Phys 111 2023

Lecture 27

Mon: HW by 5pm

Ex: 247, 248, 250, 251ab, 254, 258, 260, 262

Weds: Warm Up

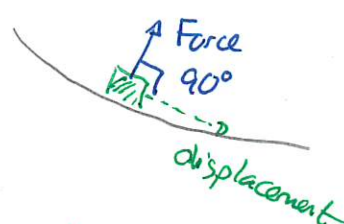
Conservation of Energy

A mathematical consequence of Newton's Laws is:

> If the only forces that do non-zero work on an object are gravity and spring forces then the total energy
>
> $$E = K + U_g + U_{sp}$$
>
> is constant throughout the motion of the object.

This is an example of the conservation of energy. Note that this is useful in situations where

1) an object slides along a surface
   ⇒ normal force does zero work



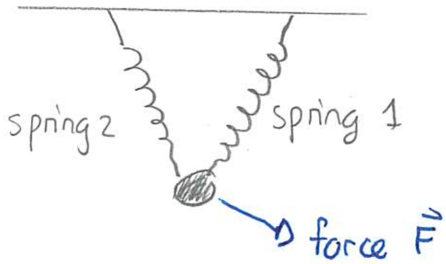
2) an object swings in a circle
   ⇒ tension does zero work.

Quiz 1 40% - 80%

DEMO: Stopped Pendulum

~~DEMO 2 Rocket Ball~~

We can frequently extend energy conservation to cases where more forces do non-zero work. For example, with two springs and gravity the energy that is conserved becomes



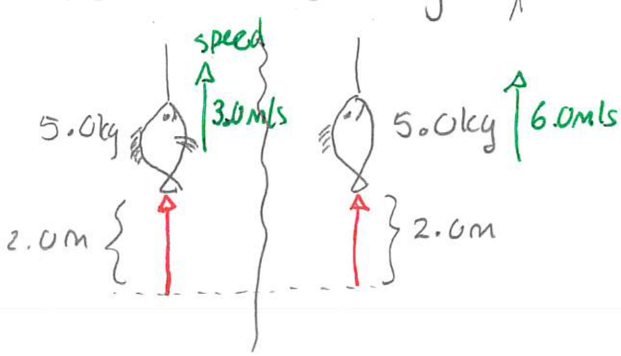
$$E = K + U_{grav} + U_{spring\,1} + U_{spring\,2}$$

If another type of force were to be included, we would have to find a potential energy for that force and include this. This is sometimes possible but in other cases provably impossible and, in those situations, energy conservation must be modified

<u>DEMO:</u> Rocket Ball

<u>Power</u>

Energy and work do not usually refer to the time taken to do a process. For example, if we were to raise two objects through the same vertical height at constant speeds the change in gravitational energy would be the same regardless of the time taken.



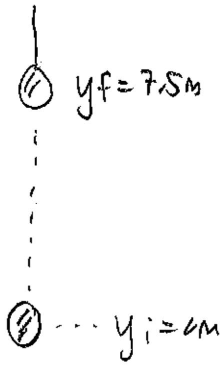
The work done by the rope would be the same. But there will be a difference in the rate at which work is done. We quantify this via power

> If work W is done on an object in time Δt then the power delivered (by the associated force) is
>
> $$P = W/\Delta t$$
>
> Units: Watts
>
> $W = J/s$
>
> If energy ΔE is delivered then the power is
>
> $$P = \Delta E/\Delta t$$

259 Lifting bananas

A 150 kg bunch of bananas is lifted by a vertical rope through a distance of 7.5 m. It takes 16 s to do this and for all but the initial and final moments it moves with constant speed. Determine the power delivered by the tension in the rope. *(111F2023)*

Answer:



The only energy that changes is the gravitational potential energy. So the change in energy is

$$\Delta E = U_{grav\,f} - U_{grav\,i}$$

$$= mgy_f - \cancel{mgy_i}$$

$$= 150\,\text{kg} \times 9.8\,\text{m/s}^2 \times 7.5\,\text{m}$$

$$= 11025\,\text{J}$$

Then the power is

$$P = \frac{\Delta E}{\Delta t} = \frac{11025\,\text{J}}{16\,\text{s}} = 690\,\text{W}$$

Power is relatively easy to measure in various situations. Typical numbers are

Light bulbs $\sim$ 10 W $\Rightarrow$ 10 J each s

Appliances $\sim$ 100 – 1000 W $\Rightarrow$ 100 – 1000 J each s.

Largest power station in US $\sim$ 7 GW = 7×10^9 W

(Grand Coulee Dam)

To compare this, the total energy consumption in the US is about 5×10^{19} J in six months. Then

$$6 \text{ months} = 6 \times 30 \text{ days} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{60 \text{ s}}{\text{min}}$$

$$= 1.56 \times 10^7 \text{ s}$$

$$\Rightarrow \text{US Power consumption} = \frac{5 \times 10^{19} \text{ J}}{1.56 \times 10^7 \text{ s}} = 3.2 \times 10^{12} \text{ W}$$

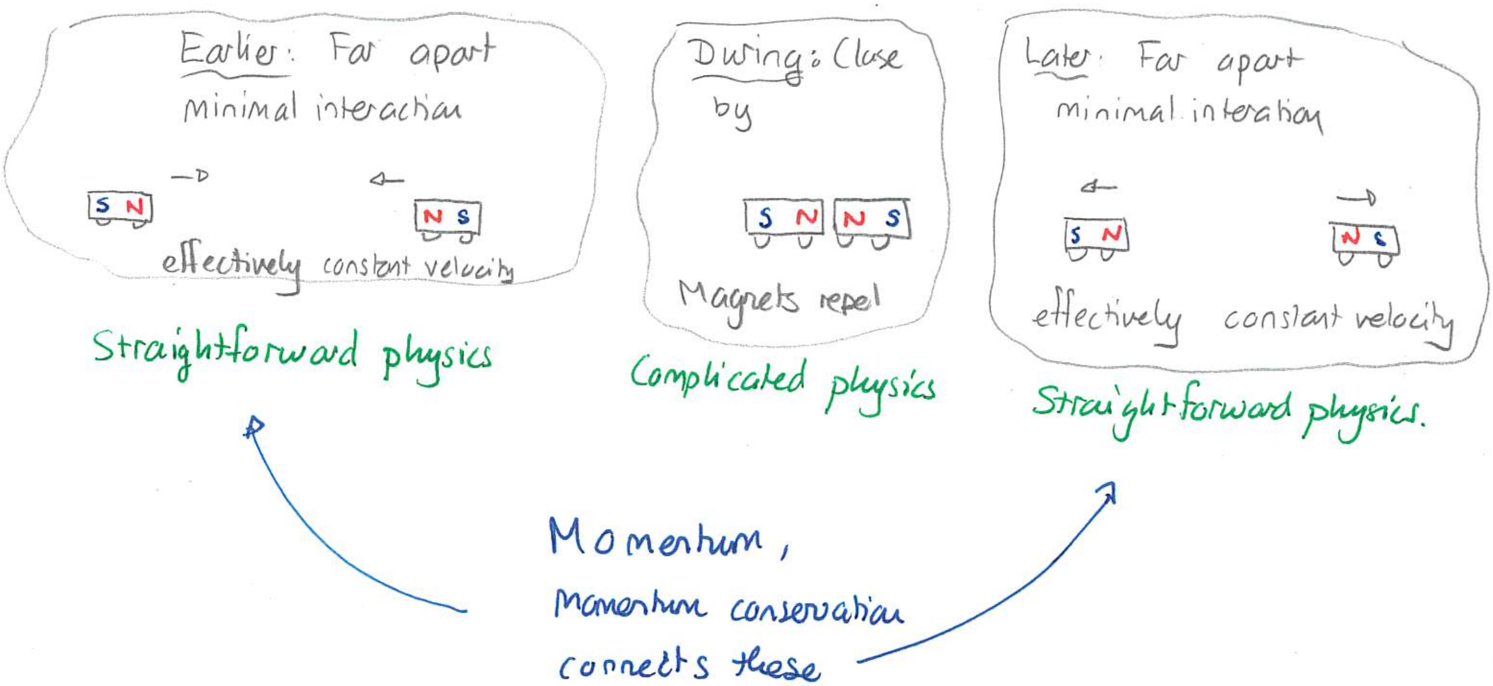
This would require $\frac{3.2 \times 10^{12}}{7 \times 10^9}$ Grand Coulee dams

$$= 460$$

Interactions in isolated systems

There are situations where objects interact with each other while they are effectively isolated from their surroundings. Consider two colliding magnetic carts.

DEMO: Colliding Carts



Despite the complicated physics during the interaction, we will be able to apply a (new) conservation law to easily determine facts about the velocities after or before.

DEMO: Ship collision

Particle collision

Momentum

The crucial new concept will be momentum which mixes information about mass and velocity. Specifically

> The momentum of an object with mass m and velocity $\vec{v}$ is
>
> $$\vec{p} = m\vec{v}$$
>
> 
>
>
> units: kg m/s

Note: 1) momentum is a vector

2) the direction of the momentum vector is the same as the direction of the velocity

3) objects with same velocities can have different momenta

4) objects with same mass can have different momenta.

Quiz 2 →