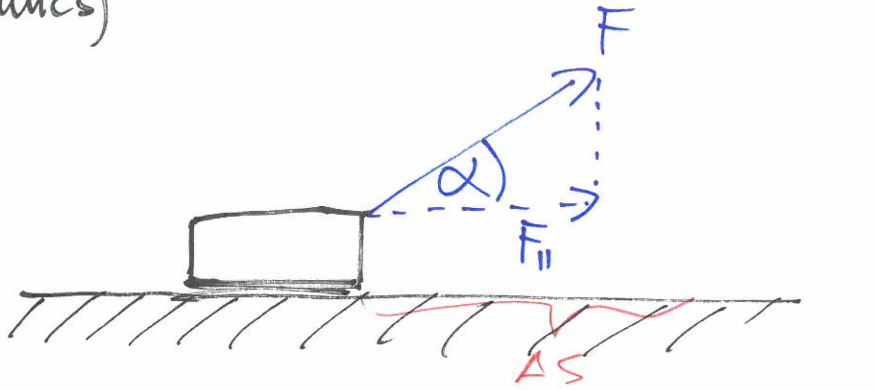
5. Energy & Work (mechanics)

work in mechanics:



$W = F_{\parallel} \cdot \Delta s$

$W = F \cdot \cos(\alpha) \cdot \Delta s$

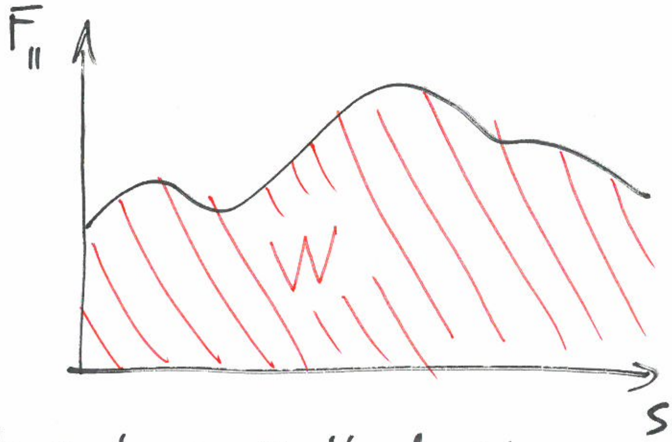
$\cos(\alpha) = \frac{F_{\parallel}}{F} \longrightarrow F_{\parallel} = F \cdot \cos(\alpha)$

$[W] = [F] \cdot [\Delta s] = N \cdot m = kg \, \frac{m}{s^2} \cdot m = kg \cdot \frac{m^2}{s^2} = kg \cdot m^2 \cdot s^{-2} = J$

joule

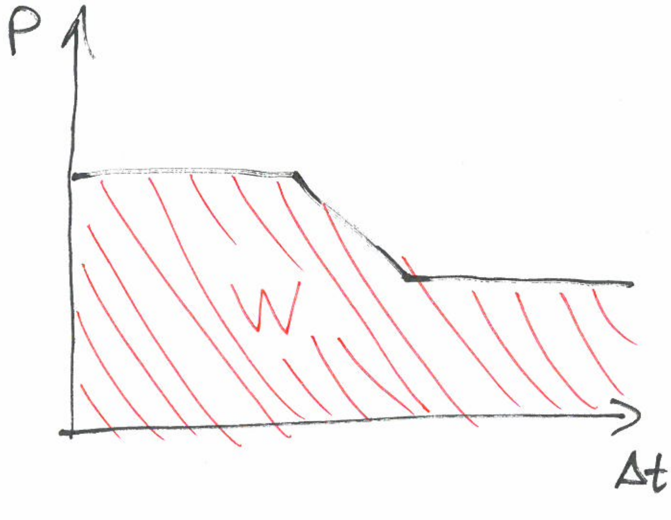
work = change or transfer of energy

$W = \Delta E$



power: work "rate": work done in a unit of time

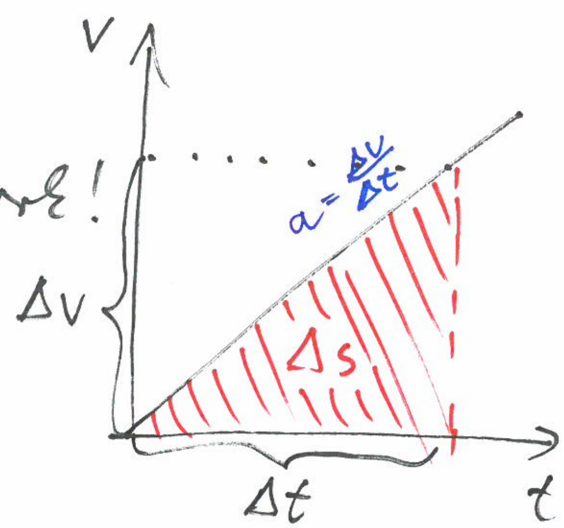
$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} \longrightarrow W = P \cdot \Delta t$



Kinetic energy: causes change in speed (= acceleration)

$$E_{kin} = \frac{m \cdot v^2}{2}$$

it is changed by acceleration work!



$$\Delta s = \frac{\Delta v \cdot \Delta t}{2}$$

$$W = F_{\parallel} \cdot \Delta s$$

$F_{\parallel} = m \cdot a$

$\frac{\Delta v}{\Delta t} = a$

$$W = m \cdot \frac{\Delta v}{\Delta t} \cdot \frac{\Delta v \cdot \Delta t}{2} = \frac{m \cdot \Delta v^2}{2}$$

$$E_{kin} = \frac{m \cdot v^2}{2}$$

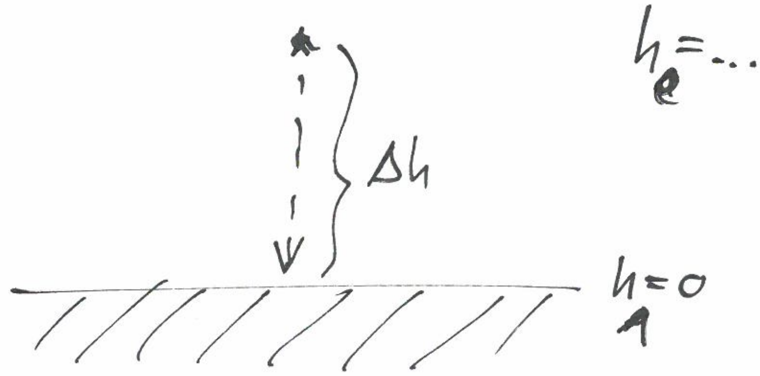
Potential (= "positional") energy in a gravitational field

$$E_{pot} = m \cdot g \cdot h$$

(ΔE)

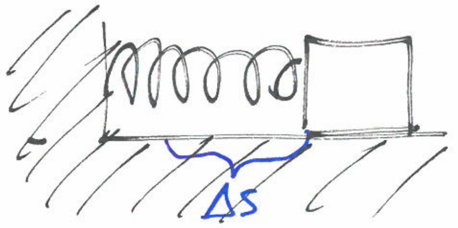
$$W = F_{\parallel} \cdot \Delta s = m \cdot g \cdot \Delta h$$

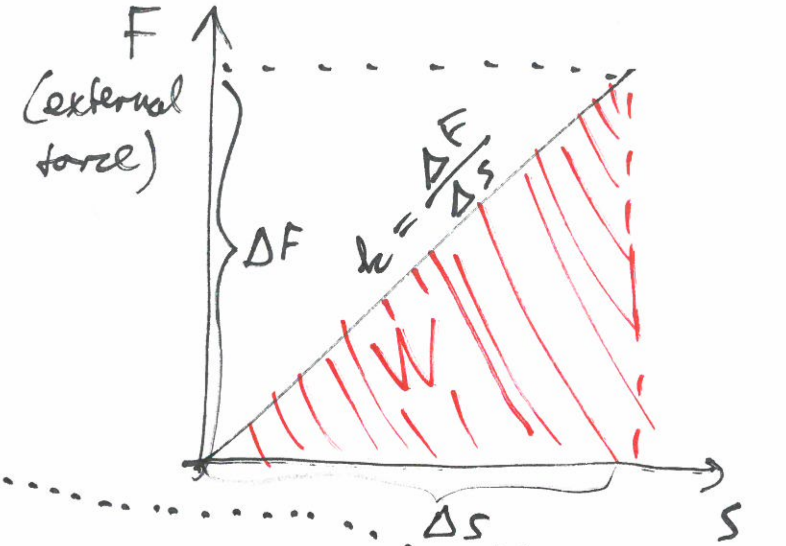
$F_{\parallel} = m \cdot g$, $\Delta s = \Delta h$



$$E_{pot} = m \cdot g \cdot h$$

Elastic (spring) energy $\quad E_{elastic} =$





Hooke's law: $F_{ex} = k \cdot \Delta s$

$$W_{elastic} = \frac{\Delta s \cdot \Delta F}{2}$$

$$W_{elastic} = \frac{\Delta s \cdot k \cdot \Delta s}{2} = \frac{k \cdot \Delta s^2}{2}$$

$$E_{elastic} = \frac{k \cdot s^2}{2}$$

Idealized mechanical system: with only mechanical interactions:

$$E_{mech} = E_{kin} + E_{pot} + E_{elastic} = \text{constant}$$

$$m(p^+) + m(n^0) > m(^2H)^+$$

$$E = mc^2 \quad \text{(Einstein)}$$

SI: joule

1 calorie = 4.18 J
cal

1 kcal = 4.18 kJ

1 eV (electronvolt) = 1.6×10^{-19} J

Homework: → BTU (British)
→ erg (CGS)

5/2 $m = 1.2\,t = 1200\,kg$

$\Delta t = 12\,s$

$v_0 = 0\,\frac{m}{s}$

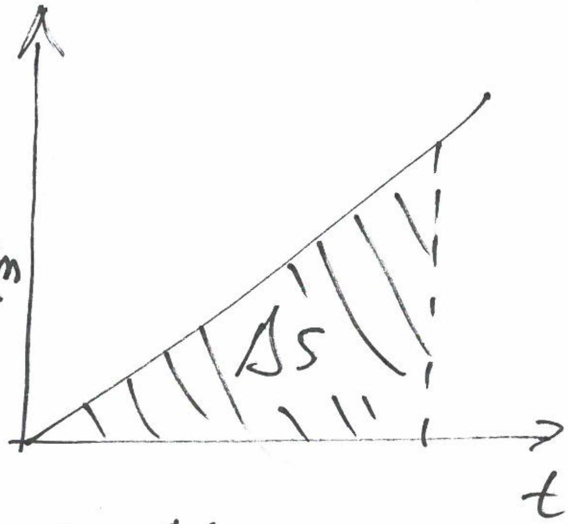
$v_1 = 100\,\frac{km}{h} = 27.78\,\frac{m}{s}$

a) $F = m \cdot a = m \cdot \frac{\Delta v}{\Delta t} = 1200\,kg \cdot \frac{27.78\,\frac{m}{s}}{12\,s} = 2778\,N$

$kg\,\frac{m}{s \cdot s} = N$

b) $\Delta s = ?$

$\Delta s = \frac{\Delta v \cdot \Delta t}{2} = \frac{27.78\,\frac{m}{s} \cdot 12\,s}{2} = 166.68\,m$



$\Delta s = \frac{\Delta v \cdot \Delta t}{2}$

c) $W = F_{\parallel} \cdot \Delta s = 2778\,N \cdot 166.68\,m = 463\,037\,J = 463\,kJ$

$Nm = J$

d) $P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \frac{463\,037\,J}{12\,s} = 38\,586\,\frac{J}{s} = 38.6\,kW$

~~Watt~~ work

$[P] = \frac{[W]}{[\Delta t]} = \frac{J}{s} = W$ ← Watt

e) $E_{kin} = W = 463\,kJ$

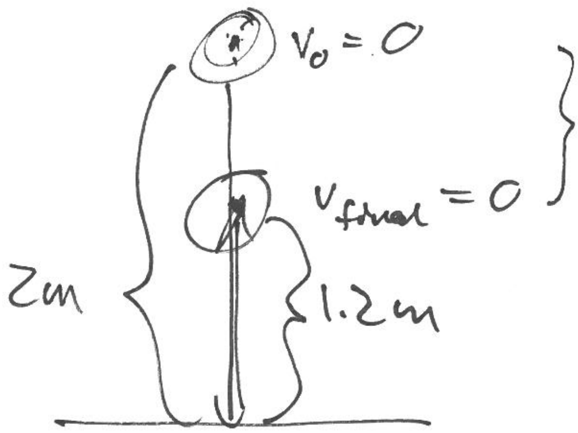
5/7 $k = 3 \times 10^5 \frac{N}{m}$

$\Delta s = 2\,mm = 2 \times 10^{-3}\,m$

$\frac{N}{m} \cdot m^2 = Nm = J$

$E_{elastic} = \frac{k \cdot s^2}{2} = ~~300~~\ 0.6\ J$

5/9 $m = 0.8\,kg$



} $\Delta h \Rightarrow$ friction, air drag...

energy loss $= \Delta E_{pot} =$

$= mg\Delta h = 0.8\,kg \cdot 9.81 \frac{m}{s^2} \cdot 0.8\,m =$

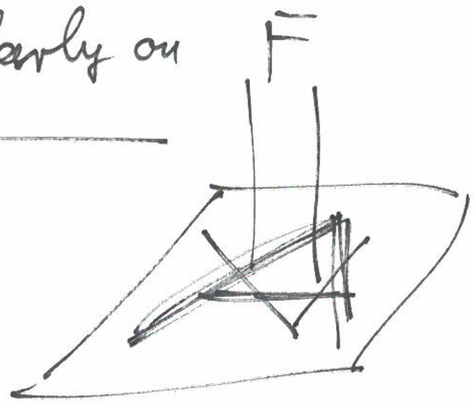
$= 6.2784\ kg\frac{m^2}{s^2}$

J

6. Pressure

pressure: the force acting perpendicularly on a given surface

surface



$$p = \frac{F_\perp}{A}$$

unit $[p] = \frac{[F]}{[A]} = \frac{N}{m^2} = \frac{kg\,\frac{m}{s^2}}{m^2} = \frac{kg}{m\,s^2} = Pa$ pascal

some non-SI units

atmosphere atm ⟶ 101 325 Pa

technical atmosphere at

bar Bar ⟶ 100 000 Pa

millimeters of mercury mmHg ⟶ ....

(microns of mercury micron)

centimeters of water cm H_2O ⟶ .... HW

pound force per inches squared PSI ⟶ US

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phases of matter

(plasma)

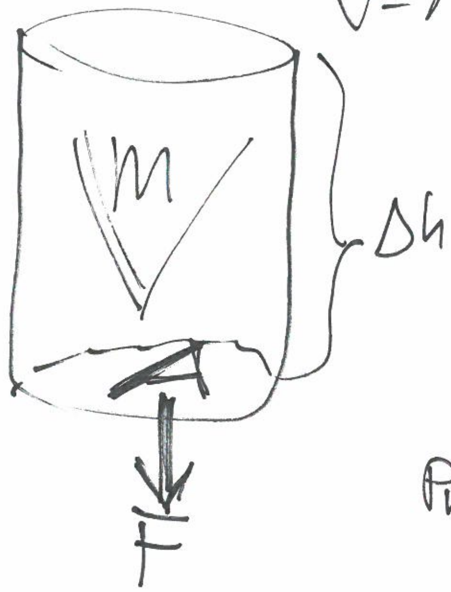
gas } fluids

liquid } fluids; liquid, solid } condensed matter

solid

hydrostatic pressure: pressure coming from the weight of a fluid

- liquids
- (gas complex) see: Biophys



$V = A \cdot \Delta h$

$F = m \cdot g$

desity $= \frac{\text{mass}}{\text{volume}}$

$m = \rho \cdot V$

$$p_{hydr} = \frac{F}{A} = \frac{\rho \cdot A \cdot \Delta h \cdot g}{A} = \rho \cdot \Delta h \cdot g$$

$$1\ \text{mmHg} = 13.6\ \frac{g}{cm^3} \times 1\ \text{mm} \times 9.81\ \frac{m}{s^2} =$$

$$= 13\,600\ \frac{kg}{m^3} \times 10^{-3}\ m \times 9.81\ \frac{m}{s^2} = \underline{133\ \text{Pa}}$$

$$1\ \text{atm} = 101\,325\ \text{Pa} = 760\ \text{mmHg}$$