Worksheet: Fluidized Bed

Name(s):____

<u>Fill in all sections.</u>

Student Learning Objectives

Students should be able to:

1. explain why a packed bed becomes fluidized
2. explain the different contributions to pressure drop in the packed bed
3. explain the meaning of the minimum fluidization velocity
4. compute the pressure drop (ΔP) across the bed

Fluidized Bed Learning Module Schematic and Properties

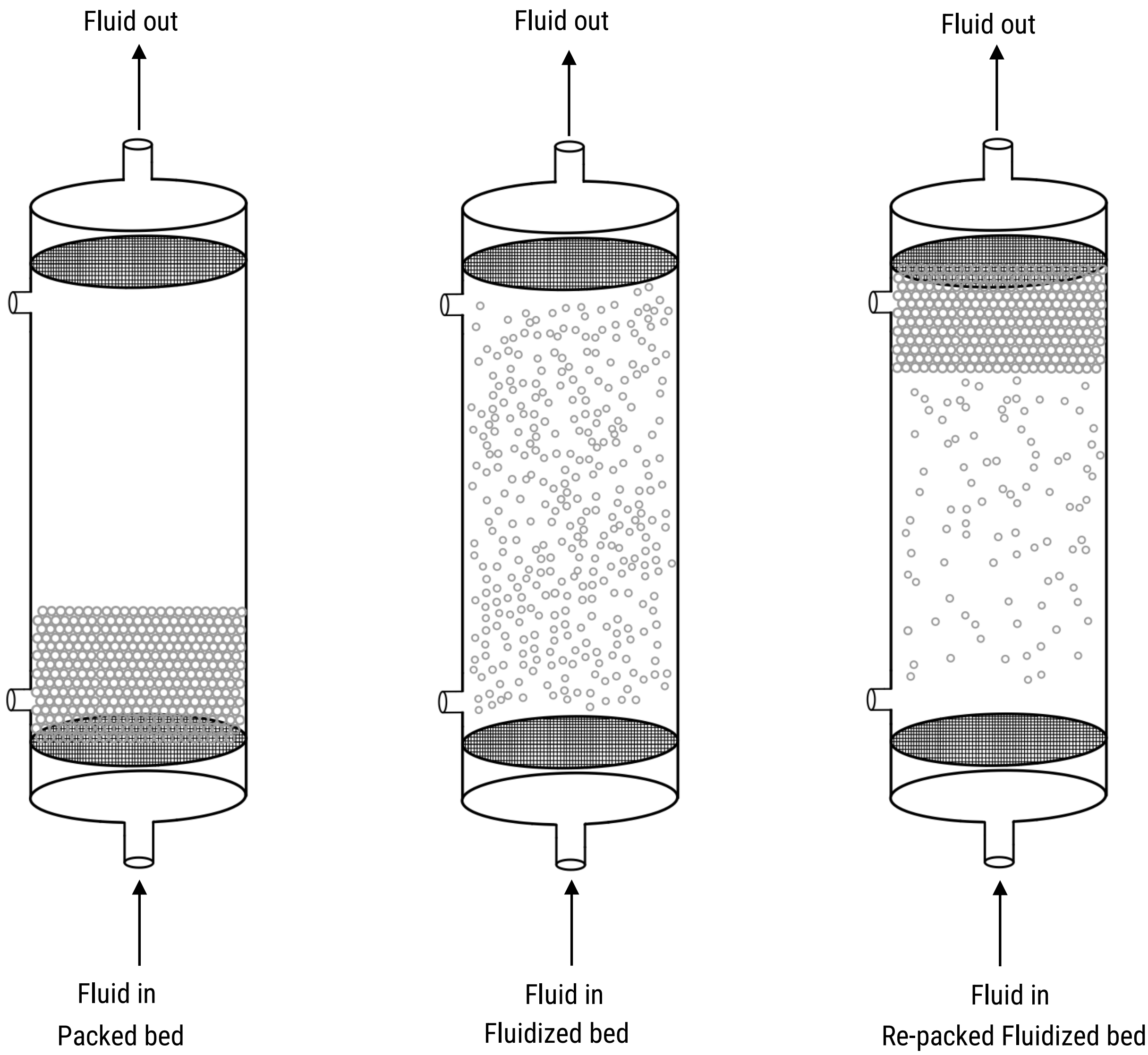

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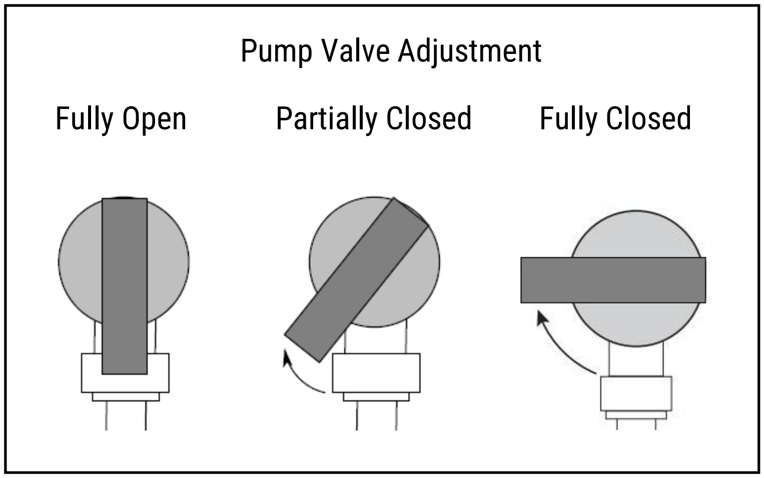
Table 1: Properties of the fluidized bed learning module

Properties							
Column properties		**Particle properties**		**Bed properties**		**Fluid properties**	
D_{col}	0.016 m	D_p	0.00107 m	e_M	0.45	r	997 kg/m^3
L_{col}	0.15 m	r_p	2400 kg/m^3	L_M	0.05 m	μ	0.001 $Pa \cdot s$

Experiments with Fluidized Bed

Before the Fluidized Bed Experiments

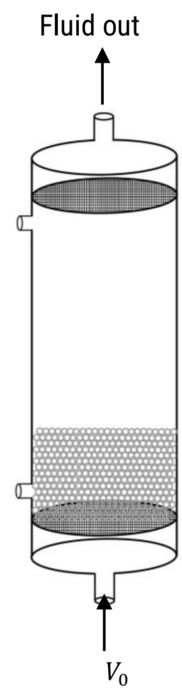
1) The beaker is filled with water, and the pump is in the beaker.
2) Keep the pump valve fully closed and start the pump.
3) Slowly adjust the pump valve until the column is fully filled with water.
4) Once you complete the setup, switch off the pump.
5) Make sure that the water levels in the manometer tubes are equal once you complete the steps above.



Experiment 1: Flow rate, pressure drop and bed height

Packed Bed

1) Keep the pump valve fully closed and switch on the pump.
2) Adjust the pump valve slowly to increase the flow rate but <u>make sure that particles are not moving.</u>
3) If you see a difference between the left and right manometer tubes, this indicates that the water is flowing.
4) Carefully observe the difference between left and right manometer tubes as you adjust the pump valve slowly.
5) If you suddenly make the particles move, switch off the pump and repeat the steps above.



Packed bed

Observe the difference between the left and right manometer tubes as you increase the flow rate but make sure that the <u>particles remain stationary.</u> Write down your observations in a few words and show them with arrows below.

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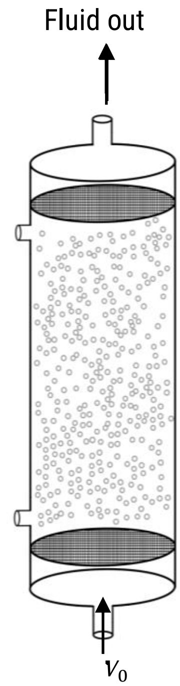
V_0 ___↑___ ΔP ______

Worksheet: Fluidized Bed

Fluidized Bed

1) Reset the fluidized bed by switching off the pump.
2) Before you start, make sure that the water levels in the manometer tubes are equal.
3) Keep the valve fully closed and switch on the pump.
4) Slowly adjust the pump valve until the particles start moving.
5) Carefully observe the difference between left and right manometer tubes as you adjust the pump valve slowly.
6) Observe the bed height as you adjust the pump valve slowly.
7) Do not allow the bed to expand all the way to the top of the column, as you increase the flow rate.

Observe the difference between the left and right manometer tubes and the bed height as you increase the flow rate when the bed is fluidized. Write down your observations in a few words and show them with arrows below.



Fluidized bed

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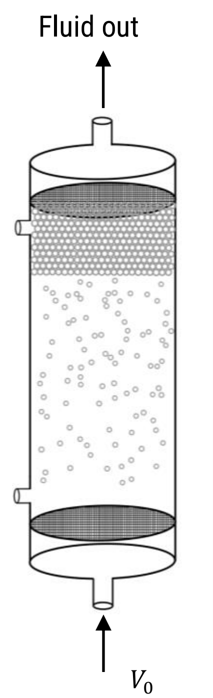
V_0 ______ ΔP ______ L ______

Re-packed Fluidized Bed

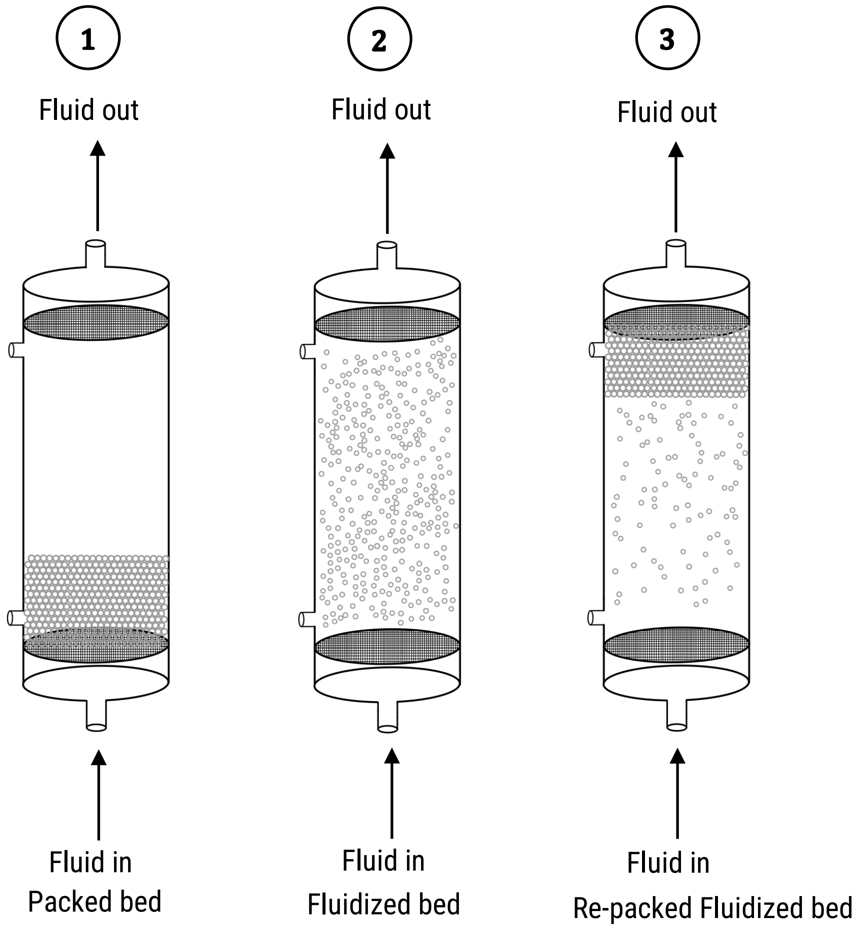
Scan the QR code for the demonstration.



Re-packed Fluidized Bed

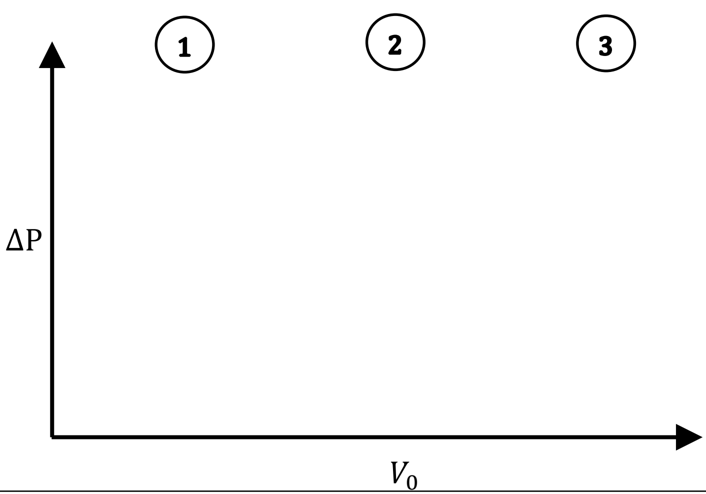
Worksheet: Fluidized Bed

Prediction of the Pressure Drop and the Bed Height



The regions 1, 2 and 3 in the plots correspond to the diagrams.

According to your observations, on the water levels in manometer tubes, plot the pressure drop trends below as you increase the flow rate.



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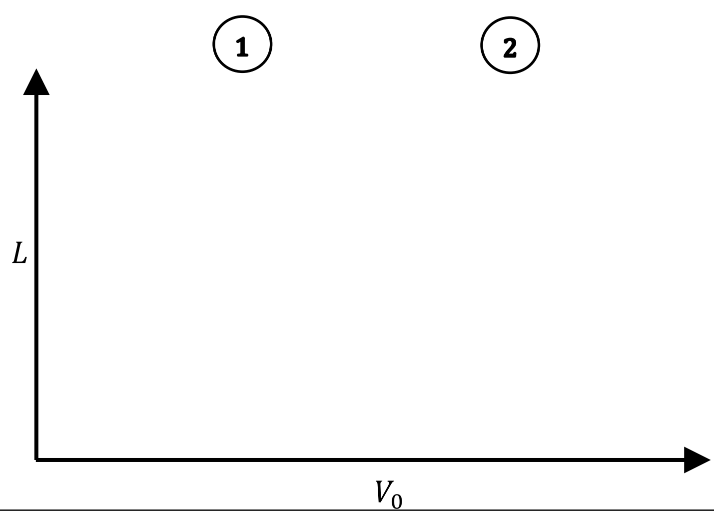

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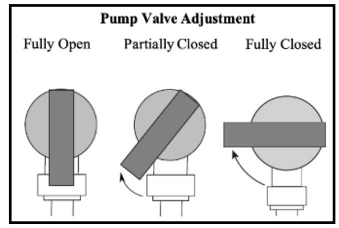
Experiment 2: Minimum fluidization velocity and particle Reynolds Number



1) Reset the fluidized bed by switching off the pump.
2) Before you start, make sure that the water levels in the manometer tubes are equal.
3) Keep the valve fully closed and switch on the pump.
4) Slowly adjust the pump valve where the bed is <u>initially</u> fluidized.
5) Measure the flow rate by switching the valve to fill the empty beaker until 200 mL and use a stopwatch to record the time. The valve to fill the empty beaker will not turn unless the pump is on. Note that the pump will shut off when the feed beaker is empty.

According to what you read on the right and left manometer tubes, fill out the table below.

Minimum fluidization flow rate (mL/s)	H_L (cmH_2O)	H_R (cmH_2O)	$\Delta P = H_L - H_R$ (cmH_2O)	L (cm)

Adjust the pump and <u>increase the bed height</u> from the point where the bed is initially fluidized. According to what you read on the right and left manometer tubes, fill out the table below for two data points.

Flow rate (mL/s)	H_L (cmH_2O)	H_R (cmH_2O)	$\Delta P = H_L - H_R$ (cmH_2O)	L (cm)

Discuss in a few words what you found different for ΔP values.

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Homework Problems

1. In Experiment 1, explain what happened in the column as you increase the pump.

2. Explain what is happening physically when the bed begins to fluidize. Draw the free body diagram of one particle.

3. Fluidization begins when:

   Pressure drop across bed = Weight of the bed per unit area – Buoyant force of the bed per unit area

$$\Delta P \quad = \quad g(1-\varepsilon)(\rho_p)L \quad - \quad g(1-\varepsilon)(\rho)L \qquad (1)$$

$(\rho = \rho_{fluid})$

For the initial fluidization, ε is the minimum porosity, ε_M, then pressure drop across the bed becomes:

$$\frac{\Delta P}{L} = g(1-\varepsilon_M)(\rho_p - \rho) \qquad (2)$$

Combine the Ergun equation (4) for ε_M *and* V_{0M}:

$$\frac{\Delta P}{L} = \frac{150 V_{0M}\mu}{\Phi_s{}^2 D_p{}^2}\frac{(1-\varepsilon_M)^2}{\varepsilon_M{}^3} + \frac{1.75\rho V_{0M}{}^2}{\Phi_s D_p}\frac{(1-\varepsilon_M)}{\varepsilon_M{}^3} \qquad (3)$$

Set the right-hand sides of equations 2 and 3 equal to each other and simplify to give a quadratic equation for the minimum fluidization velocity.

If the $Re_p < 1$, the kinetic loss term can be neglected. Simplify the quadratic equation for this case.

Solve this equation for the minimum fluidization velocity, V_{0M}, for the low Reynolds number case.

If the $Re_p > 1000$, the viscous loss term can be neglected. Simplify the quadratic equation for this case.

Solve this equation for the minimum fluidization velocity, V_{0M}, for the high Reynolds number case.

4) In Experiment 2, the minimum fluidization flow rate (mL/min) was found.
   a. From your data, find V_{0M} and Re_p. Use Table 1 (pg. 1) for additional information.

b. Depending on the Re_p you found experimentally, determine which equations derived in Question 3 should be used to predict V_{0M}. Use that equation to calculate V_{0M}.

c. Compare your experimental and predicted values and find the % errors.

$$\% \, Error = \frac{(experimental\ value - predicted\ value)}{(predicted\ value)} \ x\ 100\%$$

	V_{0M} (m/s)	Re_p
Experimental values		
Predicted values		

5) In Experiment 2, you measured the pressure drop, ΔP, across the bed at the point of minimum fluidization. Use the Ergun equation (Eq. 3) to predict the ΔP across the bed for the experimental V_{0M} and compare to the measured ΔP. Find the % error according to the expression from Question 5.
(1 cm H_2O = 98.07 Pa)

	ΔP (Pa)
Experimental values	
Predicted values	

6) Give a few examples of practical applications of fluidized beds.