B.E. CHEMICAL ENGINEERING SECOND YEAR FIRST SEMESTER 2018

MECHANICS OF FLUIDS

Part-I

Use separate answer scripts for each part.

Time: Three hours *Full marks: 100*
(50 marks for each part)

*Answer any **three** questions. All questions **do not** carry equal marks. Assume any missing data.*

1 (a) Consider a flow field given by $\vec{V} = ax^2y\hat{i} - by\hat{j} + cz^2\hat{k}$, a=1m^{-2}s^{-1}, b=3s^{-1} and c=2m^{-1}s^{-1}.

(i) Find the directionality and dimensionality
(ii) Find whether it is a possible incompressible flow
(iii) Find the acceleration of a fluid particle at point (x,y,z)=(3,1,2)

(b) Consider a flow field given by $V = Ai + btj$, $A = 2$ m/s, $B = 0.3$ m/s^2. Find the equation of the pathline followed by the particle located at (x,y)=(1,1) at the instant t=0.

(c) For flow through a pipeline expansion loss is more than contraction loss-discuss.

(d) Rotameter is an area meter-discuss.

(2+2+3)+4+3+2

2 (a) Water is flowing steadily through the 180° elbow shown (Fig.1). At the inlet to the elbow the gage pressure is 96 kPa. The water discharges to the atmospheric pressure. Assume properties are uniform over the inlet and outlet areas; A_1=2600mm^2, A_2=650 mm^2, V_1=3.05m/s. Find the horizontal component of the force required to hold the elbow in place.

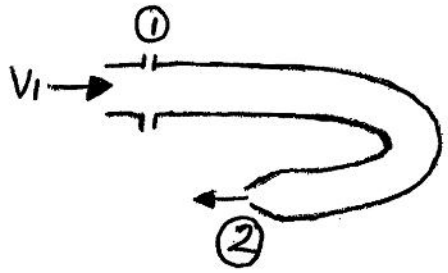

Figure 1

(b) A piping system shown in Fig.2 has been constructed from 75 mm galvanized iron pipe. All flow rates are high enough that the flow may be considered in fully rough zone. Minor losses may be neglected. Determine the gauge pressure at section 2, in terms of flow rate Q_2. Find the unknown flow rates Q_1, Q_2, Q_3 as fractions of the inlet flow rate, Q_0. All flow rates are expressed in m^3/s The fluid is water.

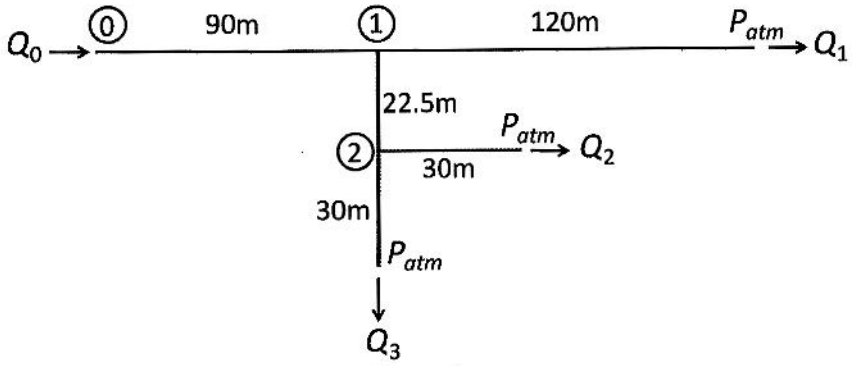

Figure 2

8+8

(a) Water is flowing from a higher reservoir to a lower reservoir (Fig. 3), elevation difference 30m. The total length of the galvanized iron pipeline is 80m. The pipeline contains three fully open globe valves and two 90° standard elbow. Determine the smallest standard pipe size that can be used to deliver water at $2.65m^3/min$. Assume that standard sizes for the pipe increase in 12.5 m steps from 25mm to 75 mm, increase from there in 25 mm steps to 150 mm. Loss coefficients for entrance =0.5, each elbow=0.3, each globe valve=6, exit =1. Assume density of water is $1000kg/m^3$ and viscosity of water is 10^{-3} Pa.s.

(b) Also Draw the Energy grade line and Hydraulic grade line.

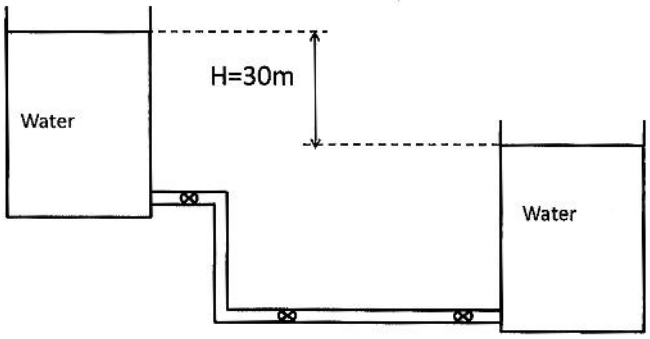

Figure 3

15+3

4 (a) Kerosene at 40°C flows through a 0.3 m diameter line in a refinery. The flow rate is expected to be 90-120 kg/s. A manometer with water as a manometer fluid with maximum possible deflection of 1 m is available for use with a square edged orifice meter. Specify a recommended orifice diameter for use with this system. Specific gravity and viscosity of kerosene at 40°C are 0.82 and $1X10^{-3}$ N.s/m^2. Discharge coefficient for the orifice meter =0.61.

(b) A cylindrical tank of diameter 50 mm drains through a 5 mm diameter opening in the bottom of the tank. The speed of the liquid leaving the tank is approximately$V = \sqrt{2gy}$, where y is the height from the tank bottom to the free surface. If the tank is initially filled with water to 0.4m, find the water depth at t=12s.

8+8

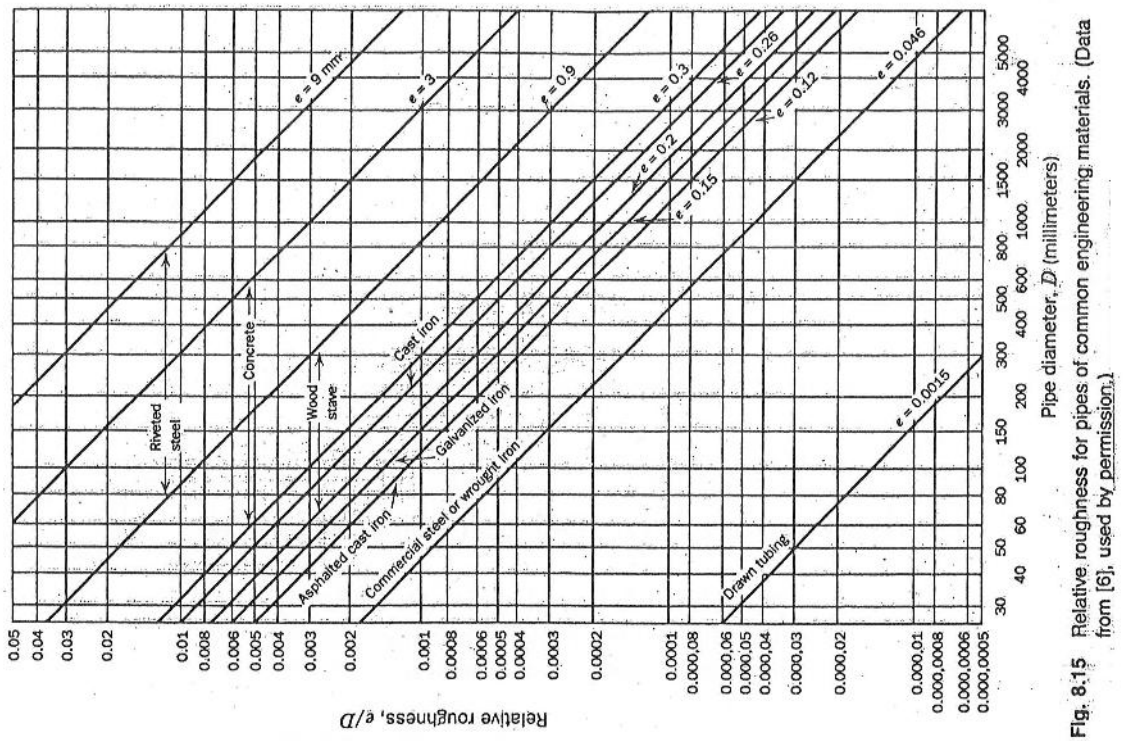

Fig. 8.15 Relative roughness for pipes of common engineering materials. (Data from [6], used by permission.)

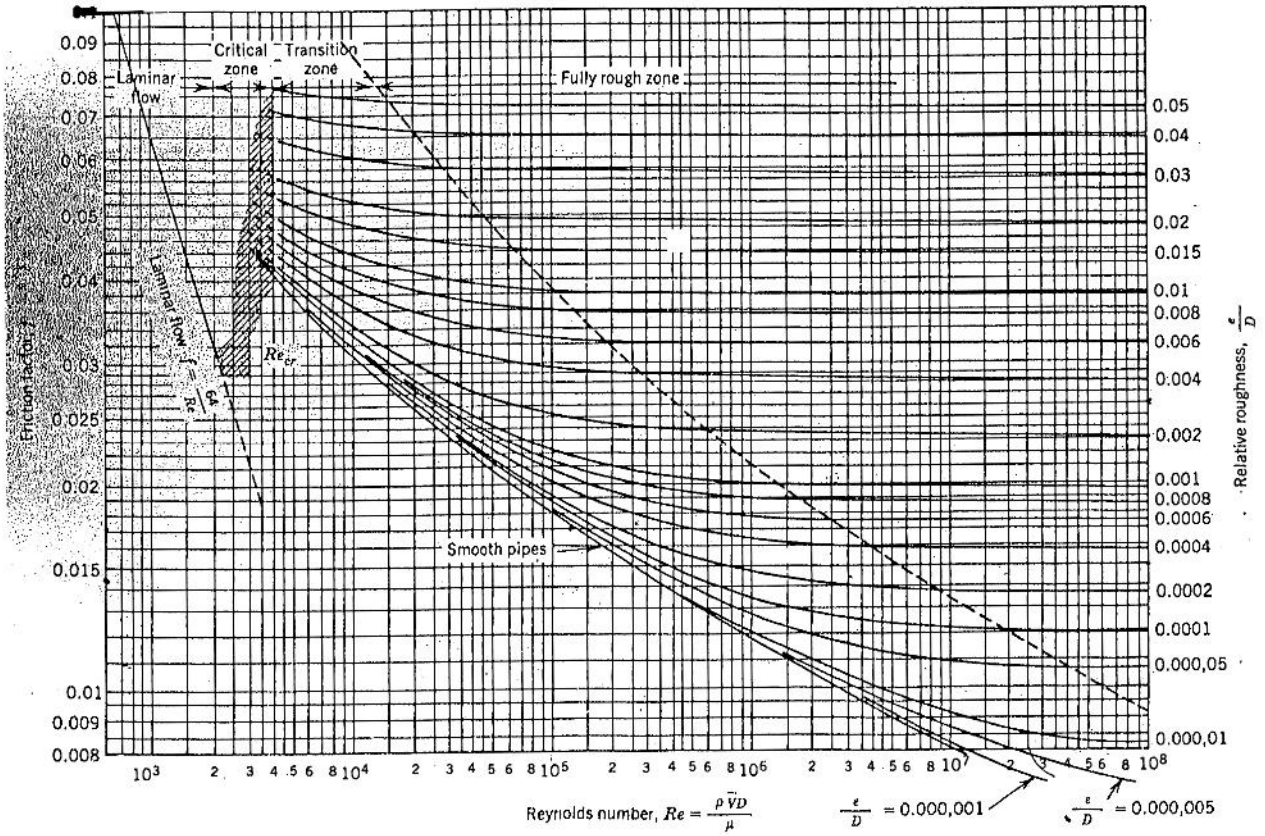

Fig. 8.14 Friction factor for fully developed flow in circular pipes. (Data from [6], used by permission.)

Ref. No. Ex/ChE/T/213/2018

B. CHEMICAL ENGINEERING 2nd YEAR 1ST SEMESTER EXAMINATION, 2018
SUBJECT: MECHANICS OF FLUIDS

Time: Three hours Full Marks 100

PART II

Answer any three questions. State all the assumptions. Assume any missing data

No. of Questions		Marks
1.(i)	A velocity field is given by $\vec{V} = 5y\hat{i} - 5x\hat{j}$ What is the directionality and dimensionality of the flow? Derive the equation of streamline passing through the point (1,1) Draw the x and y component of velocity vector on a x-y plane. Is the flow rotational? What is the vorticity vector?	1+3+2 +4=10
1.(ii)	A horizontal 2 inch. I.D. (inside diameter) pipe carries kerosene at 37°C, with density 809 kg/m^3 and viscosity 0.13 kg/(m s). In order to measure the flow rate, the line is to be fitted with a sharp-edged orifice plate, with pressure tapping, connected to a mercury manometer that reads up to a 15 inch difference in the mercury level. (a) If the largest flow rate of kerosene is expected to be 4.2 kg/s, specify the diameter of the orifice plate that would just register the full 15 inch difference between the mercury levels? Assume that Co=0.61. (b) If the orificemeter is replaced by a venturimeter having the same β, what should be the reading of the manometer? Cv=0.98	8
2.	Consider a vertical packed bed consisting of spherical particles (ρ_p= 1300 kg/m^3) of average diameter 1 mm. The bed is 1 m in diameter by 3 m long. Water (ρ=1000 kg/m^3) flows upward through the bed and is used to fluidize it. At the minimum fluidizing condition the void fraction, ϵ of the bed is 0.4. At operating condition the bed height is increased by 1.5 times. Calculate (i) The void fraction (ϵ) of the bed at operating condition (ii) the pressure drop across the bed under such condition, (iii) operating flow rate of water, (iv) the ratio of operating velocity to minimum fluidizing velocity Ergun equation for flow through packed bed having spherical particles is given below: $\frac{(-\Delta P_f)g_c}{L}\frac{D_p}{\rho V_o^{\,2}}\frac{\varepsilon^3}{(1-\varepsilon)} = 150\frac{(1-\varepsilon)}{N_{\mathrm{Re}\,p}} + 1.75$; V_o is the superficial velocity	16

Ref. No. Ex/ChE/T/213/2018

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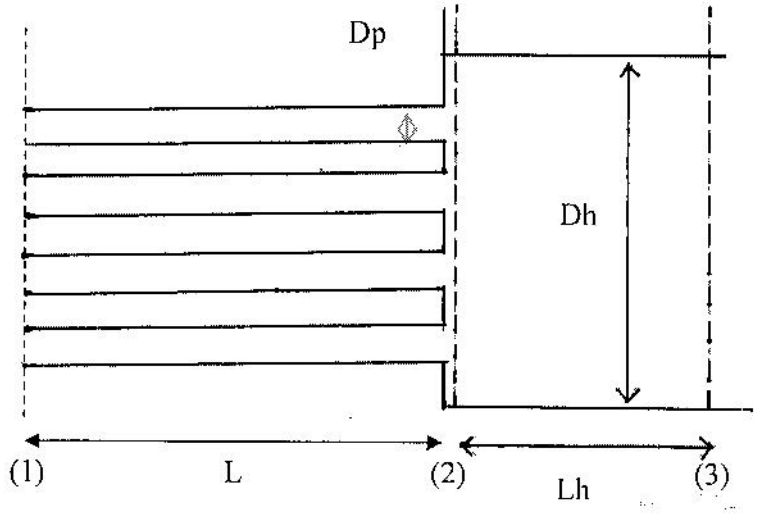
No. of Questions		Marks
3.	Consider the expansion of flow through multiple pipes into the header (refer to Fig. 1). There are 50 number of steel tubes of inside diameter dp= 0.025m of length L=1 m. The diameter and length of header are D_h=0.25m, L_h=0.5m. The average velocity of a Newtonian incompressible fluid (ρ=1000kg/m^3, μ=0.001 Pa s (kg/m s)) through each steel tube is uo=0.5 m/s. (i) Derive an expression of ΔP across section 1-2. Assume that the pressures at section 1 and 2 are uniform across the cross-section. (ii) Derive an expression of ΔP across section 2-3. (iii) Derive an expression for frictional loss (dissipation) per kg fluid flowing between section 2 and 3. (iv) The temperature of the fluid entering section 2 (T_2) is 30°C and the temperature of the fluid leaving section 3 (T_3) is 60°C. What is the rate of heat added per unit mass? The heat capacity (C_v) of water is 4187 J/(kg K).	4+4+4 +4=16

FIG.1



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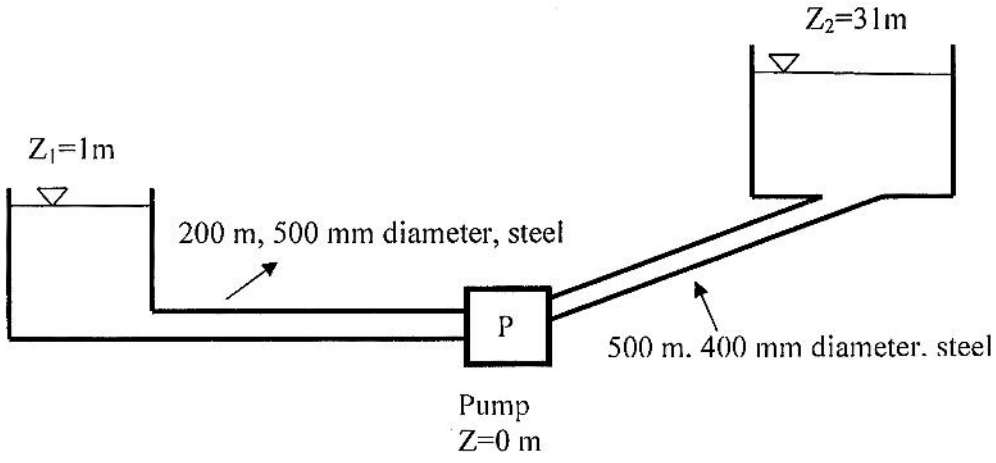
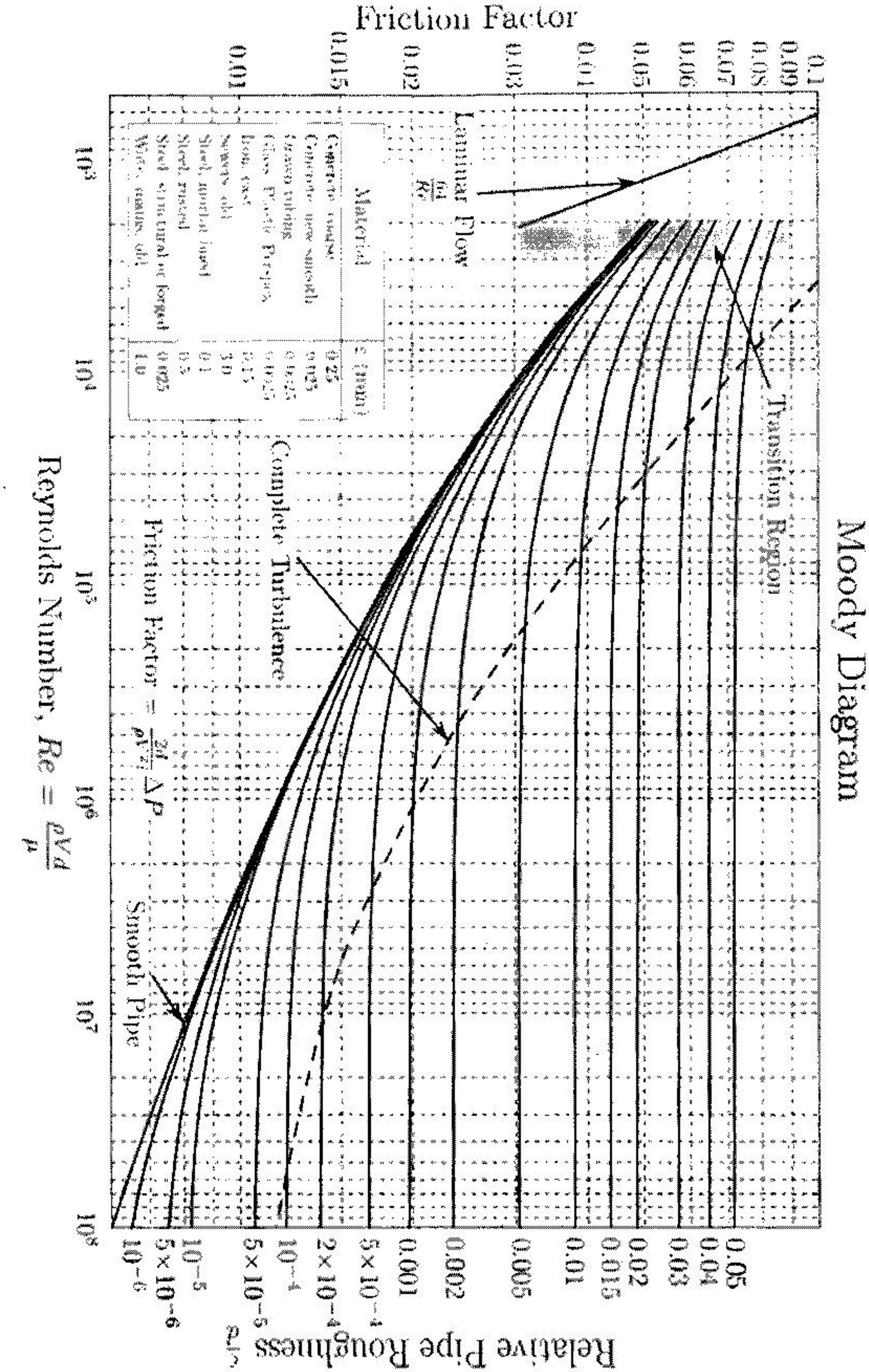
No. of Questions		Marks
4.	The pumping system shown in Fig. 2 has a pump head-discharge characteristic $H=40-24Q^2$ with head in meters and discharge in cubic meters per second. The pipe lengths include a correction for minor losses. The roughness parameter $\varepsilon=0.045$ mm for commercial steel pipe. (i) Determine the flow through the systems in liters per seconds. (ii) If the efficiency of the pumping system is 72 percent, determine the power required. (iii) Draw the EGL and HGL	8+4+4 =16




Moody Diagram
Friction Factor
Relative Pipe Roughness
Reynolds Number, $Re = \frac{\rho V d}{\mu}$
Friction Factor $= \frac{2d}{\rho V^2 l} \Delta P$
Laminar Flow
Transition Region
Complete Turbulence
Smooth Pipe
Material
Steel, riveted
Steel, structural or forged
Wire, mains, old
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.015
0.01
10^3
10^4
10^5
10^6
10^7
10^8
0.05
0.04
0.03
0.02
0.015
0.01
0.005
0.002
0.001
5×10^{-4}
2×10^{-4}
10^{-4}
5×10^{-5}
10^{-5}
5×10^{-6}
10^{-6}