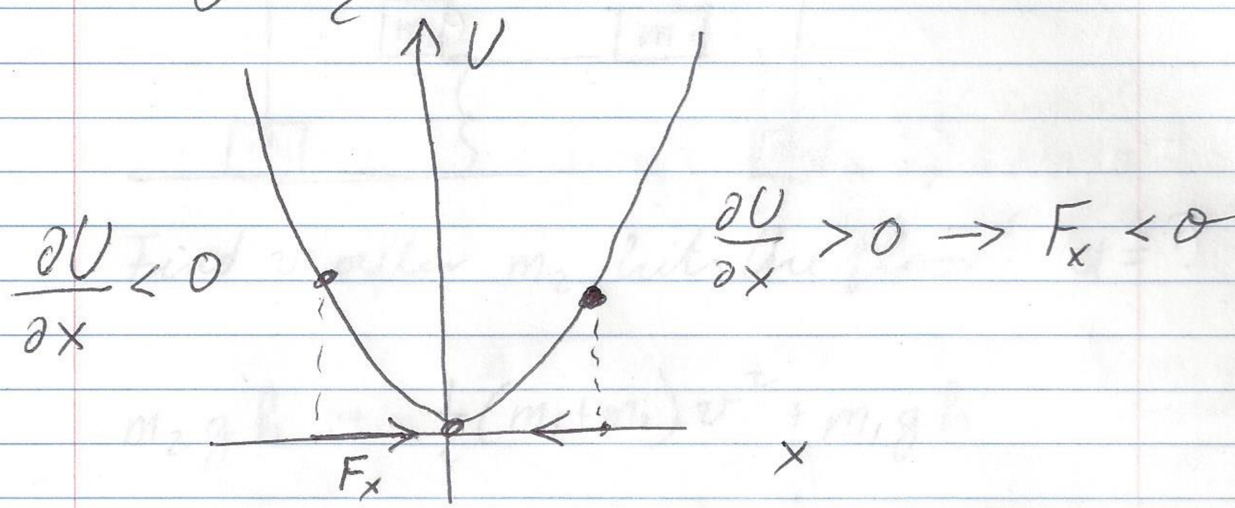
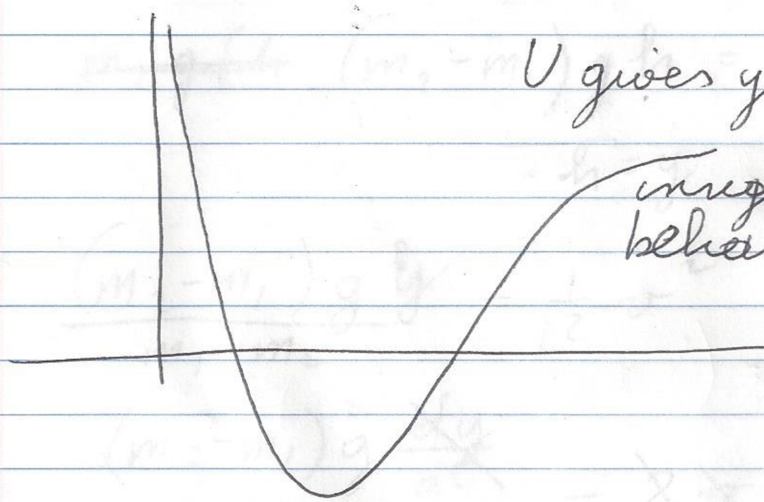
Energy Lecture 13

$$\vec{F} = -\overrightarrow{grad}\, U \;, \quad F_x = -\frac{\partial U}{\partial x}$$

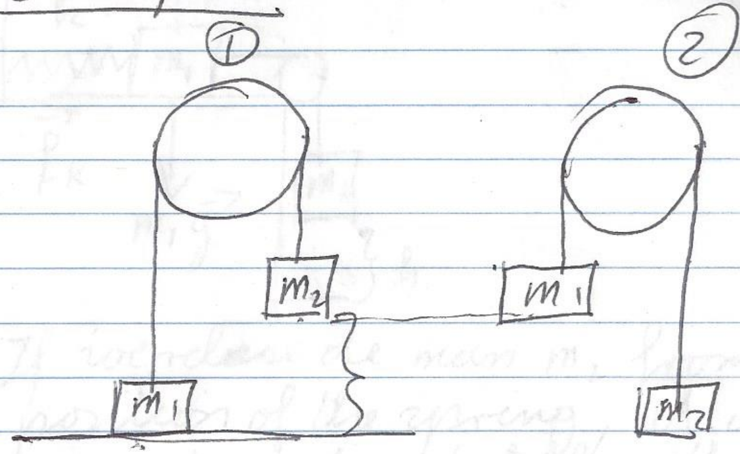
$$U = \frac{1}{2} k x^2$$





U gives you often an easy insight into the behavior of the force.

Examples:



Find v after m_2 hits the floor! $a = ?$

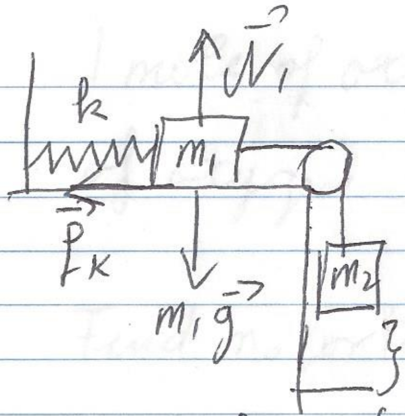
$$m_2 g h = \frac{1}{2}(m_1+m_2)v^2 + m_1 g h$$

$$\cancel{m_2 g (h} \quad (m_2-m_1) g h = \frac{1}{2}(m_1+m_2)v^2$$

$h = y$ $\qquad$ $v = v_y = \frac{dy}{dt}$

$$\frac{(m_2-m_1) g y}{m_1+m_2} = \frac{1}{2} v^2$$

$$\frac{(m_2-m_1) g \cancel{\frac{dy}{dt}}}{m_1+m_2} = \frac{\cancel{2}\cancel{v}}{\cancel{2}}\frac{dv}{dt} = a$$



If we release the mass m_2 from the equilibrium position of the spring, it will drop and come to a standstill without oscillating

$$-f_K \cdot x = \Delta K + \Delta U \qquad f_K = \mu_K \cdot m_1 g \text{ and } N_1$$

$$-\mu_K m_1 g \cdot x = \frac{1}{2} k x^2 - m_2 g x$$

$$E = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} \qquad \text{for a free particle}$$

free means : no force

$E_0 = m_0 c^2$ rest mass energy

$= 1kg \cdot c^2 = 9 \cdot 10^{16}\ J$

proton $= m_0 = 1.6 \cdot 10^{-27}\ kg$

$N_A = 6.02 \cdot 10^{23}$ Avogadro's number

= number of molecules in one mole.

1 mole = atomic mass in grams

1 mole of oxygen molecules has 32 grams of oxygen. $O_2 = O + O$

Find m_0 for the proton in $\frac{MeV}{c^2}$

$\cancel{1.6}\ 1.6 \cdot 10^{-27}\ kg$ $\qquad 1eV = 1.6 \cdot 10^{-19}\ J$

$1MeV = 1.6 \cdot 10^{-13}\ J$

$$\frac{\cancel{1.6} \cdot 10^{-27} \cdot 9 \cdot 10^{16}}{\cancel{1.6} \cdot 10^{-13}} =$$

$$10^{-14} \cdot 9 \cdot 10^{16} = 900\ MeV$$

$$m_0 = \frac{900MeV}{c^2}$$

$$E_0 = 900\ MeV$$

You find a proton with $= E = 1500\ MeV$

It moves! $K = 600\ MeV$

How fast is it?

$$\frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = \overset{1500}{\cancel{600}} MeV$$

$$\frac{900MeV}{\sqrt{1 - \frac{v^2}{c^2}}} = \overset{1500}{\cancel{600}}\ MeV = \frac{?}{\cancel{3}}$$

$$\left(\frac{9}{15}\right)^2 = 1-\frac{v^2}{c^2}$$

$$\left(\frac{3}{5}\right)^2 \quad \cancel{2.25} = 1-\frac{v^2}{c^2}$$

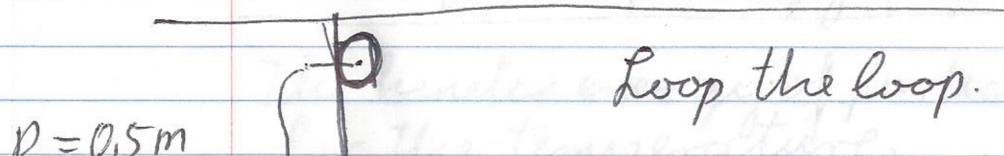
$$\cancel{\frac{v^2}{c^2} =}$$

$$\frac{9}{25} = 1-\frac{v^2}{c^2}$$

$$\frac{v^2}{c^2} = 1-\frac{9}{25}$$

$$\frac{v}{c} = 0.8 \qquad \underline{\underline{v = 0.8 \cdot c}}$$

Loop the loop.



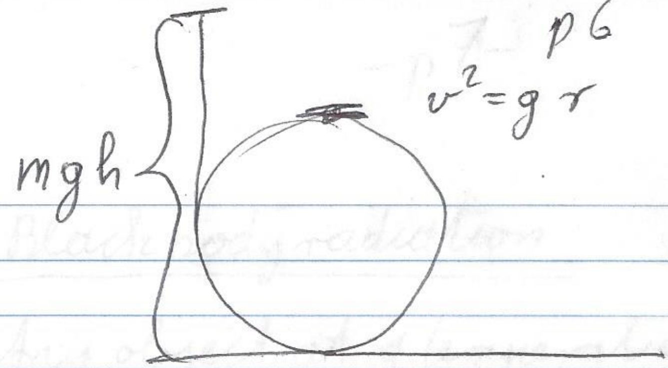
It what height must a ball be released so that it remains in a circular motion at point A

$$\vec{N} + m\vec{g} = m\vec{a}; \quad +N + mg = +m\frac{v^2}{r}$$

$$N = m\left(\frac{v^2}{r} - g\right)$$

$$\frac{v^2}{r} = g; \quad v^2 = gr$$

$$\underline{\underline{2.21\ \frac{m}{s}}}$$



$$mgh = \frac{1}{2} m v^2 + mgy$$

$$= \frac{1}{2} m v^2 + mg \cdot 2R$$

$$= \frac{1}{2} m g r + mg \cdot 2R \quad = 2.5 mgR$$

$$h = 2.5R$$

Other forms of energy and power.

The kinetic energy of particles is responsible for the temperature.

$$\frac{1}{2} M \bar{v}^2 = \frac{3}{2} RT$$

M: mole mass

T is temperature in Kelvin

$0°C = 273°K$

R is the universal gasconstant 8.314

O_2 : $\underbrace{0.032}_{kg} \bar{v}^2 = 3RT$, $\cancel{T} = 3R \cdot 293$

$$\bar{v} = 478 \frac{m}{s}$$

Black body radiation:

Any object at a temperature T (in K°) radiates energy:

$$P = \frac{dW}{dt} = \frac{dE}{dt} = e \cdot \sigma \cdot A \cdot T^4$$

$e \approx$ emissivity ≈ 1 $\qquad T = 5800$

σ = Stefan-Boltzmann constant ~~$= 6.78 \cdot 10^{-9}$~~ $5.67 \cdot 10^{-8}$

A = surface area which radiates

Calculate P for the sun:

radius sun: $6.96 \cdot 10^8$ m

$$P = 1 \cdot 5.67 \cdot 10^{-8} \cdot 4\pi (6.96 \cdot 10^8)^2 \cdot 5800^4$$

$$= 3.9 \cdot 10^{26} \text{ Watts.}$$

divide by c^2 to get the mass emitted per second

$$4.3 \cdot 10^9 \frac{kg}{s} = 4.3 \text{ million tons of matter}/s$$

How long to "burn" 10% of the mass

$m = 2 \cdot 10^{30}$ kg; $\Delta m = 2 \cdot 10^{29}$ kg

$4.6 \cdot 10^{19}$ seconds $= 1.5 \cdot 10^{12}$ years

$P = 3.9 \cdot 10^{26}$ Watts.

sun

earth

I = intensity $= \dfrac{P}{4\pi r_{se}^2}$ = power received per m^2

$$r_{se} = 1.5 \cdot 10^{11}\ m$$

$$= 1.38 \cdot 10^{3}\ \frac{W}{m^2}$$