Mon Oct 14 HW by 5pm

Tues: Warm Up 9

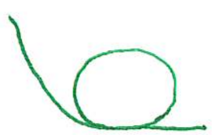
Weds: Review

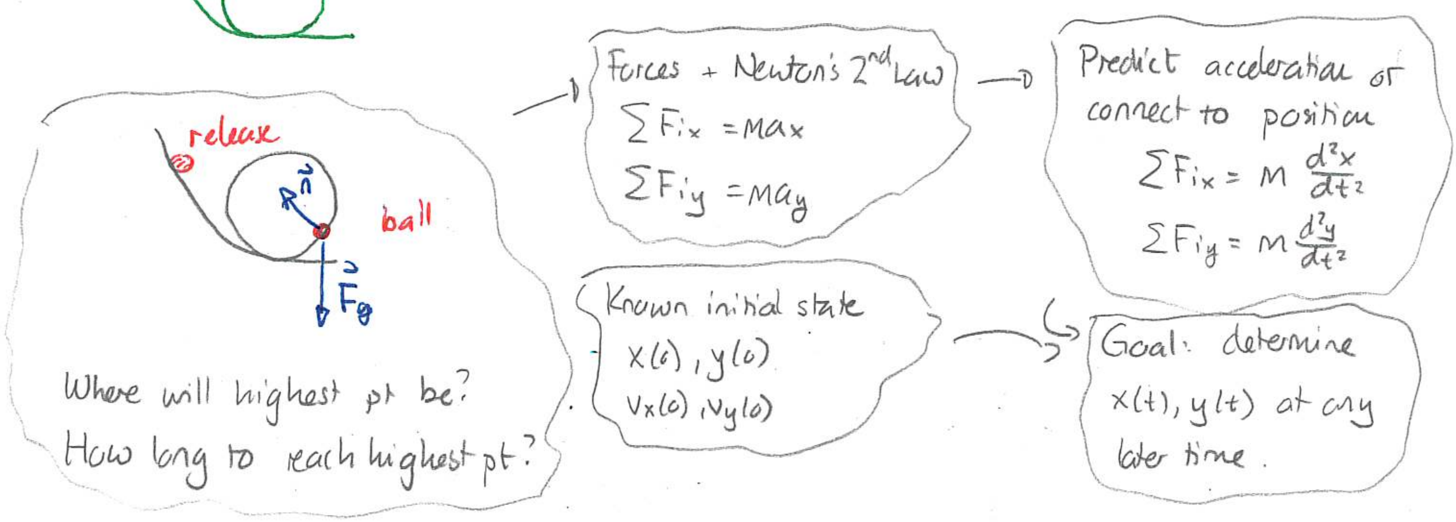
Fri: Exam II Covers Ch 5, 6, 7, 8

Energy in physics

Newton's system of mechanics provides a framework for analyzing the motion of any object. In principle, it lets us determine the acceleration of an object given a complete description of its interactions. But can this be done in practice.

DEMO: Ball on loop-the-loop - release so that it doesn't complete loop.





Challenge here: → normal force depends on position - need to know position (at time t) to determine normal force and find acceleration at time t. → acceleration depends on location

We will present an alternative strategy that uses energy and work to assess aspects of such situations.

DEMO: PhET ESP Basics → Intro
- "W" track - show bar graph / pie chart.

Energy as a concept and crucial tool for analysis is widespread in physics and other sciences:

* mechanics
* thermodynamics.
* quantum theory
* relativity
* chemistry
* biology
* climate science.

Work done by a force

Any force tends to result in acceleration which is associated with changes in velocity. Changes in velocity can either reflect changes in direction or changes in speed. Consider objects moving in a straight line

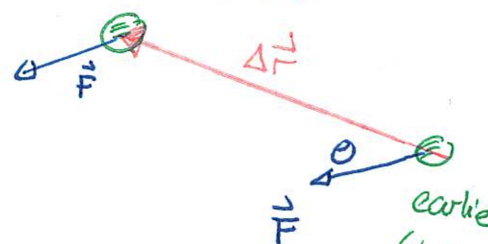
force partly causes object to speed up | force does not affect speed (prevents object falling) | force partly causes object to slow.

This motivates a definition

Consider a <u>constant force</u> acting on an object that moves in a <u>straight line</u>. Then the work done by the force on the object is

$$W = F \Delta r \cos\theta$$

where F = magnitude of force ($F > 0$)
Δr = distance traveled ($\Delta r > 0$)
θ = angle between force and displacement vectors



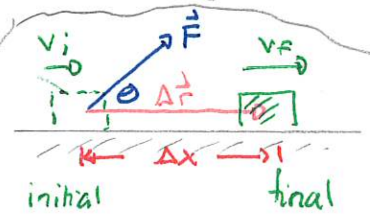
Units: Joules $J = N \cdot m$

Quiz 1 80% - 90% // 95%

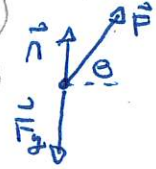
Quiz 2 60% - 80% // 40% - 80%

Work and Motion

We will now establish a connection between work and motion. Consider an object pulled along a horizontal surface by a constant force



Newton's 2nd Law



$\sum F_{ix} = m a_x$

$\Rightarrow F\cos\theta = m a_x$

$\Rightarrow a_x = \frac{F}{m}\cos\theta$

Kinematics

$v_f^2 = v_i^2 + 2 a_x \Delta x$

$\Rightarrow v_f^2 = v_i^2 + 2\frac{F}{m}\cos\theta\,\Delta x$

$\Rightarrow \frac{1}{2} m v_f^2 = \frac{1}{2} m v_i^2 + F\Delta x\cos\theta$

Work done by $\vec{F}$

$W_F = F\Delta x\cos\theta$

Work done by $\vec{n}, \vec{F}_g$

$\theta = 90^\circ \Rightarrow W = 0$

combine

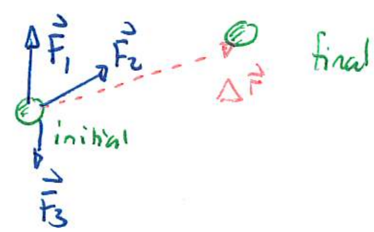
$$\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = W_F$$

This motivates the definition:

> The kinetic energy of an object with mass m, moving with speed v is
>
> $$K = \frac{1}{2} m v^2$$
>
> Units $kg\,m^2/s^2 = kg\,m/s^2 \cdot m = N m = J$

Thus it appears that the work done by a force is related to the change in kinetic energy of an object. We do, however, need to consider multiple forces

> The net work done on an object is
>
> $$W_{net} = W_{force1} + W_{force2} + W_{force3} + \dots$$
>
> where each term in the sum is the work done by that force and the sum includes all forces acting on the object



In the previous example

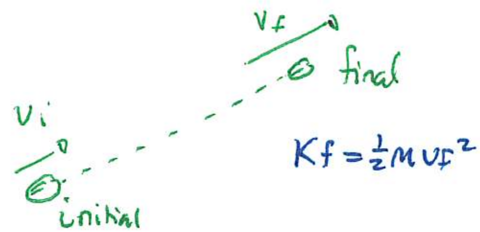
$$W_{net} = W_F + \cancel{W_g}^{0} + \cancel{W_n}^{0} = W_F \quad \Rightarrow \quad \Delta K = K_f - K_i = W_{net}$$

This is an example of the <u>work-kinetic energy theorem</u>

The kinetic energy of any object changes from one instant to another according to

$$\Delta K = W_{net}$$

$$\Rightarrow K_f - K_i = W_{net}$$



$K_i = \frac{1}{2} m v_i^2$

where W_{net} is the net work done by all forces on the object between the initial and final instants.

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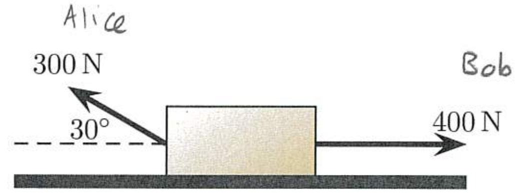
273 Work and motion

A 60 kg crate moves along a horizontal frictionless surface. Alice pulls up and left on the crate with a 300 N force as illustrated. Bob pulls right with a 400 N force. The crate is initially at rest and moves 5 m to the right while they pull on it. *(131F2024)*



5.0

a) Determine the work done by Alice on the crate.

b) Determine the work done by Bob on the crate.

c) Determine the net work done on the crate.

d) Determine the speed of the crate at moment that it reaches 5.0 m from its starting point.

Answer: a) 300N $\theta = 180° - 30° = 150°$, $\Delta r = 5m$

$W_{alice} = F \Delta r \cos\theta = 300N \times 5m \times \cos 150° = -1300J$

b) $W_{Bob} = F \Delta r \cos\theta = 400N \times 5.0m \cos 0° = 2000J$

400N, $\theta = 0$, $\Delta r = 5.0m$

c) $W_{grav} = mg \Delta r \cos 90° = 0$

$W_n = n \Delta r \cos 90° = 0$

$\vec{n}$, $\theta = 90°$, Δr, $\theta = 90°$

$W_{net} = W_{Alice} + W_{Bob} + W_{grav} + W_n = -1300J + 2000J = 700J$

d) $W_{net} = \Delta K \Rightarrow K_f - K_i = W_{net}$

$\Rightarrow \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = W_{net}$ $v_i = 0$

$\Rightarrow \frac{1}{2} \times 60kg \, v_f^2 = 700J$

$\Rightarrow v_f^2 = \frac{2 \times 700J}{60kg} = 12 m^2/s^2 \Rightarrow v_f = \sqrt{22 m^2/s^2}$

~~$v_f = 3.4 m/s$~~

$v_f = 4.8 m/s$

Quiz3 80% – 90% ≧ 60%