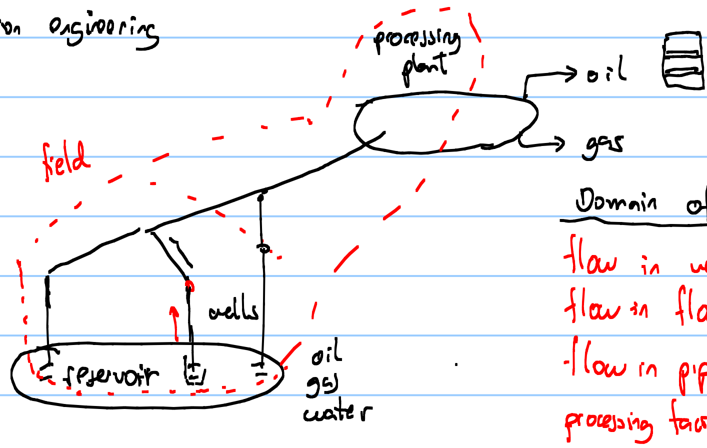
Prof. Milan Stanko NTNU → Norwegian university of science and technology

Production engineering



Domain of production engineering

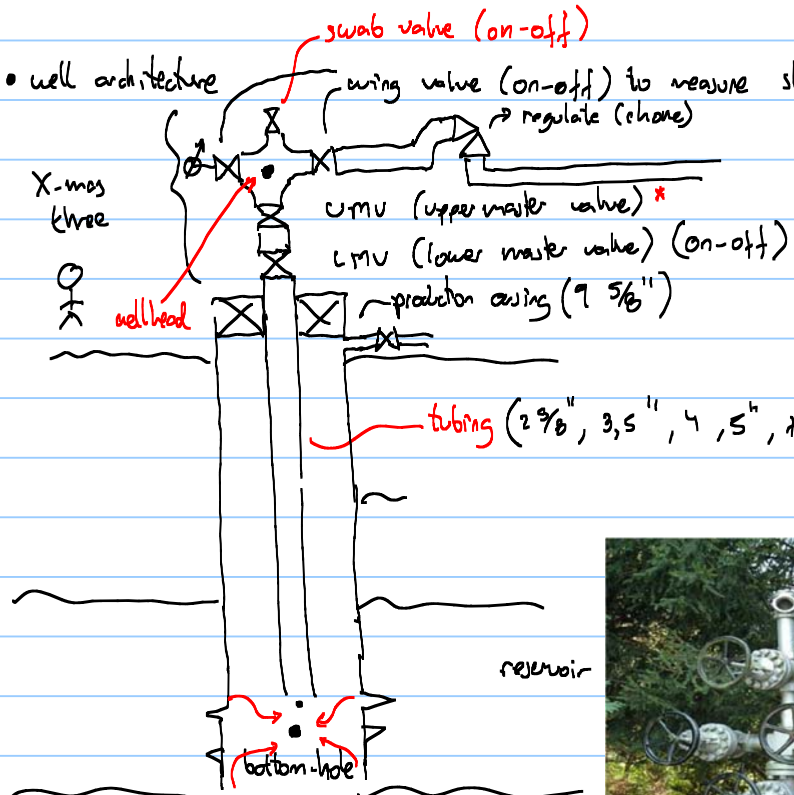
flow in wells (near wellbore formation)
flow in flowlines } gathering system
flow in pipelines }
processing facilities

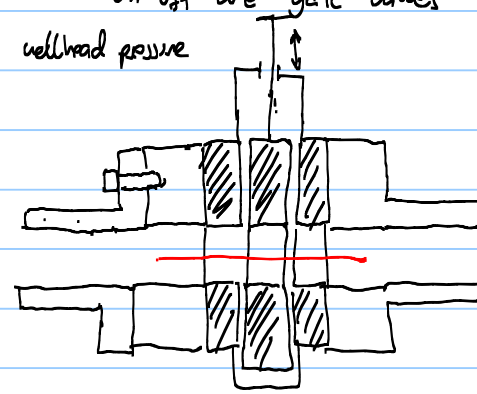
tasks of a production engineer are:

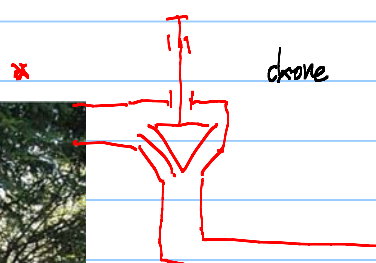
- to understand the subsurface { the reservoir }, production mechanism, productivity
- to monetize the development { to produce reserves in a way that is economically viable
- to optimize the development { maximize revenue, reduce cost, reduce failures

on-off are gate valves

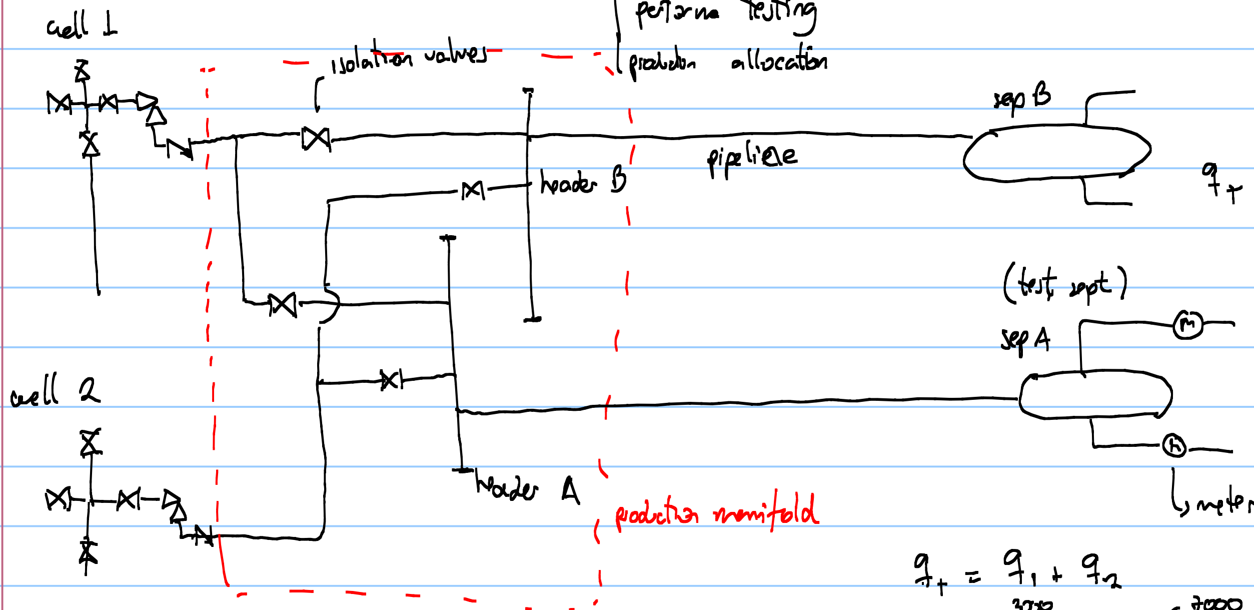
- well architecture







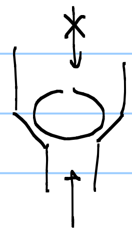
Production manifold →
- route/direct the production of a well to a destination
- perform testing
- production allocation



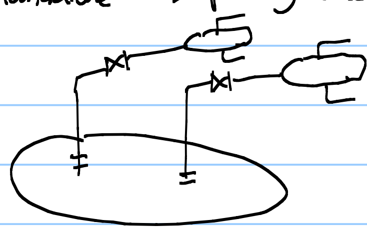
$$q_T = q_1 + q_2$$

$$f_1 = \frac{q_1}{q_T} \quad (q_1 \sim 3000,\ q_T \sim 10000) \qquad f_2 = \frac{q_2}{q_T} \quad (q_2 \sim 7000)$$

$f_1 = 0.3$ $\qquad f_2 = 0.7$

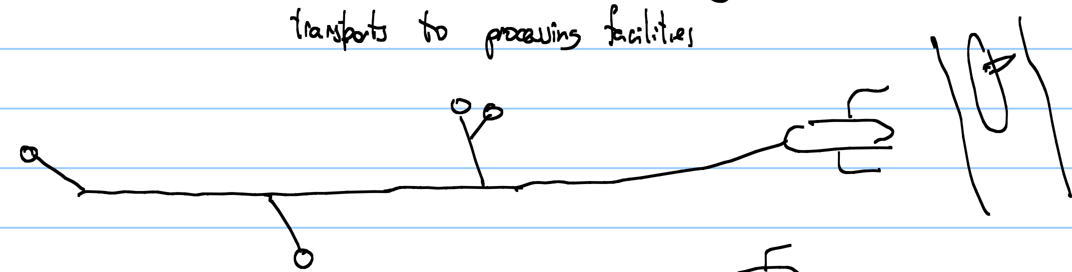


two types of wells: standalone → producing close to a separator or pipeline is very short such that $P_{header} \approx P_{sep}$

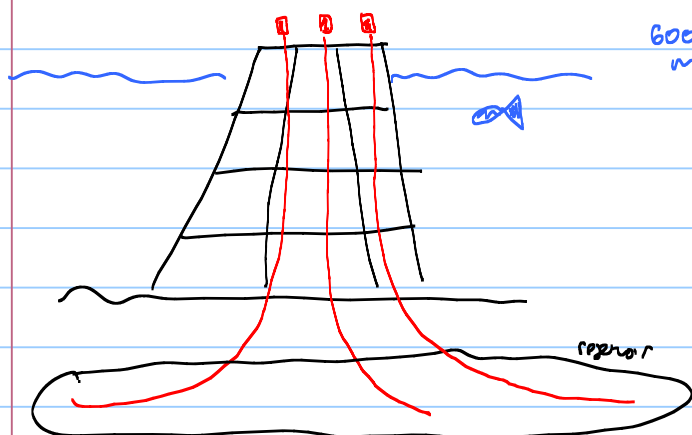


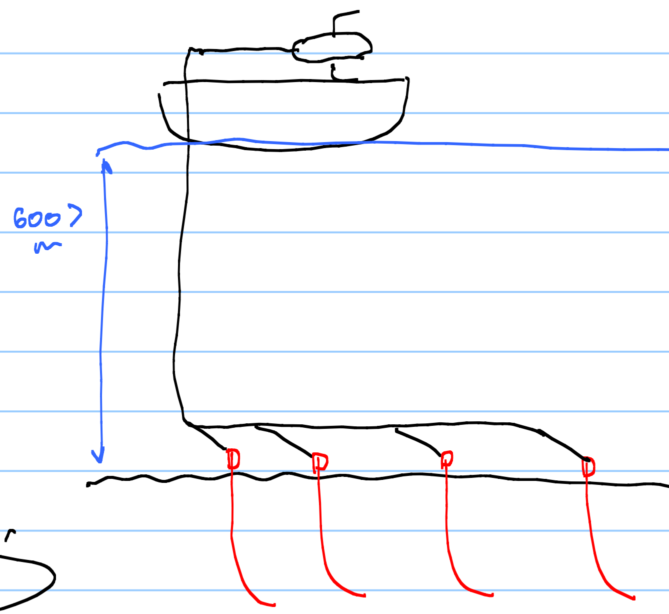
Wells in network → separator is far away from wells

→ pipeline collects production from many wells and transports to processing facilities



Offshore platform well





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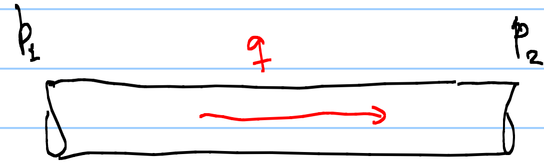
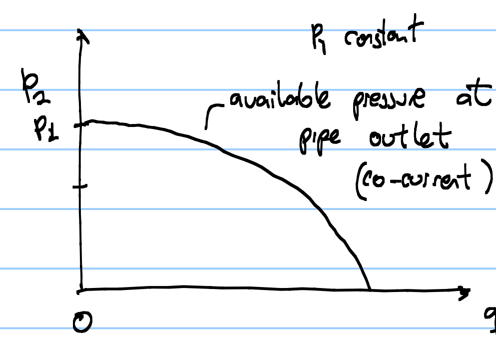
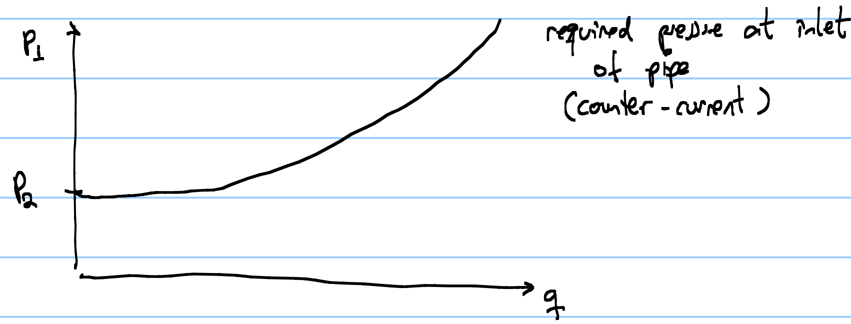
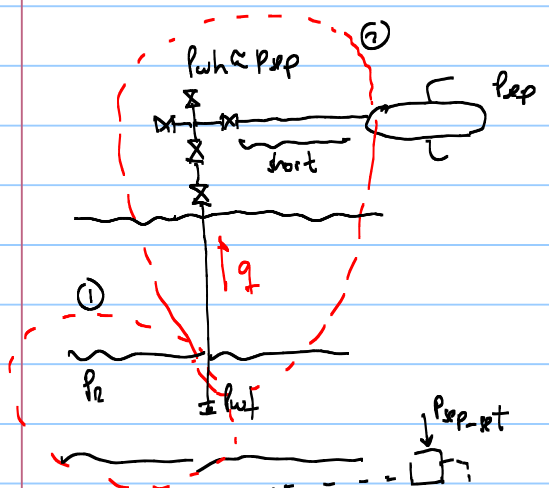
flow equilibrium (nodal analysis, inflow-outflow analysis)



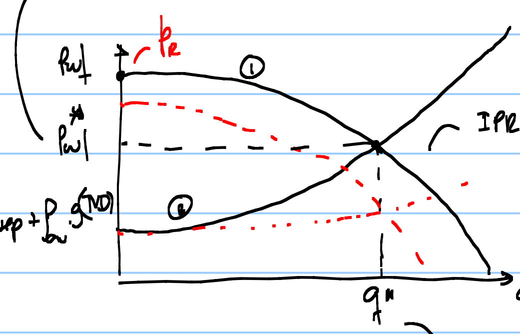


keep p_2 constant

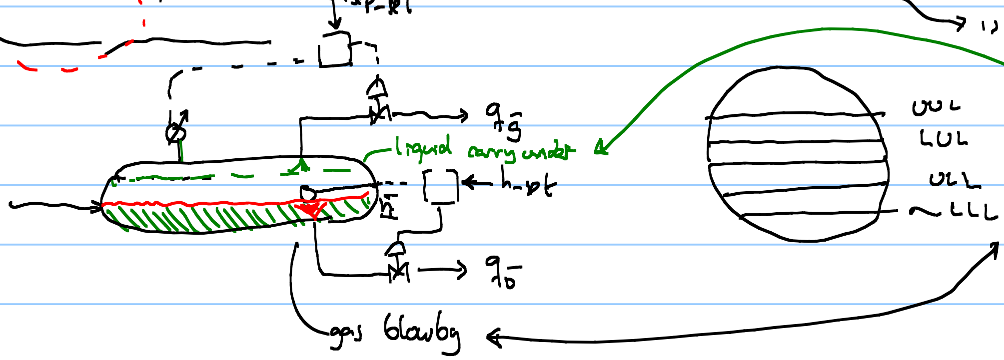




equilibrium bottom-hole pressure.

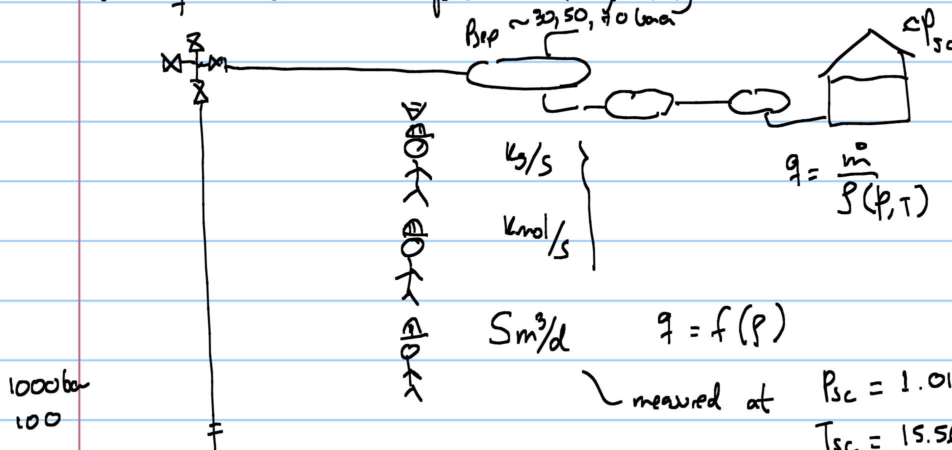


q^* is the equilibrium rate



UUL upper upper level
LUL lower upper level
ULL upper lower level
LLL lower lower level

what q to use? in petroleum engineering



kg/s

kmol/s

Sm³/d

q_o · 80 USD/bbl

$$q = \frac{\dot{m}}{\rho(p,T)}$$

$$V = \frac{q}{A} = \frac{\dot{m}}{\rho \cdot A}$$

$f(p,T)$

$q = f(p)$

measured at $p_{sc} = 1.01325$ bara 14.7 psia

$T_{sc} = 15.56$ °C 60 °F

with gas

$$\dot{m}_{sc} = \dot{m}(p,T)$$

need to calculate pressure drop!

$$q_{sc} \cdot \rho_{sc} = q_{(p,T)} \cdot \rho_{(p,T)}$$

the one measured and sold

$$q_{(p,T)} = q_{sc}\left(\frac{\rho_{sc}}{\rho(p,T)}\right)$$

$$\frac{q(p,T)}{q_{sc}} = B_g(p,T)$$

gas volume factor

if $p = p_R$

$T = T_R$

then FVF

$$B_g(p,T) = \frac{\rho_{sc}}{\rho(p,T)}$$

Boyle

Hooke

Charles

Gay-Lussac

avogadro

ideal gas law

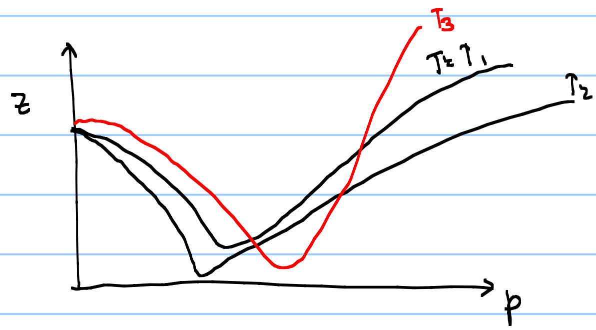
$$PV = RT$$

$$R = \frac{R_u}{MW_{gas}}$$

Real gas law

deviation factor

$$PV = ZRT$$



law of corresponding states

$$p_r = \frac{p}{p_c} \qquad T_r = \frac{T}{T_c}$$

reduced pressure

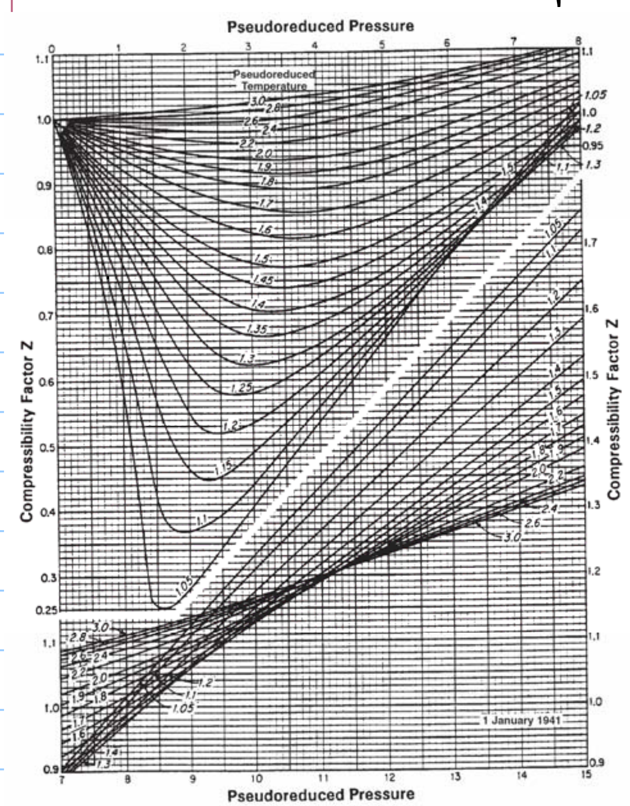


Fig. 3.6—Standing-Katz[4] Z-factor chart.

Z in production/reservoir between [0.7 - 2]

- in reality we have a mixture of

components	mole fraction	
C_1	x_{c_1}	MW_{c_1}
C_2	x_{c_2}	MW_{c_2}
C_3	x_{c_3}	MW_{c_3}
C_4	x_{c_4}	
C_5	x_{c_5}	
C_{6+}	x_{c_6}	

number of components

$$MW_m = \sum_{i=1}^{N} x_i MW_i$$

$$\gamma_g = \frac{MW_m}{MW_{air}} = \frac{MW_m}{28.97}$$

Sutton

$$T_{cm} = f(\gamma_g)$$

$$P_{cm} = f(\gamma_g)$$

$$B_g(p,T) = \frac{p_{sc}}{T_{sc}} \cdot \frac{T z}{p}$$

$$p_{sc} V_{sc} = R \cdot T_{sc} z_{sc} \quad (z_{sc} \approx 1) \qquad \rho_{sc} = \frac{1}{V_{sc}}$$

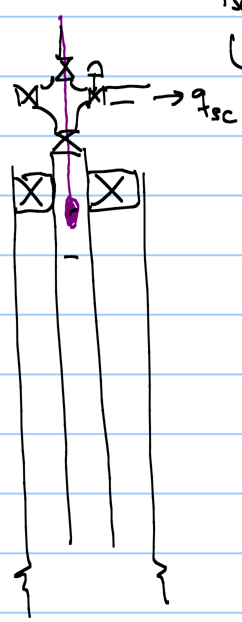
$$\rho_{sc} = \frac{p_{sc}}{R T_{sc}}$$

$$B_g(p,T) = \frac{p_{sc}}{T_{sc}} \cdot \frac{T (z)}{p}$$

p — bara, psia

(absolute unit !)

$$\rho(p,T) = \frac{p}{R T z}$$



TVD	p	T	→ v ?
TVD_1			
TVD_2			
TVD_3			

www.ipt.ntnu.no/~stanko/files/courses/POFE_UFM/2018/Exercises

UDF user defined function

VBA visual Basic applications

qg [Sm^3/d]	2.85E+06				
Gas gravity	0.7				
d [m]	0.1143				
A[m^2]	0.0103				
pressure	Temp	Z	Bg	qg	vg
[bara]	[C]	[-]	[m/Sm^3]	[m^3/d]	[m/s]
40	87	0.948259	3.00E-02	8.54E+04	96
46	89	0.942349	2.60E-02	7.41E+04	84
51	90	0.9376	2.32E-02	6.63E+04	75
56	92	0.933712	2.12E-02	6.04E+04	68
61	94	0.9305	1.96E-02	5.59E+04	63
66	96	0.92784	1.83E-02	5.23E+04	59
70	98	0.925643	1.73E-02	4.92E+04	56
74	99	0.923842	1.64E-02	4.67E+04	53
78	101	0.922386	1.56E-02	4.45E+04	50
81	103	0.921234	1.49E-02	4.26E+04	48

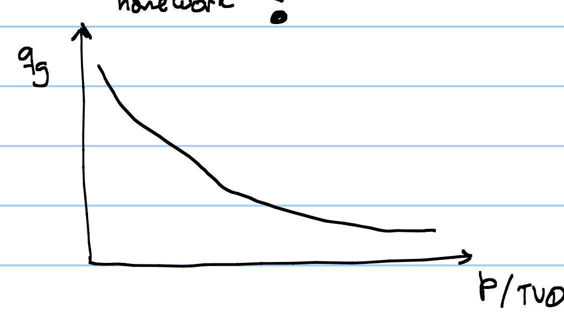
Z: zfac Standing (p, T, γ_g, unit)

Bg: $B_g(p, T, z, unit)$

qg: $q_{sc} \cdot B_g$

vg: $\frac{q_g}{A}$ $[m^3/d]$ $\left[\frac{1 d}{24 hr} \; \frac{1 hr}{3600 s}\right]$

homework !



for fixed T