OSNOVE FIZIKE IN BIOFIZIKE

Grade

6	60 -
7	
8	
9	
10	- 100

HW (MUST DO)
- Oral exam with assistant
- Every week

1.10.24

Port of Koper
- Monitoring of water and air pollution / quality

$\underbrace{\text{2 booies} \quad \text{3 stations}}_{\text{All in port Koper}}$

PM - particulate matter
PM10 → particles up to 10 μm big
PM2.5 → particles up tu 2.5 μm big

PROTEINS

Structures:
- Primary → chain of amino acids (AA)
- Secondary → α-helixs and β-planes
- Tereiar → 3D model, bonds and fields
- Quartar → function and conections of multiple chains

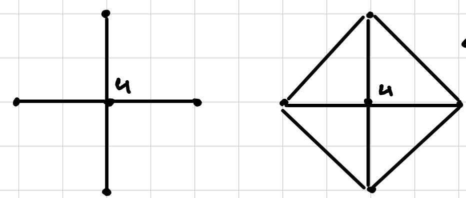
PDB - to store and analyse similarities and connections between proteins

Graphs (graph teory)
- 2D represetation of 3D structure

Quantitative analysis
- With protein distance matix

Graphlets
- Used to analyse huge molecules

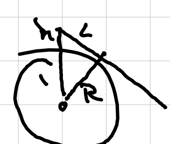
More stable



- Node we are looking at in graph is always the end node in graphlet

Estimation of body volume
- Using water density

Radius of EARTH



- Burj Khalifa : 800m
- Distance to horizon: 100km

$$R^2 + L^2 = (R+h)^2$$
$$R^2 + L^2 = R^2 + 2Rh + h^2$$
$$L^2 = 2Rh + h^2$$
$$\Downarrow$$
$$R = \frac{L^2}{2h} = \frac{100^2}{2 \cdot 0{,}8} = 6250\,km$$

Å ... 10^{-10}m ← unit for mesuring distance between atoms in molecule

8.10.24

MOTION IN ONE DIMENSION:
displacement, speed, velocity, acceleration

Kinematiks
- Describes quantitatively how a body moves through space

Mesurment motion
- To mesure motion we must first mesure position

One dimential motion
- Frame of reference is one line
- Distance - length of way from one to another position
- Displacement - difference in position

Average speed and average velocity
- Speed is scalar
- Velocity is vektor
- Average speed $= \frac{\text{distance}}{\text{time}}$
- Average velocity $= \frac{\text{displacement}}{\text{time}}$. It can be negative!

Instantaneous velocity

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} \rightarrow v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

- The limit of velocity funktion when $\Delta t \to 0$, a.k.a the derivative of the space relative to time

Acceleration
- Average acceleration $= \frac{\Delta v}{\Delta t} = a$
- Acceleration describes change of velocity

Instantaneous acceleration

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

- acceleration is the derivative of velocity relative to time

Units

- Displacement: meters (m)
- Velocity: meters per second ($\frac{m}{s}$)
- Acceleration: meters per second per second ($\frac{m}{s^2}$

Constant acceleration

$$\frac{dv}{dt} = a = const$$

- Constant acceleration means the rate of change of velocity is constant
- A solution to above equation is $v = v_0 + at \Leftarrow \int_{v_1}^{v_2} dv = \int_{t_1}^{t_2} a(t)\,dt$

Distance and constant Acceleration

- At constant acceleration, $\frac{dx}{dt} = v(t) = v_0 + at$

- The solution of the equation is $x(t) = x_0 + v_0 t + \frac{1}{2}at^2$

Constant acceleration formulas

$$v = v_0 + at$$

$$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

Exercises

1. $B = 2{,}4\,\mathrm{m s^{-2}}$, $C = 0{,}12\,\mathrm{m s^{-3}}$

$v = X(t) \Rightarrow v = 2Bt - 3Ct^2$

$v(0_s) = 2B(0_s) - 3C(0_s)^2 = 0$
$v(3_s) = 15$
$v(10) = 12$

$a = V(t) \Rightarrow a = 2b - 6Ct$

$v = 0\frac{m}{s}$

$2Bt - 3Ct^2 = 0$
$t(2B - 3Ct) = 0 \qquad t_1 = 0_s$
$2B - 3Ct_2 = 0$
$t_2 = \frac{2B}{3C} = 13{,}\dot{3}\,s$

2. $k = 5\,\mathrm{m s^{-\frac{3}{2}}}$
$v = k \cdot \sqrt{t}$

$a = v(t) = \frac{1k}{2\sqrt{t}}$

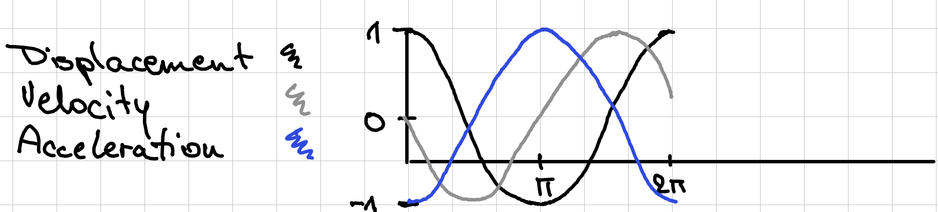
initial displacement

$x = x_0 + \int_{t_1}^{t_2} v(t)\,dt \qquad t_1 = 15_s,\ t_2 = 25_s \qquad x_0 = 0$

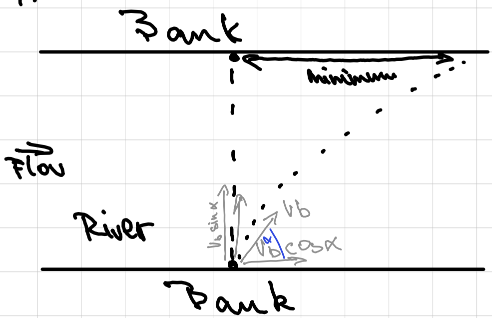
$= k\int_{t_1}^{t_2} \sqrt{t}\,dt = k\frac{2}{3}t^{\frac{3}{2}}\Big|_{15_s}^{25_s} = \frac{2}{3}k\left((25s)^{\frac{3}{2}} - (15s)^{\frac{3}{2}}\right) \doteq 223\,m$

3.

$x = A\cos(\omega t)$, A and ω are constants.



4.



$x: v_r, v_b \cos\alpha$

$y: v_b \sin\alpha$ $\qquad l = 1$

$l = v_b \sin\alpha \cdot t$

$x = (v_r + v_b \cos\alpha) \cdot t$

$t = \dfrac{l}{v_b \cdot \sin\alpha}$

$$x = (v_r + v_b \cos\alpha) \cdot \frac{l}{v_b \cdot \sin\alpha} = l\left(\frac{v_r}{v_b \sin\alpha} + \frac{\cos\alpha}{\sin\alpha}\right)$$

$$\left.x(\alpha) = \frac{\eta}{\sin\alpha} + \frac{\cos\alpha}{\sin\alpha}\right\}$$ usable in matlab for HW

$$x'(\alpha) = 0$$

$$x'(\alpha) = \eta \frac{\cos\alpha}{\sin^2\alpha}(-1) + \frac{-\sin\alpha}{\sin\alpha} + \frac{\cos\alpha \cdot \cos\alpha}{\sin^2\alpha} \cdot (-1)$$

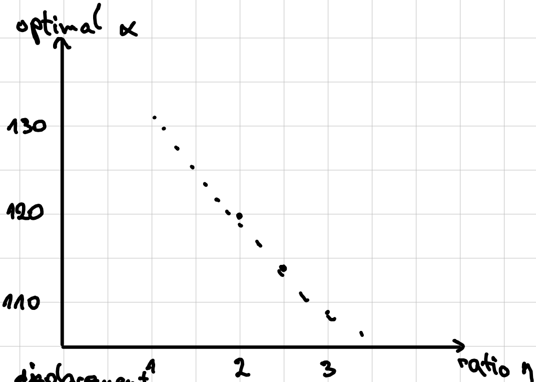
$$= \eta \frac{\cos\alpha}{\sin^2\alpha} \cdot (-1) + (-1) + \frac{\cos^2\alpha}{\sin^2\alpha} \cdot (-1)$$

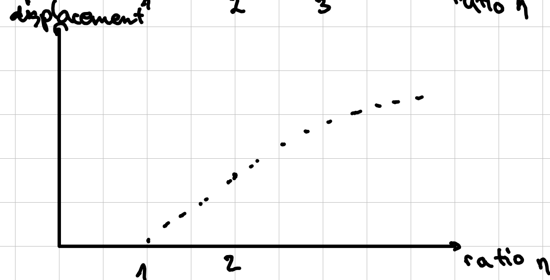
$$= -\eta \frac{\cos\alpha}{\sin^2\alpha} - 1 - \frac{\cos^2\alpha}{\sin^2\alpha} = 0$$

solution: $\cos\alpha = -\dfrac{1}{\eta}$

HW

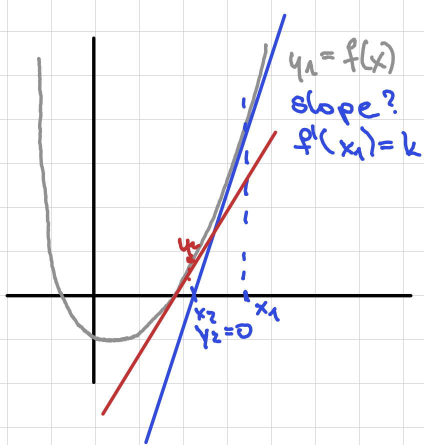
15.10.24





HW:
- Step by step script of Newtons method
- Script that writes what's on next pg.

Bisection - Newton's metho



$$y = kx + n$$
$$n = y - kx$$
$$n = y_1 - kx_1$$

$$y_2 = kx_2 + n$$

$$0 = kx_2 + n$$
$$x_2 = -\frac{n}{k}$$

Task

$f(x) = x^2 - 2$; $x_0 = 14$ $f(14) = 194 = y$

$f'(x) = 2x$

$k = f'(14) = 28$ $n = y - kx = 194 - 28 \cdot 14 = -198$

$y = 28x - 198$ $y = 0 \Rightarrow x_1 = \frac{198}{28} = 7.07$

$f(7,07) = 47,98 = y$

$k = f'(7.07) = 14.14$ $n = 47,98 - 14 \cdot 7.07 = -51$

$y = 14.14x - 51,8849$ $y = 0 \Rightarrow x_2 = 3,64$

$f(3,64) = 11,25 = y$

$k = f'(3.64) = 7.28$ $n = -15.25$

$x_3 = \frac{15.25}{7.28} = 2.09$

Newton's formula

$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

22.10.24

NEWTON LAWS

Newton's first law of motion
- Object countinues to move at constant velocity unless acted on by external forces
- Force: contact and non-contact
- Pushing force, friction force, gravitational force

Relating the change in velocity to force
- This can only be done experimentaly
- Care must be taken to make sure forces likefriction are minimal

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Force and acceleration
- Force accelerrate the object
- Double the force, double the acceleration
- Acceleration is proportionaly aded to force

Unit of force
- $kg \cdot \frac{m}{s^2} = N$ $\quad \Sigma \vec{F} = m \cdot \vec{a}$

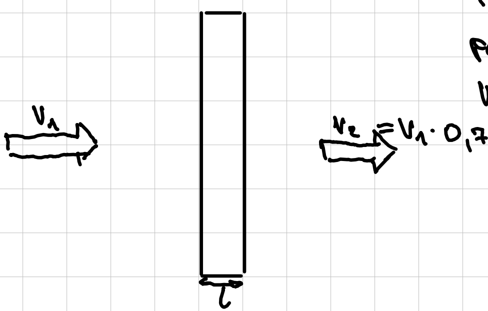
$$\vec{F} = \frac{d\overset{\text{momentum}}{\vec{p}}}{dt} = \underbrace{\frac{dm}{dt} \cdot \vec{v}}_{0 \text{ if } m = const} + m \cdot \frac{dv}{dt}$$

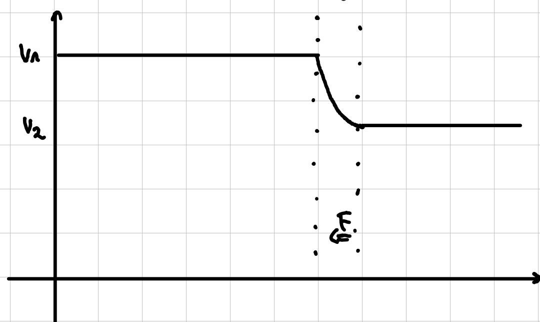
F means total force

Newton's 3rd law, action riaction

Applaying newton's laws

Projectal of mass m and velocity v_1 penetrates the board of thicknes l. velocity decreases by 30%.





$$F = k \cdot v^2$$

$$ma = -k v^2$$

$$\frac{dv}{v^2} = -\frac{k}{m} dt$$

$$\int_{v_1}^{v_2} \frac{dv}{v^2} = -\frac{k}{m} \int_0^t dt$$

$$-\frac{1}{v} \Big|_{v_1}^{v_2} = -\frac{k}{m} \cdot t$$

$$\frac{1}{v_1} - \frac{1}{v_2} = -\frac{k}{m} t$$

$$\frac{1}{v_1} - \frac{1}{v_2} = \frac{\ln \frac{v_2}{v_1}}{l} t$$

$$v = \frac{dx}{dt}$$

$$m \cdot \frac{dv}{dt} \cdot \frac{dx}{dx} = m \cdot v \cdot \frac{dv}{dx} \rightarrow a = \frac{dv}{dx}$$

$$m \cdot v \cdot \frac{dv}{dx} = -k v^2$$

$$m \cdot \frac{dv}{dx} = -k v$$

$$\frac{dv}{v} = -\frac{k}{m} dx$$

$$\int_{v_1}^{v_2} \frac{dv}{v} = -\frac{k}{m} \int_0^l dx \Rightarrow \ln \frac{v_2}{v_1} = -\frac{k}{m} l$$

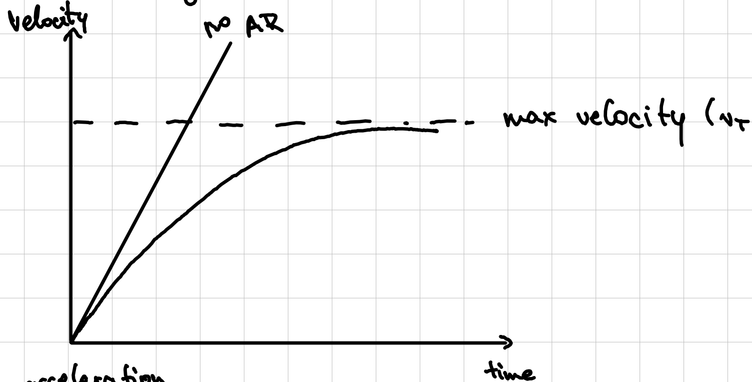
$$-\frac{k}{m} = \frac{\ln \frac{v_2}{v_1}}{l}$$

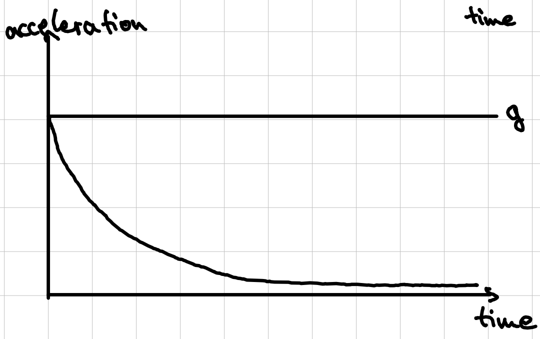
Free fall with air resistance

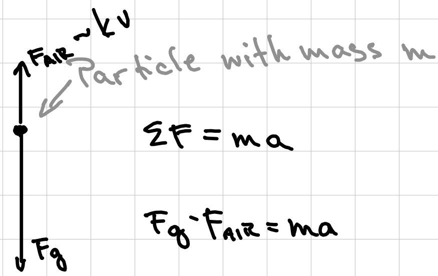
$$F_D = \frac{1}{2} \underbrace{cS\rho v^2}$$

c - drag
S - cross-section
ρ - density
v - velocity

- Air resistance is a force that affects objects moving through air.







$$\Sigma F = ma$$

$$F_g - F_{AIR} = ma$$

$$mg - kv = ma$$

v_T is when $a = 0$. $t \to \infty$

$$mg - kv_T = m \cdot 0$$

$$v_T = \frac{mg}{k}$$

$$mg - kv = m\frac{dv}{dt} \quad /:k$$

$$\frac{mg}{k} - v = \frac{m\,dv}{k\,dt}$$

$$v_T - v = \frac{m}{k}\cdot\frac{dv}{dt} \quad \Rightarrow \quad v - v_T = -\frac{m}{k}\cdot\frac{dv}{dt}$$

$$-\frac{k}{m}\,dt = \frac{dv}{v - v_T} \quad \Rightarrow \quad -\frac{k}{m}\int_0^t dt = \int_0^v \frac{dv}{v - v_T}$$

$$-\frac{k}{m}\,t = \ln(v - v_T)\Big|_0^v$$

$$= \ln(v - v_T) - \ln(0 - v_T)$$
$$= \ln\left(-\frac{v - v_T}{v_T}\right)$$
$$= \ln\left(\frac{v_T - v}{v_T}\right)$$

$$e^{-\frac{k}{m}\cdot t} = \frac{v_T - v}{v_T}$$

$$v = v_T\left(1 - e^{-\frac{k}{m}t}\right) \longrightarrow v = v_T - v_T e^{-\frac{k}{m}t}$$

$$a = \frac{dv}{dt} = -v_T\left(-\frac{k}{m}\right)e^{-\frac{k}{m}\cdot t}$$
$$= \frac{mg}{k}\cdot\frac{k}{m}\,e^{-\frac{k}{m}t}$$
$$= g\,e^{-\frac{k}{m}t}$$

$$v(t) = \frac{dy}{dt} \Rightarrow v_T\left(1 - e^{-\frac{k}{m}t}\right) = \frac{dy}{dt}$$

$$\int_0^y dy = \int_0^t v_T\left(1 - e^{-\frac{k}{m}t}\right) dt$$

$$y - 0 = \int_0^t v_T\, dt - v_T \int_0^t e^{-\frac{k}{m}t}\, dt = v_T \cdot t - v_T\left(-\frac{m}{k}\right) e^{-\frac{k}{m}t}\Big|_0^t$$

$$= v_T \cdot t + v_T \frac{m}{k} e^{-\frac{k}{m}t} - v_T \frac{m}{k}$$

$$= v_T\left(t + \frac{m}{k}\left(e^{-\frac{k}{m}t} - 1\right)\right)$$

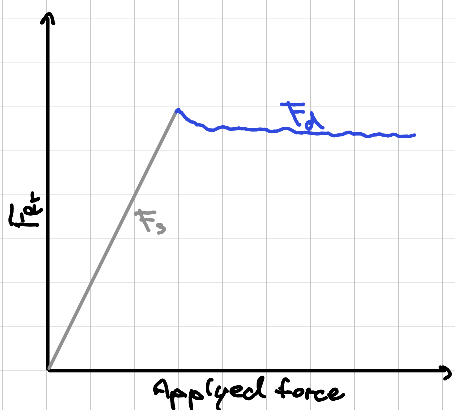
HW

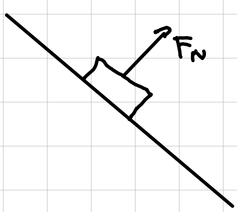
dsolve

29.10.24

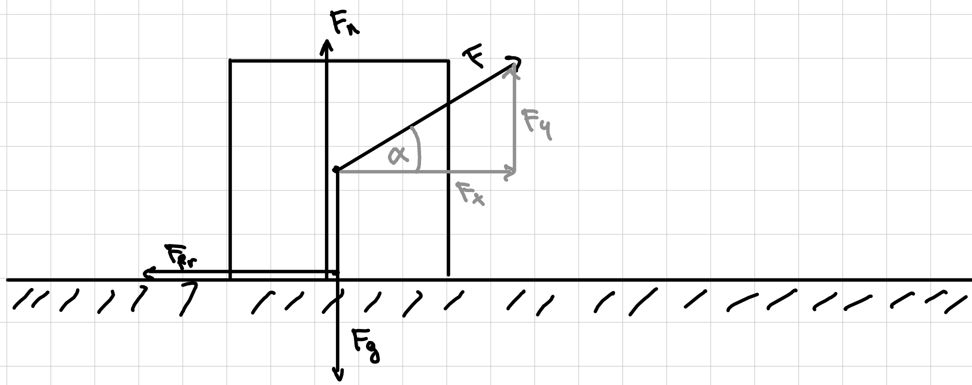
Dynamic and static friction

- Dynamic - when the object slides (Velocity is not zero)
- Static - when the object doesn't slide (Velocity is zero)
- Dynamic fri. force formula: $F_{fr} = k_d F_N$
- Static fri. force formula: $F_{fr} = k_s F_N$





Calculating opt. angle to pull object



$\Sigma F_x = 0$ $\quad$ $x: F_x - F_{fr} = 0$

$\Sigma F_y = 0$ $\quad$ $y: F_N + F_y - F_g = 0$

$v = const$

$F_N = F_g - F_y$ $\qquad$ $F_{fr} = F_x$

$$F_{fr} = F_N \cdot k = (F_g - F_y) \cdot k$$

$$\Downarrow$$

$$F_x = (F_g - F_y) \cdot k$$

$$F_x = F_g k - F_y k$$

$$\Downarrow$$

$$F \cos\alpha = F_g k - F \sin\alpha \cdot k$$

$$F \cos\alpha + F \sin\alpha \cdot k = F_g k$$

$$F = \frac{F_g k}{\cos\alpha + k \cdot \sin\alpha} \Rightarrow F(\alpha) \Rightarrow F'(\alpha) = 0 \,?$$

$$F'(\alpha) = -\frac{F_g k(-\sin\alpha + k\cos\alpha)}{(\cos\alpha + k \cdot \sin\alpha)^2} = 0$$

$$-\sin\alpha + k \cdot \cos\alpha = 0$$

$$\sin\alpha = k\cos\alpha$$

$$k = \frac{\sin\alpha}{\cos\alpha} = \tan(\alpha) \qquad \alpha_{opt} = \arctan(k)$$

$k = 0{,}1 \Rightarrow 5{,}7°$

$k = 0{,}2 \Rightarrow 11{,}3°$

$k = 0{,}3 \Rightarrow 16{,}7°$

Work is only done by a force
- The force has to move something!
- Definition: if I push with 1N through 1m, I do 1 Joul of work

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Potencial energy
- Stored work is $W_p \Rightarrow \Delta W_p = mg\Delta h = mg(h_2 - h_1)$

Kinetic energy

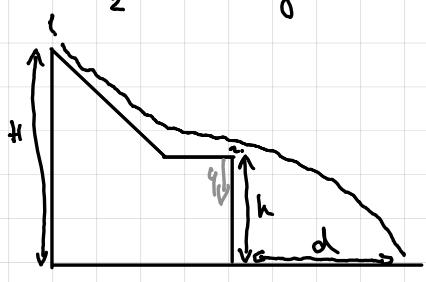
$$F\,dx = m \cdot a \cdot dx = m\frac{dv}{dt}dx = mv\,dv$$

Total work:

$$\int_{v_1}^{v_2} mv\,dv = \frac{1}{2}mv^2\Big|_{v_1}^{v_2} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

Conservation of mechanical energy

$$\frac{1}{2}mv^2 + mgh = \text{const}$$



$$y = y_0 + \overset{0}{v_{0y}}\,t + \frac{\overset{(-g)}{a_y}\,t^2}{2}$$

$$y = \frac{gt^2}{2} = h$$

$$\underbrace{\frac{1}{2}mv_1^2}_{} + mgH = \frac{1}{2}mv_2^2 + mgh \qquad t = \sqrt{\frac{2h}{g}} \qquad d = v_2 \cdot t$$

$$mgH = \frac{1}{2}mv_2^2 + mgh \qquad d = \sqrt{2g(H-h)} \cdot \sqrt{\frac{2h}{g}}$$

$$v_2 = \sqrt{2g(H-h)} \qquad d(h) = 2\sqrt{(H-h)h}$$

$$d'(h) = \frac{1}{2} \cdot \frac{2(H-2h)}{\sqrt{(H-h)h}} = 0 \Rightarrow H - 2h = 0 \Rightarrow h = \frac{H}{2}$$

$$F = -\frac{m_E m}{r^2} G$$

$$\text{work} = \int F\,dr$$

$$\text{work} = -m_E m G \int_{r_1}^{r_2} \frac{1}{r^2} = (-m_E m G)\left(-\frac{1}{r}\right)\Big|_{r_1}^{r_2}$$

$$= m_E m G\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

gravitational potential energy

$U = -\frac{G m_E m}{r}$ → works even far away fromearth

HW5

Read data from file
calculate with raw data
build fun to smooth the data

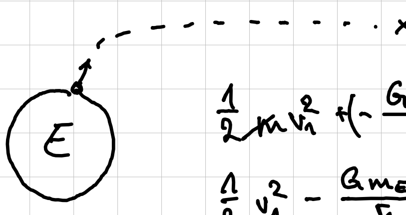
5.11.24

$$\Delta U = mg(r_2 - r_1)$$

g

$$\frac{G m m_E}{r_1} - \frac{G m m_E}{r_2} = \frac{(r_2 - r_1)\, m\, G m_E}{r_1 \cdot r_2} = mg(r_2 - r_1)$$

$$K_1 + U_1 = K_2 + U_2$$



$U_2 \approx 0$
$K_2 \approx 0$ $\Rightarrow v_2 = 0$

$$\frac{1}{2}\cancel{m} v_1^2 + \left(-\frac{G\cancel{m} m_E}{r_1}\right) = \overbrace{\frac{1}{2} m v_2^2}^{=0} + \overbrace{\left(-\frac{G m m_E}{\underbrace{r_2}_{=\infty}}\right)}^{=0}$$

$$\frac{1}{2} v_1^2 - \frac{G m_E}{r_1} = 0 \Rightarrow v_1 = \sqrt{\frac{2 G m_E}{r_1}}$$

$$v_1 = \sqrt{\frac{2 \cdot 6{,}6742 \cdot 10^{-11} \cdot 5.8 \cdot 10^{24}\ \text{Nm}}{6300 \cdot 10^3}} \approx 1.1 \cdot 10^4$$
$$= 1.12 \cdot 10^4$$

$t = 1\,day = 24\,h = 3600\,s \cdot 24$

$s = 2\pi R_E \cdot \cos\alpha$

$$v = \frac{2\pi R_E \cdot \cos\alpha}{t}$$

$$v_{FL} = \frac{2\pi R_E \cos 28^\circ}{24 \cdot 3600\,s} = 403\,\frac{m}{s}$$

$$v_{FQ} = \frac{2\pi R_E \cos 6^\circ}{24 \cdot 3600\,s} = 450\,\frac{m}{s}$$

GASES AND LIQUIDS

Boyle's law

Constant temperature. If the presure increases, then the volume decreases. They discovered that the produkt of presure and volume is a constant.

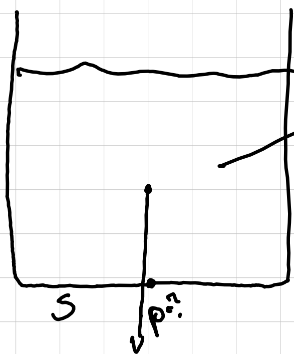
Presure

- $p = \frac{F}{S}\ [\frac{N}{m^2}]\ Pa \quad (10^5\,Pa = 1\,bar)$
- 1013 mbar (at sea level)

Constant presure: there is a linear relation between volume and temperature

Formula (ideal gas law)

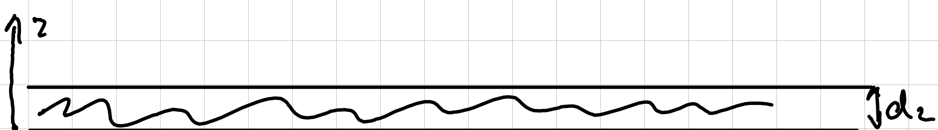
$pV = nRT$, $R = 8.314\,J\,mol^{-1}\,K^{-1}$



$V = S\cdot h$ $\qquad \rho = \frac{m}{V} \rightarrow m = \rho\cdot V$

$$p = \frac{F_g}{S} = \frac{mg}{S} = \frac{\rho\cdot V\cdot g}{S} = \frac{\rho\cdot S\cdot h\cdot g}{S} = \rho h g$$

$$pV = nRT$$
$$pV = \frac{m}{M}RT$$
$$\frac{pM}{RT} = \frac{m}{V} = \rho \qquad \rho = \frac{pM}{RT}$$



$$dp = -\rho g\, dz$$
$$dp = -\frac{pMg}{RT}\, dz$$
$$\int_{p_0}^{p}\frac{dp}{p} = -\frac{Mg}{RT}\int_{0m}^{h} dz \quad \Big\}\ p \text{ at sea level}$$
$$\ln\Big|_{p_0}^{p} = -\frac{Mg}{RT}\, z\Big|_0^h$$
$$\ln\frac{p}{p_0} = -\frac{Mg}{RT}h \Rightarrow p = p_0 e^{-\frac{Mgh}{RT}}$$

$$\rho_{air} = \frac{p\,M}{RT}$$

$$M_{air} = 0.8\,M_{N_2} + 0.2\,M_{O_2}$$

$M_{N_2} \nearrow 28\,\frac{g}{mol}$, $M_{O_2} \nearrow 32\,\frac{g}{mol}$

Humidity

- Concentration of water vapor in air
- Relative (%) and absolute ($g\,m^{-3}$)

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Kinetic theory of gases 12.11.24

- Gas pressure is caused by force exerted by gas molecules

Momentum

- $F = ma \rightarrow$ 2. Newton's law

$$= (m\cdot v)' = m'v + mv' = 0 + m\cdot a = m\cdot a$$

- $p = m\cdot v \rightarrow \frac{dp}{dt} = m\cdot \underbrace{\frac{dv}{dt}}_{=a} = F \Rightarrow \frac{dp}{dt} = F \Rightarrow dp = F\,dt \Rightarrow \Delta p = F\Delta t$

($(m\cdot v) = p$)

Elastic collisions

- Where there is no net loss of kinetic energy

$\Delta p = 0$ if $\Sigma F_{EXT} = 0$

before collision after collision

$$m_1\cdot v_1 + m_2 v_2 = m_1\cdot v_1' + m_2 v_2'$$

$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2$$

Gas in 1D

$$\Delta p = 2mv \qquad s = 2l \qquad t = \frac{2l}{v}$$

path from start to finish

$$F = \frac{\Delta p}{\Delta t} = \frac{2mv}{\frac{2l}{v}} = \frac{mv^2}{l}$$

$$F_N = \frac{mv_1^2}{l} + \frac{mv_2^2}{l} + \ldots + \frac{mv_N^2}{l}$$

Gas in 3D

$$F_x = \frac{m v_x^2}{L} \quad F_y = \frac{m v_y^2}{L} \quad F_z = \frac{m v_z^2}{L}$$

$$F_{Nx} = \frac{m v_{x_1}^2}{L} + \ldots + \frac{m v_{x_N}^2}{L} \rightarrow \text{similar for } F_{Ny} \text{ and } F_{Nz}$$

$$\bar{v}_x^2 = \frac{v_{x_1}^2 + \ldots + v_{x_N}^2}{N} \Rightarrow N\bar{v}_x^2 = v_{x_1}^2 + \ldots + v_{x_N}^2$$

$$\Rightarrow F_x = \frac{m}{L} N \bar{v}_x^2$$

$$\bar{v}^2 = \bar{v}_x^2 + \bar{v}_y^2 + \bar{v}_z^2 \Rightarrow \bar{v}_x^2 = \bar{v}_y^2 = \bar{v}_z^2 \Rightarrow \bar{v}_x^2 = \frac{1}{3}\bar{v}^2$$

$$F_x = \frac{m}{L} N \bar{v}^2 \frac{1}{3}$$

$$\Downarrow$$

$$F_x = \frac{N m \bar{v}^2}{3L} \Big/ : L^2$$

$$\text{Pressure} \Rightarrow p = \frac{F}{S} = \frac{F}{L}$$

$$\frac{F}{L^2} = \frac{N m \bar{v}^2}{3 L^3} \Rightarrow p = \frac{N m \bar{v}^2}{3V}$$

$$pV = \frac{N m \bar{v}^2}{3} \wedge pV = nRT \Rightarrow nRT = \frac{N m \bar{v}^2}{3}$$

$$W_k = \frac{1}{2} m v^2$$

$$pV = \frac{2N(\frac{1}{2} m \bar{v}^2)}{3} = \frac{2 \boxed{\frac{1}{2} N m \bar{v}^2}}{3}$$

K.E. of gas

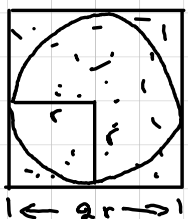
$$\frac{R}{N_A} = k \Rightarrow \text{Boltzman const}$$

$$nRT = \frac{2N\frac{1}{2} m \bar{v}^2}{3} \Rightarrow \frac{N}{N_A} RT = \frac{2N\frac{1}{2} m \bar{v}^2}{3} \Rightarrow \frac{RT}{N_A} = \frac{2\frac{1}{2} m \bar{v}^2}{3}$$

$$\Rightarrow \frac{3}{2} kT = \frac{1}{2} m \bar{v}^2 \Rightarrow T \sim \text{K.E. of gas}$$

$$pV = \frac{1}{3} m_{tot} \bar{v}^2 \Rightarrow p = \frac{1 m_{tot} \bar{v}^2}{3V} = \frac{\rho \bar{v}^2}{3}$$

HW (calculate π)



$$\left.\begin{array}{l} S_{\circ} = \pi r^2 \\ S_{\square} = (2r)^2 \end{array}\right\} \frac{S_{\circ}}{S_{\square}} = \frac{\pi r^2}{4r^2} = \frac{\pi}{4} \Rightarrow \pi = 4\frac{S_{\circ}}{S_{\square}}$$

$$\pi = 4\frac{N_{IN}}{N_{TOT}}$$

Plot line: yline(pi,...)

19.11.24

Difusion
- Mixing of two or more gases

Motion of molecules
- In air about $500\frac{m}{s}$
- They move in a zigzag because they bounce of each other
- Volume per 1 molekule in air $= 1000d^3$; d = diam. of molecule

  $V = S \cdot h = \pi d^2 \cdot l \Rightarrow \pi d^2 \cdot l = 1000d \Rightarrow l = \frac{1000d}{\pi} \approx 300d$

  l = avg. distance between 2 collisions

Random walk
- Movement of a molekule
- Steps are different lenght and in different directions

  1D ⇒ start to finish

  $(x_1 + x_2 + x_3)^2 = x_1^2 + x_2^2 + x_3^2 + \overbrace{2x_1x_2 + 2x_1x_3 + 2x_2x_3}^{\sim 0}$

  $r^2 = 1^2 + 1^2 + 1^2 = 3\} N$

  $r = \sqrt{N}$ $(r_{10} = \sqrt{10})$

Fick law

$\frac{\Delta c}{\Delta x}$ ... gradient $\quad J_x = -D\frac{\Delta c}{\Delta x} \Rightarrow J = -D\nabla \rho$

J ... diffusion flux, D ... diffusion const, ρ ... amount of substance per unit volume

The gradient of a scalar field is a vector field that points

Diffusion and Random walk

- If l known

$$r = \sqrt{(l_1, l_2, \dots, l_N)} = \sqrt{N}\, l$$

$$v \cdot t = N l \Rightarrow N = \frac{v \cdot t}{l} \Rightarrow r = \sqrt{\frac{v \cdot t}{l}}\, l = \sqrt{\underbrace{v \cdot l}_{\text{diffusional constant}} \cdot t}$$

Example 1: What's the deffusion distance of O_2 molecule in classroom?

time = 1h $\quad v = 500\,\frac{m}{s} \quad l = 300d = 300 \cdot 2\,\text{Å}$

$$r = \sqrt{500\,\frac{m}{s} \cdot 300 \cdot 2 \cdot 10^{-10}\,m \cdot 3600s} = \sqrt{0{,}108} \doteq 0{,}3$$

Diffusion constant: temperature, viscosity, size of molekules

$$D = \frac{kT}{6\pi\eta r} \quad \eta \text{ ... viscosity}$$

26.11.24

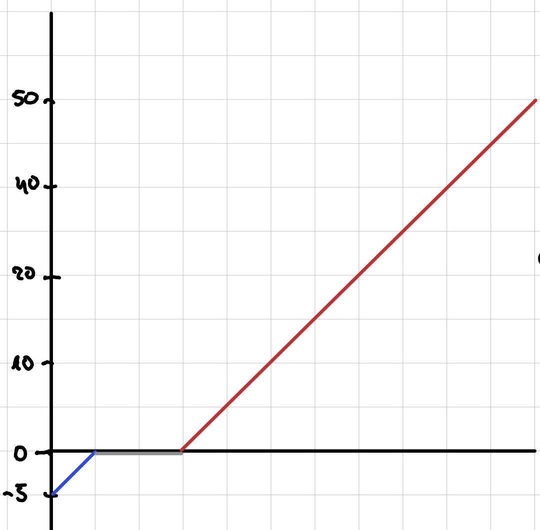
Heat ($T_H \Rightarrow T_{Low}$) [J] (older unit: calorie)
- Regarded as a form of energy
- 1 calorie of energy is requered to heat 1g of water by 1°C

Specific and latent heat
- Specific heat: amount of heat necessary to change the T of 1kg of mass by 1K

*

Exercise

a)



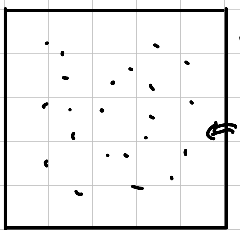
$Q_1 = m \cdot c_{ice} \cdot \Delta T$
$= 0{,}5\cancel{kg} \cdot 2000 J \cancel{kg^{-1}} \cancel{K^{-1}} \cdot 5\cancel{K}$
$= 5000 J$

$Q_2 = m \cdot 334 \cdot 10^3 J kg^{-1}$
$= 0{,}5 kg \cdot 334 \cdot 10^3 J \cancel{kg^{-1}}$
$= 167 \cdot 10^3 J = 167 kJ$

$Q_3 = m \cdot c_w \cdot \Delta T =$
$= 0{,}5\cancel{kg} \cdot 4200 J \cancel{kg^{-1}} \cancel{K^{-1}} \, 50\cancel{K}$
$= 105 kJ$

Total heat $\Phi = \frac{Q}{t}$ $\quad t = \frac{277\cdot 10^3 J}{800 \frac{J}{min}} = 346 \, min \doteq 6h$

b)



$m_{STEAM} = 0{,}04 kg$ $(T = 100°C)$

$m_L = 0{,}2 kg$ $(T = 50°C)$

If all vapor liquifies:

$Q = 0{,}04 \cancel{kg} \cdot 2{,}2\cdot 10^6 J \cancel{kg^{-1}} = 88000 J$

If all liquid vaporises:

$Q = 0{,}2 kg \cdot 4200 J kg^{-1} 50 K = 42000 J$

$\Big\}$ Not all steam liquifies

$42\cdot 10^3 J = m_x \cdot 2.2\cdot 10^6 J kg^{-1}$

$42 = m_x \cdot 2.2 \cdot 10^3 kg^{-1}$

$m_x = \frac{42 kg}{2.2\cdot 10^3} = 0{,}019 kg$

$m_{STEAM} = 0{,}04 kg - 0{,}019 kg = 0{,}021 kg$

$m_{WATER} = 0{,}2 kg + 0{,}019 kg = 0.219 kg$

$T_{FINAL} = 100°C$

c) $m = 70 kg$

$Q = m \cdot 3500 J kg^{-1} K^{-1} \cdot 1K$ $\qquad$ Sweat $(H_2O) \Rightarrow$ Evaporates $\Rightarrow L \rightarrow Q$

$Q = 70 \cancel{kg} \cdot 3500 J \cancel{kg^{-1}} \cancel{K^{-1}} \cdot \cancel{1K} = 245 kJ = m_x \cdot 2400 kJ kg^{-1}$

$m_x = \frac{245 \cancel{kJ} kg}{2400 \cancel{kJ}} = 0{,}1 kg$

Scaling

- Kube

$m_1 \to m_2 = \frac{m_1}{2} \Rightarrow V_2 = \frac{V_1}{2} = \frac{a^3}{2} = x^3$

$S_2 = ?$ $x = \frac{a}{\sqrt[3]{2}}$ $S_2 = 6 \cdot x = 6 \cdot \frac{a^2}{\sqrt[3]{2^2}}$

$\frac{S_1}{S_2} = \frac{\cancel{6}\, a^2}{\cancel{6} \cdot \frac{\cancel{a^2}}{\sqrt[3]{2^2}}} = \sqrt[3]{2^2} = 1.6 \Rightarrow t = \frac{60}{2} \cdot 1.6$

3.12.24

$\rho = 1000 \frac{kg}{m^3}$ $S_1 = 1\ cm^2$

$p_1 \neq p_2$
$a_1 < a_2$
$\Downarrow$
$p_1 < p_2$

$\Leftarrow \begin{cases} p_1 = \frac{F_1}{S_1} = \frac{F_{g1}}{S_1} = \frac{m_1 \cdot g}{S_1} \\ = \frac{V_1 \cdot \rho \cdot g}{S_1} = \frac{a_1^3 \rho g}{a_1^2} = a_1 \rho g \\ p_2 = a_2 \rho g \end{cases}$

$a_1 \cdot 2 = a_2 \Rightarrow 2 p_1 = p_2$ $a_2 = 2 a_1 \cdot \sqrt{2}$

$a = g$ (const. if no air drag)

$a = 0$ $\quad \Sigma F = F_g - F_{AIR}$
$\Sigma F = 0$ $\quad t \to \infty,\ a = 0$

S, ρ_{AIR}, shape (c)

$mg - kv = 0$

$mg - S \rho c \cdot v = 0$

$\Downarrow$

$mg - S \rho c \cdot v_T = 0$

$v_T = \frac{mg}{S \rho_{Air} c} = \frac{\rho_m a^3 g}{a^2 \rho_{Air} c}$

size = a $\Rightarrow v \sim a$

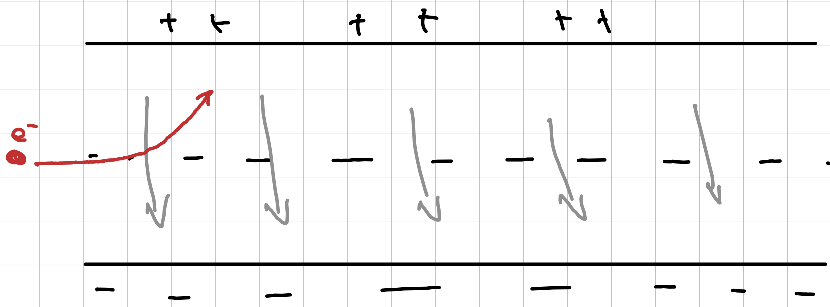
Electric charge

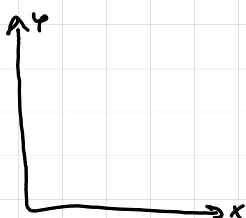
- Charge is quantized (it's an integer) $\cdot 1{,}602 \cdot 10^{-19}$ C

Electric field $E = \frac{e}{4 \pi \varepsilon_0 r^2}$

Electric force

- El. field is defined as el. force per unit charge
  $F = e \cdot E_{EXT}$ (Force = charge · Field(external))





$x: a_x = 0 \qquad x = v_x \cdot t \Rightarrow t = \frac{x}{v_x}$

$v_x = const$

$y: a_y \neq 0, \; a_y = \frac{eE}{m} \qquad y = \frac{a_y t^2}{2}$

$= \frac{eE t^2}{2m}$

$= \frac{eE x^2}{2m v_x^2}$

Electrostatic potencial

$$\int_{r_1}^{r_2} e_1 \frac{e_2}{4\pi\varepsilon_0 r^2} dr = \frac{e_1 e_2}{4\pi\varepsilon_0} \int_{r_1}^{r_2} \frac{1}{r^2} dr = \frac{e_1 e_2}{4\pi\varepsilon_0} \left(-\frac{1}{r}\right)\Big|_{r_1}^{r_2}$$

Magnetic field

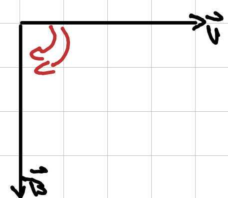
10.12.24

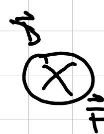
- All moving charged particles produce magnetic field
- Magnetic field is „similar" to electric field
- Electric current is inside copper wire and magnetic field is around it

$\vec{F} = e\vec{E}_{EXT}$ → Elect. static force

$\vec{F}_B \Rightarrow (v, B_{EXT}, e)$ → Magnetic force

$F_B = e\vec{v} \times \vec{B}$ $\quad\vec{B}$ ... magnetic field [T]

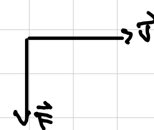




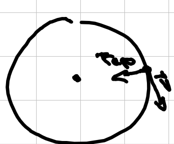
$F = m \cdot a$

$\alpha = 90°$

$\vec{F} \perp \vec{v}$



Uniform circular motion

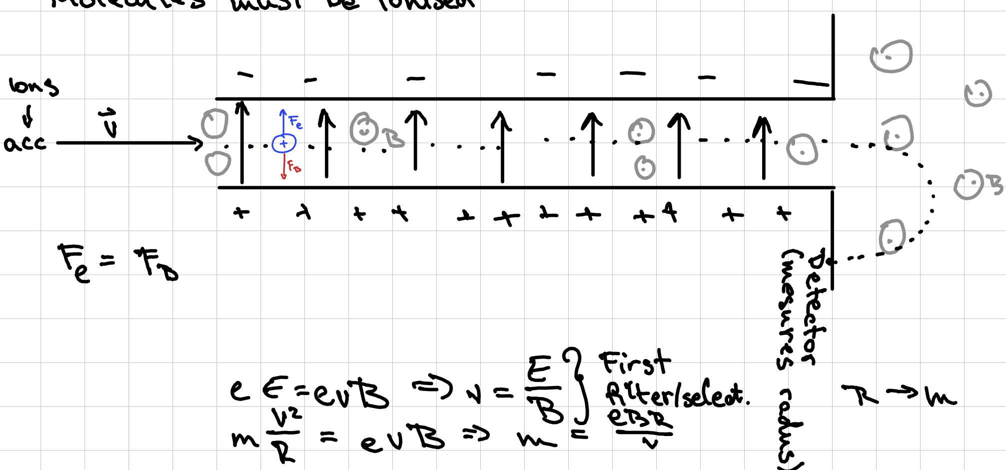


centipental force:

$F_{cp} = ma = m\frac{v^2}{R}$

Mass spectrometer

- Molecules must be ionised



$F_e = F_B$

$eE = evB \Rightarrow v = \frac{E}{B}$ } First filter/select.

$m\frac{v^2}{R} = evB \Rightarrow m = \frac{eBR}{v}$

$R \rightarrow m$

Example

$E = 1.12 \cdot 10^5 \, V m^{-1}$
$B = 0{,}540 \, T$
$R = 31 \, cm$
Charge = positive ⊕ (+1)

$$m = \frac{eBR}{v} = \frac{eB^2R}{E}$$

$$m = \frac{1.6 \cdot 10^{-19} C \cdot 0.31 m \cdot (0.540 T)^2}{1.12 \cdot 10^5 \frac{V}{m}}$$

$$m = 0.129 \cdot 10^{-24}$$

atomic mas = 77.71

Example

$E = 1.88 \cdot 10^4 \, V/m$
$B = 0.701 \, T$
$m_{82} = 82 \cdot 1.66 \cdot 10^{-27} \rightarrow R_1 = \frac{mv}{eB} = \frac{mE}{eB^2} = 0.0325$
$m_{84} = 84 \cdot 1.66 \cdot 10^{-27} \rightarrow R_2 = 0.0333$
$m_{86} = 86 \cdot 1.66 \cdot 10^{-27} \rightarrow R_3 = 0.0341$

Stefan-Boltzmann law

$j = \sigma T^4$: j = power density $\quad j = \frac{P}{S} = \left[\frac{W}{m^2}\right]$

$S_E j = S_S j \rightarrow 4\pi (150 \cdot 10^9 m)^2 \cdot 1400 \frac{W}{m^2} = 4\pi (7 \cdot 10^8 m)^2 \sigma T^4$

$\sigma = 5.67 \cdot 10^{-8} \frac{W}{m^2 K^4} \qquad T = 5800 \, K$

Proteins

17.12.24

- Made from amino acids
- Primary struct: chain of AA (1 or 3 letter codes)
- Secundary struct: α-helixs, β-sheets
  - β-sheets: paralel and anti-paralel
- (Terciarna) struct: 3D struct. of AA chain
- (Kvartarna) struct: 3D struct. of protein (multiple chains of AA)
- N-terminal: Where the AA chain starts
- AA connected with peptide bonds

Amino acids

- Hydrofilic, Hydrofobic
- Proline AA special

Cristallization

- Purification before cristallization
- Small cristals stable at low temps.
- Bragg's law