal energy generated by non-conservative forces such as friction or drag (unless you consider the thermal energy being part of the system).

Friction



Constant acceleration:

$$v^2 = v_0^2 + 2ad$$

$$ma = m(v^2 - v_0^2)/2d$$

$$Fd = f_k d + f_W d + m(v^2 - v_0^2)/2$$

ΔK

ΔU

Loss due to friction = increase in E_{th}

Applied positive Work

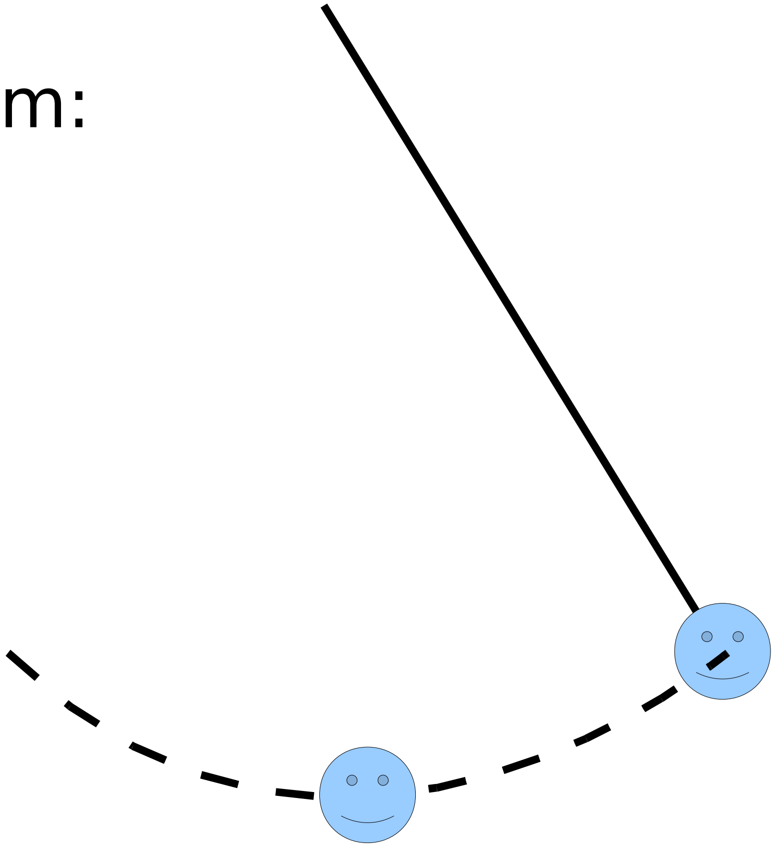
In most cases, people are usually only interested in the mechanical energy and treat the thermal energy as a loss. E_{th} would be energy lost although it still exists.

Different forms of energy

- Potential Energy
  - Gravity
  - Elastic (Spring)
- Kinetic Energy
  - Linear motion
  - Rotation (next chapter)
- Internal Energy
  - Chemical Energy
  - 'hidden' kinetic or potential energies
  - ...
- Thermal Energy

Example 1

Pendulum:



At turning point:
v=0, K=0

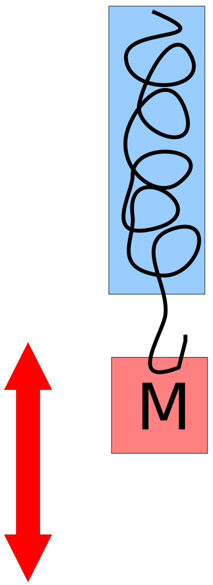
U_{max}=mgh

At lowest point:
y=0, U=0,
$K=K_{max}= mv^2/2 = U_{max}+E_{th}$

Friction will slowly reduce amplitude

Example 2

Spring:



Forces involved:
- Gravity: -mg
- Spring: kd, d:extension of spring

Define coordinate system:
y=0 at equilibrium position
where mg=kd

Net Force: $F_{net} = -ky = ma = m\ddot{y}$

Solution: $y(t) = y_0 \cos\Omega t$

$v(t) = -y_0 \Omega \sin\Omega t$

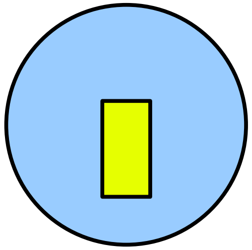
$a(t) = -y_0 \Omega^2 \cos\Omega t$

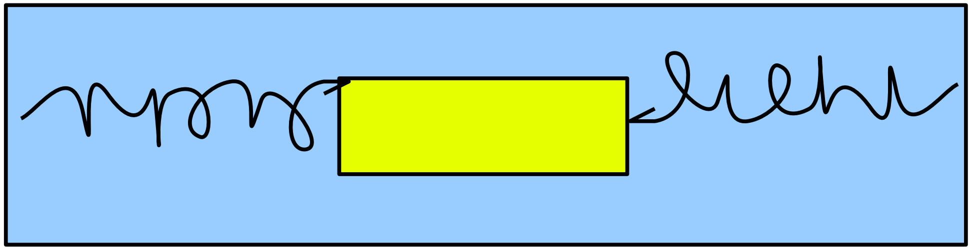
with $\Omega^2 = k/m$

Harmonic Oscillator
Friction will damp the amplitude

Example 3

Can with 'internal' energy:





rubber band rolls up and stores energy.

Friction

Is friction always bad?

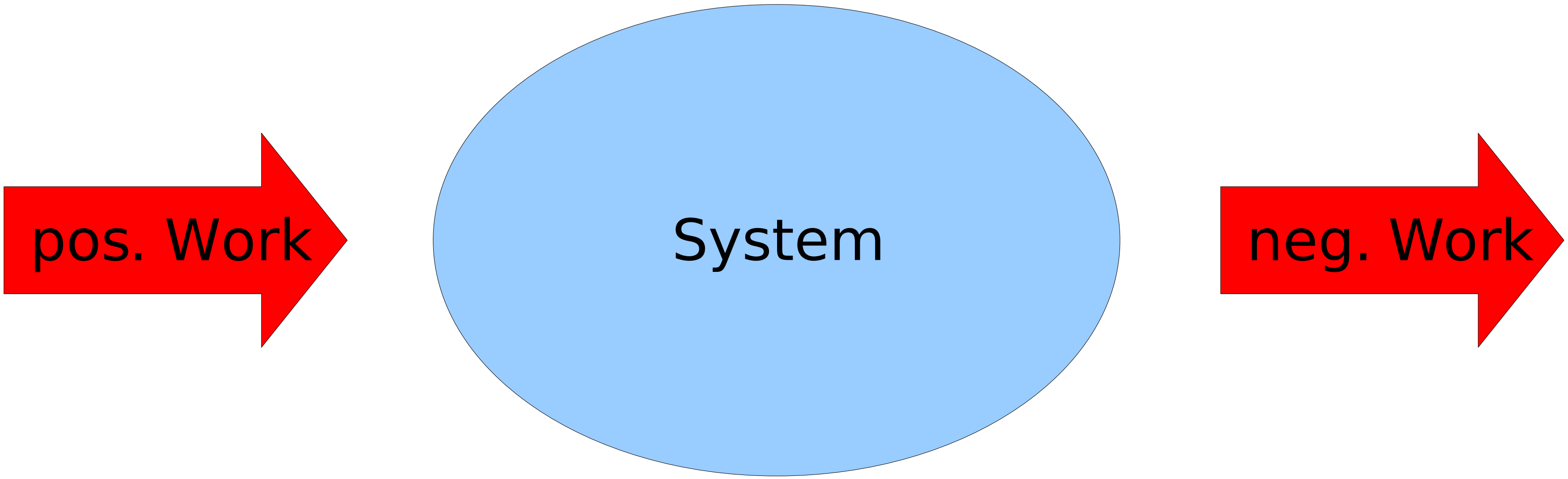
- Try to walk w/o friction
- Try to drive w/o friction

without friction:
The wheels would slip

Imagine trying to accelerate on ice

Energy is coming from an internal source (your gas tank)

Power



Power: Rate of Energy transferred from one type to another

Examples:

- Work done on a system per unit time $P=dW/dt$
- Internal energy transferred into mechanical energy $P=dE/dt$
  - Car engine: $P=-dE_{internal}/dt$