$v = 2\,000\,000 \frac{m}{s}$

$r = 0{,}25\,m$

$v_\perp = 600\,000 \frac{m}{s}$

$B = ?$

$\sqrt{v^2 - v_\perp^2} = v_\parallel = 1{,}907878403 \cdot 10^6 \frac{m}{s}$

$F_L = F_{zp}$

$F_L = p\,|\vec{v}_\parallel| \cdot |\vec{B}| \cdot \cancel{\sin \gamma}$

$F_{zp} = \frac{v_\parallel^2}{r} m$

$|\vec{B}| = \frac{v_\parallel^{\cancel{2}} \cdot m}{r \cdot \cancel{v_\parallel} \cdot p} = \frac{v_\parallel \cdot m}{r \cdot p} = 7{,}967937489 \cdot 10^{-2}\,T$

p: $+1{,}602 \cdot 10^{-19}\,C = e$

$|\vec{B}| = \sim 8{,}0\,T \Rightarrow \vec{B} = 8{,}0\,T$

Haus aufg.:

Molekül	„Art" Molekül	Anz. Freiheitsgrade (f)	$\frac{f}{2}R$ $[\frac{J}{mol \cdot K}]$	C_v (DMK/DPK)
He	einatomig	3	12,47	12,82
N_2	(linear) zweiatomig	5	20,79	20,77
CO_2	mehratomig	6	24,94	28,46
~~NO_2~~ Methan	mehratomig	6	24,94	27,22
NH_3	mehratomig	6	24,94	28,2

Methan?

$\cancel{\frac{C_p}{C_v} = \frac{\frac{f}{2}+1}{\frac{f}{2}}}$

$$pV^3 - nb_pV^2 + n^2aV - nbn^2a = nRTV^2$$

$$V(pV^2 - nb_pV + n^2a) = nRTV^2 - n^3ba$$

$$\cancel{\frac{nb_p \pm \sqrt{n^2b_p^2 - 4p \cdot n^2a}}{2n^2a}}$$

$a\ (L^2\,atm/mol^2)$ $\quad$ $b\ (L/mol)$

$$p = \frac{RT}{V_m - b} - \frac{a}{V_m^2} \qquad V_m = \frac{V}{n}$$

kritisches molvolumen

$$V_{m,c} = 3b$$

$$T_c = \frac{8a}{27bR}$$

$$p_c = \frac{a}{27b^2}$$

Hausaufg.: Für He sei

$a = 3{,}45 \cdot 10^{-3} \frac{Pa \cdot m^6}{mol^2}$

$b = 0{,}0237 \cdot 10^{-3} \frac{m^3}{mol}$

Berechne

a) Krit. Temp.: $T_c = \frac{8a}{27bR}$

b) Krit. Druck: $p_c = \frac{a}{27b^2}$

a) $T_c = 5{,}188\ K$

b) $p_c = 227468\ Pa$

Max. Wirkungsgrad einer Brennstoffzelle mit Knallgasreaktion

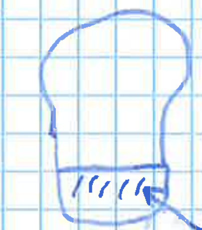
$2H_2 + O_2 \rightarrow 2H_2O$

~~$Z_a C - 4OC$~~ annähernd

$\Rightarrow$ annähernd 100

Ideale Gase

2.

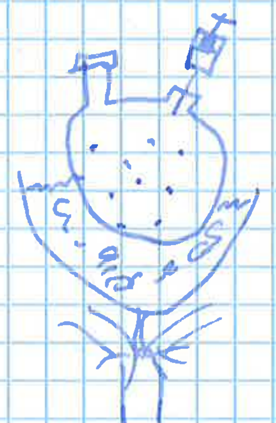


$1kg = 1000g \hat{=} 55{,}56\,mol = n$

$$V = \frac{nRT}{p} = \frac{55{,}56\,mol \cdot 8{,}314 \cdot 373}{101000}\,m^3$$

$$V = 1{,}71 \cdot 10^3\,dm^3 = 1{,}71 \cdot 10^3\,l$$

3.

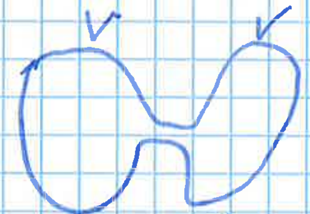


~~$V = 1{,}5\,dm^3$~~
~~$T = 100\,°C$~~

$$\overset{10100}{p}\,\underset{0{,}015\,m^3}{V} = \overset{?}{n}\,R\,\overset{373K}{T}$$

$$\underset{\text{Molmasse}}{M} = \frac{m}{n} = \frac{0{,}23\,g}{n}$$

4.



p_1	p_1
$T_1 = T_2$	$T_1 = T_2 = 293K$
$\downarrow$	$\downarrow$
$p_2 = ?$	$p_2 = ?$
$T_1' = 373K$	$T_2' = 293K$

Was bleibt gleich?

→ Gesamtzahl Gasteilchen

$$n_1 + n_2 = n_1' + n_2'$$

$n_1 = n_2$

$$2n_1 = n_1' + n_2'$$

$n = \frac{pV}{RT}$, $T_1 = T_2$

Kelvin $\Delta T \hat{=} \Delta \vartheta$ Celsius

$$\frac{2p_1V}{RT_1} = \frac{p_2V}{RT_1'} + \frac{p_2V}{RT_2'} \longrightarrow p_2\left(\frac{1}{T_1'} + \frac{1}{T_2'}\right) = \frac{2p_1}{T_1}$$

$T_1' = 373K$, $T_2' = 293K$

$$p_2 = \frac{\frac{1}{T_1}}{\frac{1}{T_1'} + \frac{1}{T_2'}}\,2p_1 = 4bar\,\frac{\frac{1}{293}}{\frac{1}{373} + \frac{1}{293}}$$

$$p_2 = 2{,}24\,bar$$

Zustandsänderungen von Gasen

1. isochor → $V = \text{konst.}, \Delta V = 0$

Zust.	p	V	T	
1	p_1	X	293K	
2	p_2	X	373K	

$V_2 = V_1$

$$\frac{p_1 \cancel{V_1}}{\cancel{n_1} T_1} = \frac{p_2 \cancel{V_2}}{\cancel{n_2} T_2} \quad \Big| \begin{matrix} : p_1 \\ \cdot T_2 \end{matrix} \quad \frac{T_2}{T_1} = \frac{p_2}{p_1} = \frac{372}{293} = 1{,}27 \rightarrow \text{Antwort:}$$

$\rightarrow p_2 = 1{,}27\, p_1$

→ 27% Zunahme

2. $R = \frac{pV}{nT} \rightarrow \frac{p_1 V_1}{n_1 T_1} = \frac{p_2 V_2}{n_2 T_2}$

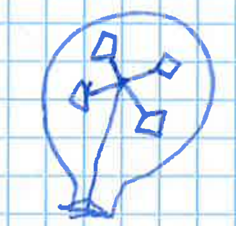
$n_2 = 1{,}5\, n_1$

$$\Rightarrow p_2 = p_1 \frac{1{,}5 \cancel{n_1} T_2}{\cancel{n_1} T_1} = p_1 \frac{1{,}5\, T_2}{T_1} = 1{,}5 \cdot 1\,\text{bar} \cdot \frac{\overset{2600°C}{2873\,K}}{\underset{20°C}{293\,K}} = 14{,}7\,\text{bar}$$

adiabatische Zustandänderungen

1. a) Edelgas: $f =$

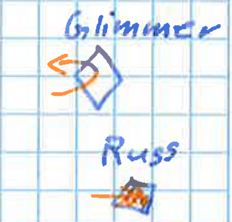
Hausaufg



Lichtmühle:

2 Erklärungen ← · Wie funktioniert sie?

· Photonen entsprechen Solarkonstante: Strahlungsdruck pro cm^2?



Ideale Gase

1. $T = 300\,K$ $\quad V = 20\,dm^3 = 0{,}02\,m^3$ $\quad p = ?$

$pV = nRT$ $\quad n = 1\,mol$

$p = \frac{RT}{V} = \cancel{\ldots}\ 124614\,Pa = \cancel{25 \cdot 10^3\,Pa}\ 1{,}2 \cdot 10^5\,Pa = \underline{\underline{1{,}2\,bar}}$ ✓

2. $h = 11000\,m$

$p = 226 \cdot 10^2\,Pa$ $\quad M = \frac{m}{n} = \frac{29\,g}{mol} = \frac{0{,}029\,g}{mol}$

$T = 216\,K$ $\quad \frac{nM}{V} = \frac{m}{V} = \rho = ?$ $\quad \frac{nM}{V} = pM/RT = \underline{\underline{365\,g/m^3}}$

$pV = nRT$

$V = \frac{nRT}{p} = \frac{mRT}{Mp} = N_a^2 \cdot n$

$\frac{n}{V} = \frac{p}{RT}$

Zustandsänderungen von Gasen

3. $\Delta Q = 4\,K$

$T_1 = 289\,K$ $\quad T_2 = 293\,K$

$\frac{\cancel{p} V_1}{\cancel{N} T_1} = \frac{\cancel{p} V_2}{\cancel{N} T_2} \rightarrow T_2 \frac{V_1}{T_1} = V_2 = 1{,}014\,V_1 \Rightarrow \underline{\underline{1{,}38\,\%}}$ ✓

4. $V_2 = 8400\,m^3$

$T_2 = 243\,K$

$p_2 = 0{,}28\,bar = 28000\,Pa$

$p_1 = 1\,bar = 10^5\,Pa$

$T_1 = 293\,K$

$V_1 = ?$

$V_1 = \frac{V_2 T_1 p_2}{p_1 T_2} = 2835{,}95\,m^3 \Rightarrow \underline{\underline{V_1 = 2800\,m^3}}$ ✓

5. $T_1 = 293\,K$

$p_1 = 20 \cdot 10^6\,Pa$

$p_2 < 28 \cdot 10^6\,Pa$

$T_2 = ?$

$\frac{p_1}{T_1} = \frac{p_2}{T_2} \Rightarrow T_2 = \frac{p_2}{p_1} T_1 \Rightarrow T_2 = 410{,}2\,K$

$T_2 = 137{,}2\,°C$

$\Rightarrow \underline{\underline{T_2 = 410\,K}}$

$\underline{\underline{T_2 = 137\,°C}}$ ✓

Adiabatische Zustandsänderungen

1. a) $T_1 = 293K$ $\quad T_2 = ?$

$p_1 = 10^5 Pa$ $\quad p_2 = ?$ $\quad 10V_2 = V_1$

$p = \frac{2N}{3V} \cdot \frac{3}{2} kT = \frac{NkT}{V}$

$p_1 = \frac{NkT_1}{10V_2} \Rightarrow p_2 = \frac{T_2}{T_1} 10p_1$

$T_2 V_2^{\varkappa-1} = T_1 (10V_2)^{\varkappa-1}$

$\varkappa = \frac{c_p}{c_V} = \frac{c_p}{\frac{3}{2}R} = \frac{R+\frac{3}{2}R}{\frac{3}{2}R} = \frac{\frac{5}{2}}{\frac{3}{2}} = \frac{5}{3}$

$\varkappa - 1 = \frac{5}{3} - 1 = \frac{2}{3}$

$T_2 V_2^{\frac{2}{3}} = T_1 \sqrt[3]{100}\, V_2^{\frac{2}{3}}$

$\Rightarrow T_2 = 1{,}4 \cdot 10^3 K$

~~$p_1 \sqrt[3]{100} = p_2 = 4{,}6$ bar~~

$p_1 10^{\frac{5}{3}} = p_2 = 4{,}6 \cdot 10$ bar

b) $T_2 = 10^{\frac{2}{5}} T_1$ $\quad \varkappa = \frac{\frac{7}{2}}{\frac{5}{2}} = \frac{7}{5}$

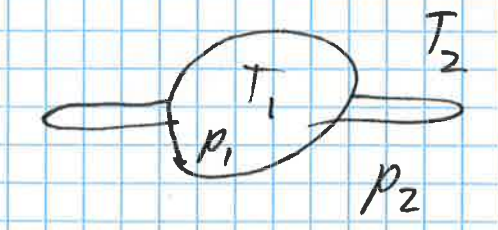
$T_2 = 740K$ ✓

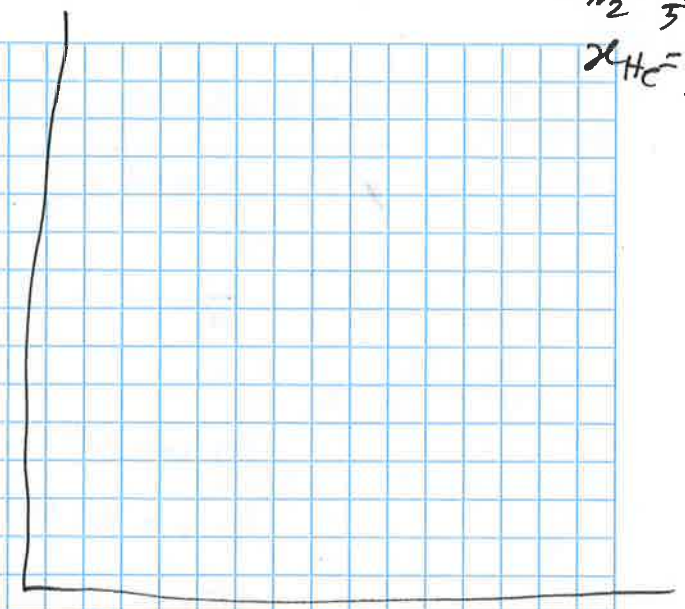
$p_1 \cdot 10^{\frac{7}{5}} = p_2 = 2{,}5 \cdot 10$ bar ✓

$\varkappa_{N_2} = \frac{7}{5}$

$\varkappa_{He} = \frac{5}{3}$

2.





$T_{1max} = ?$

$p_1 = 0{,}75$ bar

$T_2 = 220K$

$p_2 = 0{,}25$ bar

$p_1^{1-\varkappa} T_1^{\varkappa} = p_2^{1-\varkappa} T_2^{\varkappa}$ $\quad \varkappa = \frac{7}{5} = 1{,}4$

$T_1 = \left(\frac{p_2}{p_1}\right)^{-0{,}4} T_2^{1{,}4} = 1226K \to 1200K$ $\quad 1-\varkappa = -\frac{2}{5} = -0{,}4$

4. $288K = T_0$ $\quad T_1 = ?$

$p_0 = 10^5 Pa$

$p_1 = 9{,}88 \cdot 10^4 Pa$

$\varkappa = 1{,}4$

$\sqrt[1{,}4]{\frac{(10^5)^{-0{,}4}\, 288^{1{,}4}}{(9{,}88 \cdot 10^4)^{-0{,}4}}} = T_1 = 148{,}65K$

5. $c = \sqrt{\varkappa RT / M}$

$\sqrt{\frac{\varkappa_1 RT}{M_1}} = \sqrt{\frac{\varkappa_2 RT}{M_2}}$

$\frac{\varkappa_1}{M_1} = \frac{\varkappa_2}{M_2}$ $\quad \frac{5}{3M_1} = \frac{7}{5M_2}$

$He \to \varkappa_1 = \frac{(1+\frac{3}{2})R}{\frac{3}{2}R} = \frac{10}{6} = \frac{5}{3}$

$O_2 \to \varkappa_2 = \frac{(1+\frac{5}{2})R}{\frac{5}{2}R} = \frac{7}{5}$

$M_1 = 7{,}2 M_2$

$\frac{5}{3} = \frac{7}{5 \cdot 7{,}2}$

$\Rightarrow 2{,}93$ mal

Kinetische Gastheorie

1. $\bar{E}_k = \frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$ $m(N_2) = 28{,}02\,u = 4{,}65 \cdot 10^{-26}$

$\frac{1}{3k} m \overline{v^2} = T$

↳ $v = 3 \frac{m}{s}$ → $T = \cancel{2{,}2 \cdot 10^{13} K}$ $\underline{0{,}01 K}$

↳ $v = 50 \frac{m}{s}$ → $T = \cancel{1{,}2 \cdot 10^{24} K}$ $\cancel{6{,}0 \cdot 10^{25} K}$ $\underline{2{,}8 K}$

↳ $v = 330 \frac{m}{s}$ → $T = \cancel{2{,}6 \cdot 10^{27} K}$ $\underline{122 K}$

7. $T = 20°C = 293K$ $T_2 = ?$

$2 \overline{v_1^2} = \overline{v_2^2}$

$\frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$

$$T_1 = \frac{1}{3k} m \overline{v_1^2}$$

$$T_2 = \frac{1}{3k} m \, 2\overline{v_1^2}$$

$$\frac{3kT_1}{m} = \frac{3kT_2}{2m}$$

$2T_1 = T_2 \Rightarrow T_2 = \cancel{\ }\ 586 K$

verursacht durch $\overline{v_2^2} = 2\overline{v_1^2}$

stat $\overline{v_2^2} = \overline{(2v_1)^2}$

sonst würd's stimmen

~~8. a)~~ Zustandsänderung nach van der Waals

1. ~~pV~~

$\varkappa = \frac{(4)R}{3R} = \frac{4}{3}$

$pV = NkT$

$p = \frac{NkT}{V}$

$1{,}01 p = \frac{NkT}{V}$

$V = 0{,}022 m^3$

a) $0{,}99\,T$, $0{,}01\,T$

b) $0{,}09\,T$ & $0{,}001\,T$

5. $n = 1 mol$ $V = 0{,}022 m^3$ $\varkappa = \frac{4}{3}$ $T = ?$

$$\left(p + a\left(\frac{n}{V}\right)^2\right)(V - bn) = nRT$$

$$\left(p + \frac{an^2}{V}\right)(V - bn) = pV - pbn + an^2 - abn^3 V^{-1} = nRT$$

$$p(V - bn) + an^2 - abn^3 V^{-1} = nRT$$

$$p = \frac{nRT - an^2 + abn^3 V^{-1}}{V - bn} = \frac{nRT - an^2 \overbrace{(1 - bnV^{-1})}^{(V-bn)V^{-1}}}{V - bn}$$

$$p = nRT - an^2 V^{-1}$$

~~$V = RT + ap$~~

$RT + ap \overset{!}{=} RTV$

$RT + a = RTV$

$\frac{RT + a}{RV} = T$

$pV = nRT$

$p = \frac{nRT}{V}$

$p = p$

$\frac{nRT}{V} = nRT - \frac{an^2}{V}$

$nRT = VnRT - an^2$

$RT = VRT - an$

$\frac{T}{V} + \frac{a}{RV} = T$

Schwarzer Strahler

1. $\frac{b}{T} = \lambda_{max} = 4{,}83 \cdot 10^{-7} m = 483 nm$

2. $A = 1{,}4 m^2$ $T_A = 306 K$

$T = 293 K$

3.

1.

Die mittlere freie Weglänge, Diffusion

2. $J = \frac{P}{A} = \sigma T^4$

$\frac{1{,}4 m^3 \cdot \sigma (293^4 - 306^4) K^4}{\Delta t}$ $P = 110{,}5 J$

3. $T = 5800 K$

$\Delta s = 150 \cdot 10^9 m$

$r = 696 \cdot 10^6 m$

$J = \frac{P}{A} = \sigma T^4 = 6{,}4 \cdot 10^7$

$\frac{1 m^3}{696 \cdot 10^6 m} = \frac{x m^3}{1{,}50696 \cdot 10^{11} m}$

$x m^3 = 216{,}5 m^3$

$\frac{\sigma T^4}{A} = \frac{6{,}4 \cdot 10^7}{216{,}5} = 295588{,}5 \frac{J}{m^2}$

4. $\sqrt[4]{\frac{P}{A \sigma}} = T = 276 K = 3°C$

Entropie

1. $m = 1\,kg$

$\Delta Q = -100\,°C = -100\,K$

$T = 0\,°C$

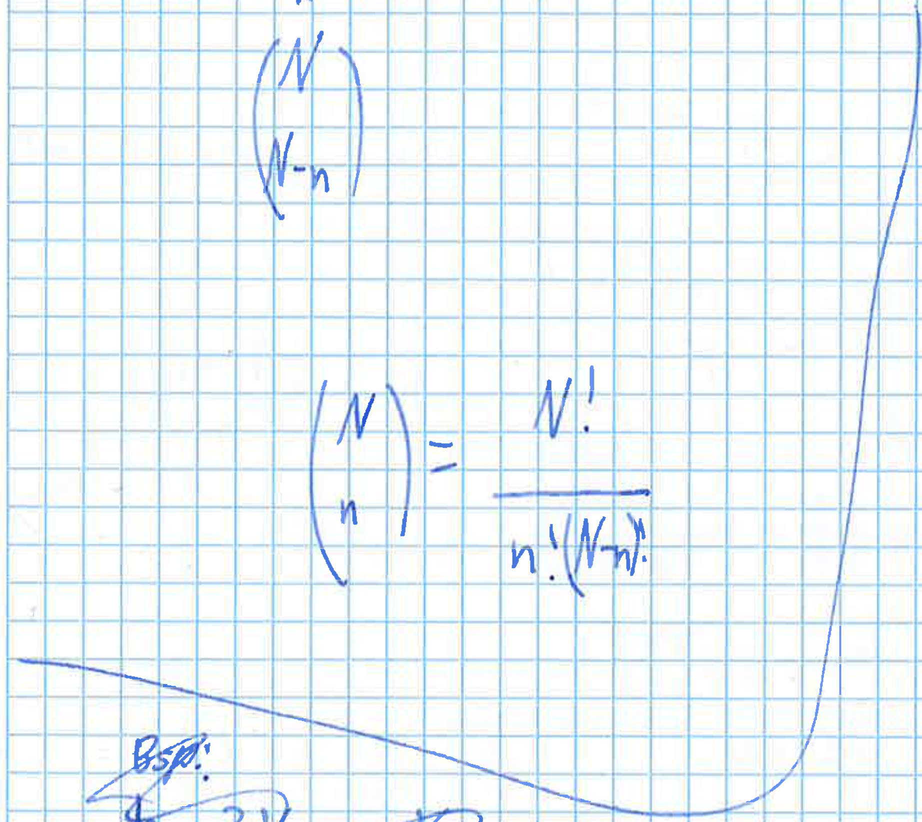
$$\Delta S = 1\,kg \cdot \ln\left(\frac{273}{373}\right) \cdot 4{,}128 \cdot 10^3$$

$$P = \binom{N}{n} p^n \cdot (1-p)^{N-n}$$

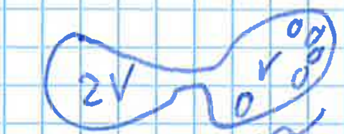
$$\parallel$$

$$\binom{N}{N-n}$$

$$\binom{N}{n} = \frac{N!}{n!(N-n)!}$$



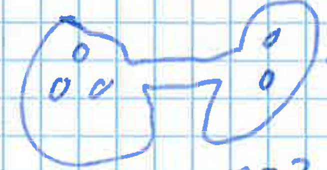
Bsp: 1. 2V → V



$\leftarrow P_1 = ?$

$n = N = 5$

$p = \frac{1}{3}$



$\leftarrow P_2 = ?$

$n = 2 \quad N = 5$

Lsg.:

$P_1 = \binom{5}{5}\left(\frac{1}{3}\right)^5 \underbrace{\left(\frac{2}{3}\right)^0}_{\to 1} = \left(\frac{1}{3}\right)^5 = 0{,}00412$

$P_2 = \binom{5}{2}\left(\frac{1}{3}\right)^2\left(\frac{2}{3}\right)^3 = \frac{5!}{2!\,3!} \cdot \frac{8}{243} = \frac{80}{243} = 0{,}233$

6.)

$\boxed{m}$ 373K

$\boxed{m}$ 273K $\longrightarrow$ $\boxed{2m}$ 323K

$$\Delta S_1 = m c_p \left(\frac{\frac{1}{2}(T_1 + T_2)}{T_1} \right)$$

$$\Delta S_2 = m c_p \left(\frac{\frac{1}{2}(T_1 + T_2)}{T_2} \right)$$

$$\Delta S = \Delta S_1 + \Delta S_2$$

$$\frac{1}{2}(T_1 + T_2) = T_m$$

T_{misch}

$$m c_p \left(\ln \frac{323}{373} + \ln \frac{323}{273} \right)$$

$$\underbrace{-0{,}144 + 0{,}168}_{+0{,}0243}$$

$$\left[1 \cdot 0{,}0243 \cdot 4182\right] \frac{J}{K} = \underline{\underline{101\ J/K}}$$

Bsp.)

dünner positiv geladener Draht.

Ladung: $0{,}020\ \frac{nC}{m}$ ← pro meter Länge des Drahts

Elektr. Feldstärke im Abstand v. 5,0 mm vom Draht gesucht

- Kreiszylinder: elektr. Feldlinien ⊥ zur Mantelfläche
- kein elektr. Fluss durch Grund & Deckfläche
- h = 1m → Q = 0,020 nC

Adiabatische Zustandsänderung

6.) Adiabatisch

$$He: p_0 \cdot V^{\varkappa_{He}} = p_1 \left(\frac{V}{2}\right)^{\varkappa_{He}}$$

$$N_2: p_0 V^{\varkappa_{N_2}} = p_2 \left(\frac{3V}{2}\right)^{\varkappa_{N_2}}$$

$$\boxed{F = (p_1 - p_2) \cdot A}$$

$$He: p_1 = p_0 \left(\frac{V}{V/2}\right)^{\varkappa} = p_0 \cdot 2^{\varkappa} = 3{,}175\ \text{bar}$$

$$N_2: p_2 = p_0 \left(\frac{V}{3V/2}\right)^{\varkappa_{N_2}} = p_0 \cdot \left(\frac{2}{3}\right)^{\varkappa_{N_2}} = 0{,}567\ \text{bar}$$

$$F = (p_1 - p_2) \cdot A = \Delta p A = 2{,}608 \cdot 10^5 \cdot 0{,}1^2\ N = \underline{\underline{2{,}6\ kN}}$$

$$\cancel{P_1 = \binom{12}{3} \left(\frac{1}{2}\right)^3 \left(\frac{1}{2}\right)^9}$$

$$\cancel{P_2 = \binom{12}{3} \left(\frac{1}{2}\right)^6 \cdot \left(\frac{1}{2}\right)^6}$$

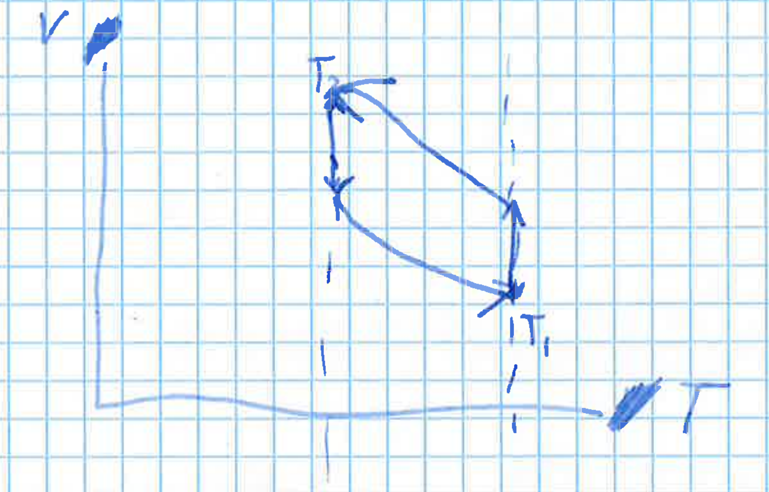
$$\cancel{P_1 = \binom{12}{6} \left(\frac{2}{3}\right)^6 \left(\frac{1}{3}\right)^6}$$

$$P_1 = \binom{6}{6} \left(\frac{1}{2}\right)^6 \left(\frac{1}{2}\right)^6 \cdot \binom{6}{6} \left(\frac{1}{2}\right)^6 \left(\frac{1}{2}\right)^6 = \cancel{0{,}000244141}$$

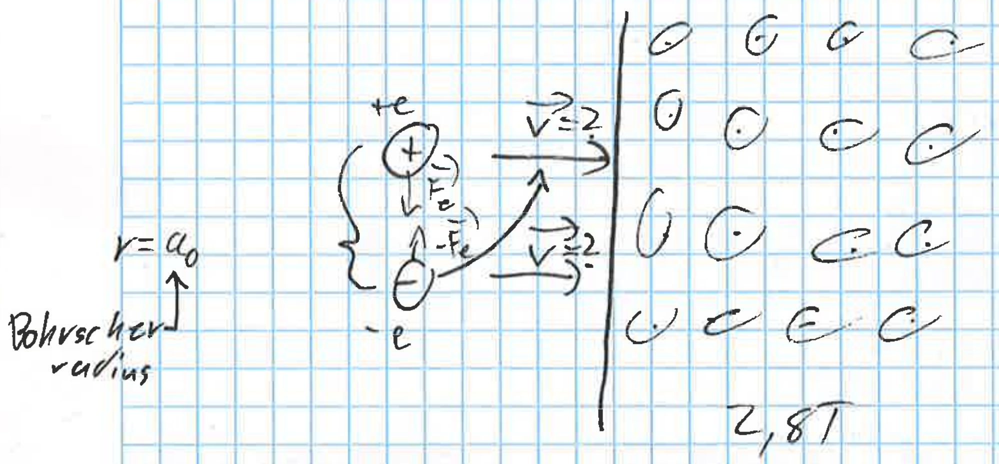
$$P_1' = \cancel{0{,}00655058}\ \ 0{,}015625$$

$$P_2 = \left[\binom{6}{3} \left(\frac{1}{2}\right)^3 \left(\frac{1}{2}\right)^3\right]^2 = 0{,}0390625$$

$$P_2' = 0{,}19742354$$



17.



$$F_e = F_L$$

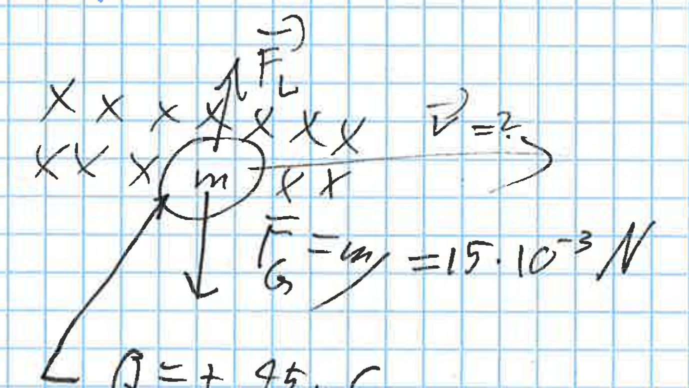
$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{e^{\cancel{2}}}{a_0^2} = \cancel{e}\, v B \quad \Big|:B$$

$$v = \frac{e}{4\pi\varepsilon_0\, a_0^2 B} = 1{,}84\cdot 10^{11}\,\frac{m}{s}$$

$$|\vec{E}| = 9\cdot 10^9\,\frac{|1C|^2}{(1m)^2} \Rightarrow |\vec{E}| = 9\cdot 10^9\,\frac{V}{m}$$

+1C

7.



$\vec{F}_G = mg = 15\cdot 10^{-3}\,N$

$Q = +45\,nC$

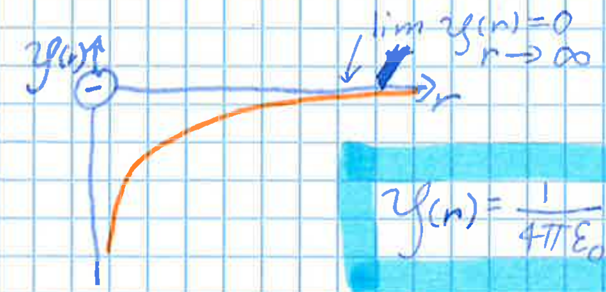
$$Q\cdot v\cdot B\cdot \sin 90^\circ = F_G \quad \Big|:(Q\cdot B)$$

?

$$v = \frac{F_G}{Q\cdot B} = \frac{0{,}015}{45\cdot 10^{-9}\cdot 0{,}05} = 6{,}7\cdot 10^6\,\frac{m}{s}$$

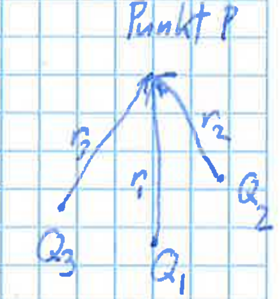
0,05 T

Potential von Punktladungen



$$\boxed{\varphi(r) = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r}}$$

Elektr. Potential einer Punktladung



$$\boxed{\varphi_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1}+\frac{Q_2}{r_2}+\frac{Q_3}{r_3}\right]}$$

bei P