PHYS 1901 – Physics 1A (Advanced)
Mechanics module

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Force and Potential Energy

Work done is related to potential energy via

$$W = -\Delta U$$

Remembering the definition of work, this is

$$W = \int_i^f \vec{F} \cdot d\vec{s} \quad \underset{\text{for 1-dim}}{\Longrightarrow} \quad F = -\frac{dU}{dx}$$

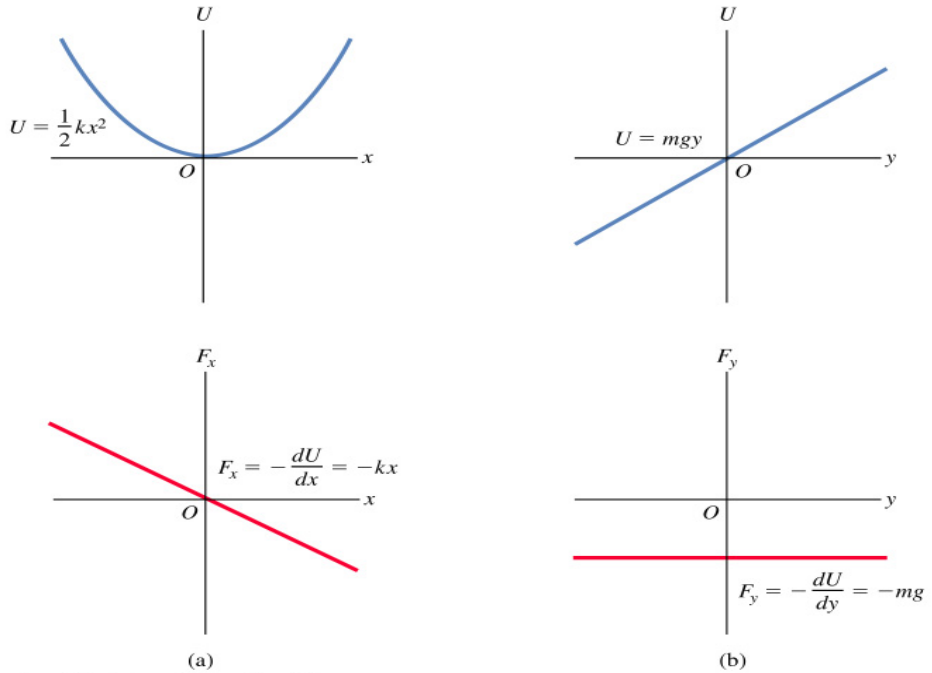
The force is the gradient of the potential!

Force and Potential Energy

In 3-D: $\vec{F} = -\vec{\nabla} U = \left(-\frac{\partial U}{\partial x}, -\frac{\partial U}{\partial y}, -\frac{\partial U}{\partial z}\right)$

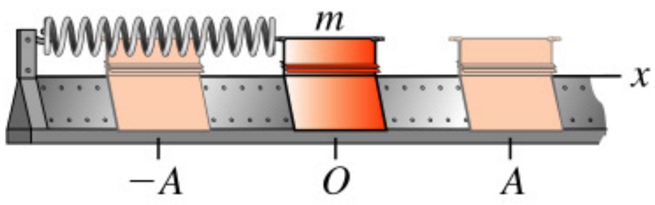
This can be quite useful when you have complicated potential functions.

For gravity & springs:

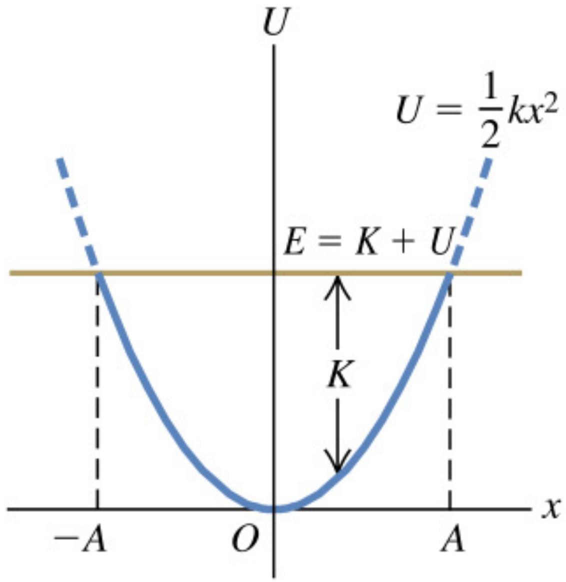


$F = -kx$

Energy diagrams



(a)

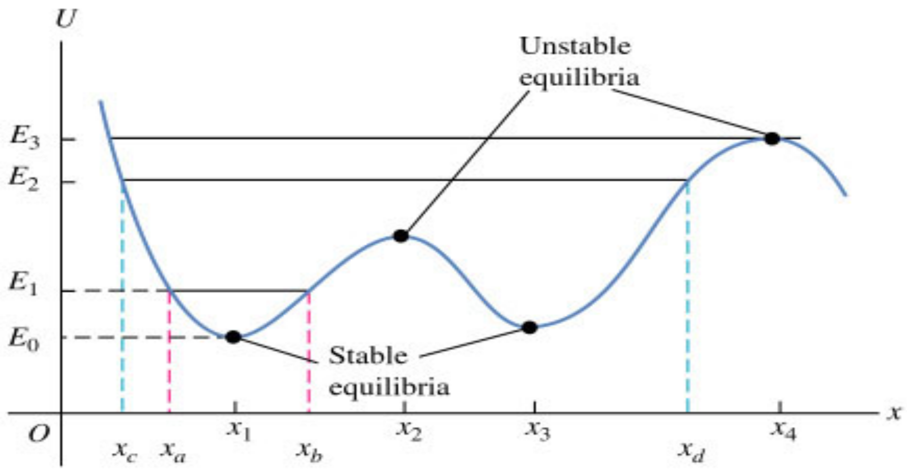


(b)

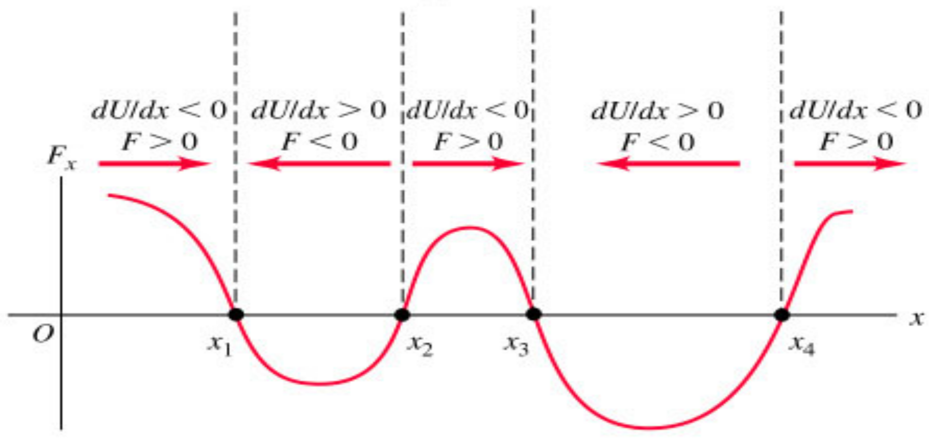
For an object with a total energy E, the potential curve can be used to calculate the kinetic energy.

In this case, the mass oscillates between -A and A. The mass is stuck in a **potential well** and can't get to other values of *x*.

Force and Potential Energy



(a)



(b)

Non-conservative forces

- When moving a mass in a gravitational field, the amount of work done by gravity is independent of the path taken.
- The same is not true of friction as it always opposes the direction of motion.
- Whereas gravity can do positive and negative work on an object, friction only does negative.

Momentum, Impulse, and Collisions

Chapter

8

Collisions: how to analyse

- Newton's laws?
- Work & Energy?

Each applicable in a large number of problems

For collisions, either can be problematic

Momentum

Newton's second law

$$\vec{F} = m\vec{a}$$

However, Newton actually said

$$\vec{F} = \frac{d\vec{p}}{dt}$$

where $\vec{p} = m\vec{v}$

$$\vec{F} = \frac{d}{dt}(m\vec{v})$$
$$= m\frac{d\vec{v}}{dt}$$
$$= m\vec{a}$$

(this is important in relativity!)

Impulse

- We can define an **impulse**

$$\vec{J} = \Delta \vec{p} = \int_i^f \vec{F}\, dt$$

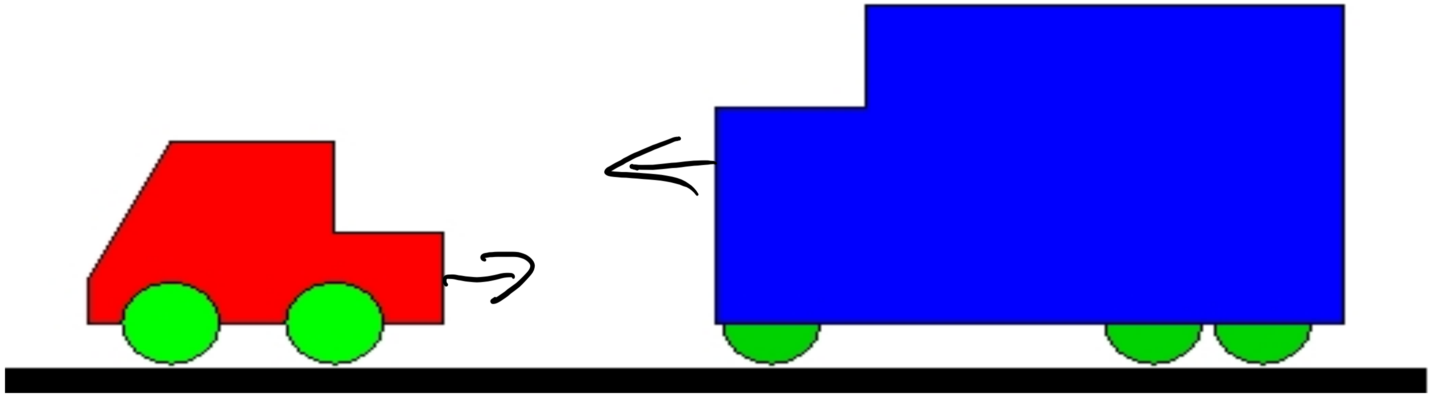
- Force acting over time changes the momentum of an object
- If there is no net force acting, the momentum is constant:

$$\vec{F} = \frac{d\vec{p}}{dt} = 0 \quad \Rightarrow \quad \vec{p} \text{ is constant}$$

$$(m\vec{v} \text{ constant})$$

- *No net force means momentum is conserved*
- (Haven't we covered this?)

Collisions



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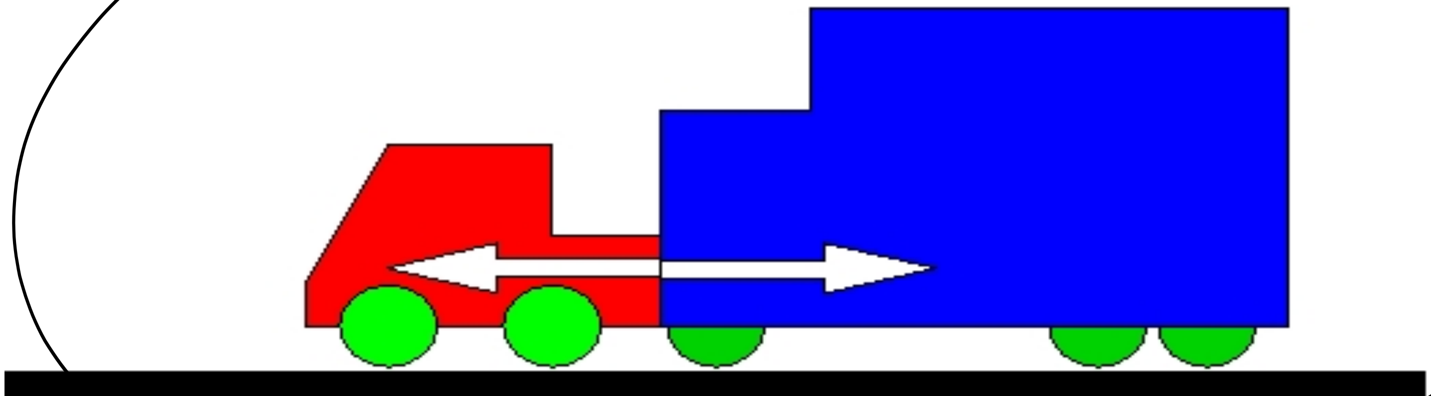
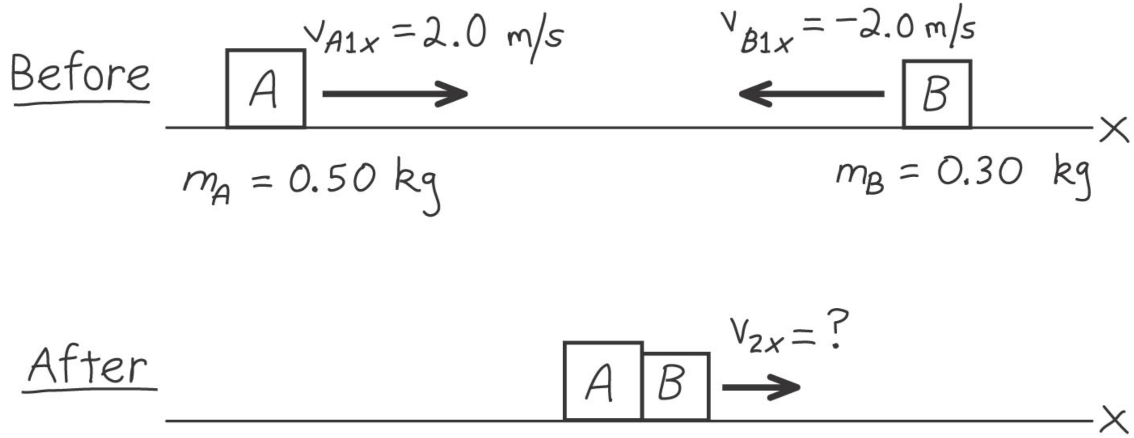
Collisions



in a collision, we have no net force on the whole system

Collisions

- By Newton's third law, the car & truck exert equal and opposite forces on one another.
- If we consider the car and truck together, the net force is zero.
- Again, taken together, momentum must be conserved in a collision
- In a collision, internal forces cancel (due to Newton's third law)
- As long as no external forces are acting, the total momentum is conserved.
- YOU define the object(s)



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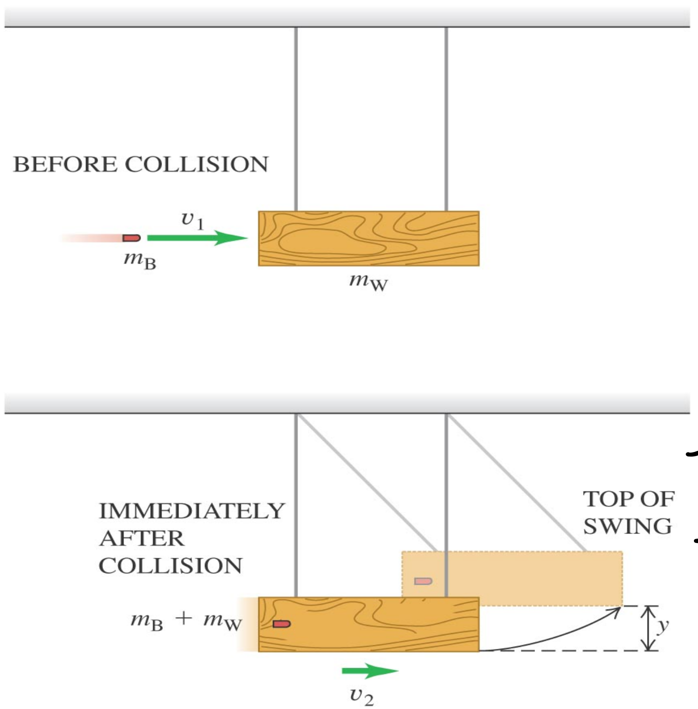
Ballistic pendulum



A 12.0g rifle bullet is fired into a ballistic pendulum with mass 6.00kg, which rises a high of 3.00cm.

What was the initial speed of the bullet?

Conservation of momentum of "system" (bullet + block)

$$\vec{p}_{system,i} = \vec{p}_{system,f}$$

$$\vec{p}_{system,i} = \vec{p}_{bullet,i} + \vec{p}_{block,i}$$

$$= m_{bullet}\vec{v}_{bullet,i} + m_{block}\cancel{\vec{v}_{block,i}} \rightarrow 0$$

equal

$$\vec{p}_{system,f} = (m_{bullet} + m_{block})\vec{v}_2$$

$$m_{bullet} v_{bullet,i,x} = (m_{bullet} + m_{block}) v_{2,x}$$

$$\Delta K = W_G = -\Delta U_G$$

$$\cancel{K_f} - K_i = -(m_{bullet} + m_{block}) g y$$

$$\frac{1}{2}(m_{bullet} + m_{block}) v_2^2 = (m_{bullet} + m_{block}) g y$$

$$v_2 = \sqrt{2gy}$$

$$v_{bullet,i} = \frac{m_{bullet} + m_{block}}{m_{bullet}}\sqrt{2gy}$$

$$= 384 \text{ m/s}$$