

FLUIDS

NJ-OER TOPIC-11/12

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The [Open Textbook Collaborative](#). (OTC) project is a statewide project managed by Middlesex College along with assistance from Brookdale Community College, Ocean County College, Passaic County Community College, and Rowan University.

The project engages a consortium of New Jersey community colleges and Rowan University to develop open educational resources (OER) in career and technical education STEM courses.

The courses align to [career pathways in New Jersey’s growth industries](#) including health services, technology, energy, and global manufacturing and supply chain management as identified by the New Jersey Council of Community Colleges.

General Physics I

Moe Tabanli



Learning Outcomes

Define heat as transfer of energy.

Calculate equilibrium temperature after heat transfer between two objects without phase change

State energy conservation after heat transfer between many objects with or without phase change

Calculate thermal conductivity.

Calculate total heat transfer between a cold reservoir and hot reservoir

Discuss the method of heat transfer by convection.

Calculate the radiation power of different materials.

Establish the relationship between the area, temperature, power, emissivity for objects that are going through a process

Concepts

ρ = Density

V = Volume

v = Velocity

A = Area

P = Pressure

P_0 = Zero level pressure

$P_0 = 1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$
for open containers
under normal conditions

$P_0 = 0$ for vacuum

h = Depth of the liquid column ,
measured downward

I = Rate of flow

F_B = Buoyant force

$W_{\text{displaced}}$ = Weight of the displaced
fluid

V_s = volume of submerged part of the
object

V_o = volume of an object

y = y coordinate of a point measured
upward

Units

SI UNITS

Density is in " kg/m^3 "

Pressure is in Pascal " Pa "

Height and y is in meters " m "

Rate of flow is in " m^3/s "

NON-SI UNIT

Pressure in atm

Pressure in Hgmm

Volume $1\text{L} = 10^{-3}\text{m}^3$

Formulas and Constants

$$\rho = m/V$$

Specific Gravity = Ratio of density of substance to water density

$$P = F/A$$

$$P_{\text{gauge}} = P_{\text{absolute}} - P_{\text{atmospheric}}$$

Pascal's principle

$$P_a = P_b \text{ at the same level of the liquid}$$

Archimedes' Principle

$$F_B = W_{\text{displaced}} = \rho(\text{liquid}) V(\text{object in the liquid}) g$$

when floating

$$\rho_o / \rho_l = V(\text{in}) / V_o$$

$$\rho_o / \rho_l = h(\text{in}) / h_o$$

$$\text{Apparent Weight} = mg - F_B$$

Apparent weight can be tension or normal force

$$P = P_o + \rho gh \text{ For static fluids}$$

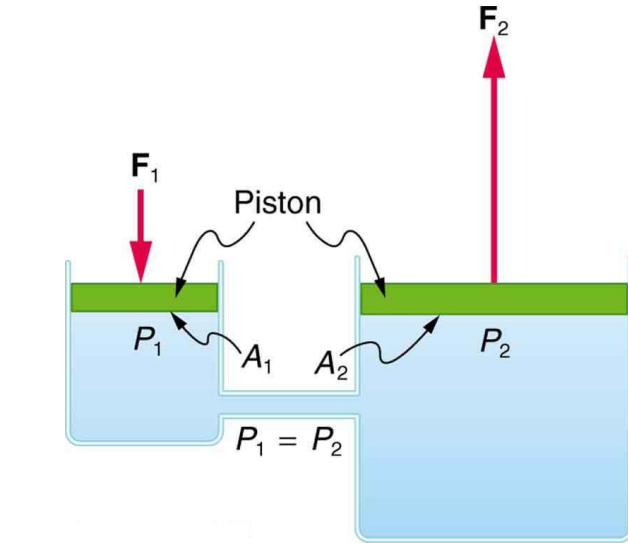
$$P = P_o + \rho_1 g h_1 + \rho_2 g h_2 + \dots \text{ multiple layers}$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_1 \quad \text{Bernoulli's equation}$$

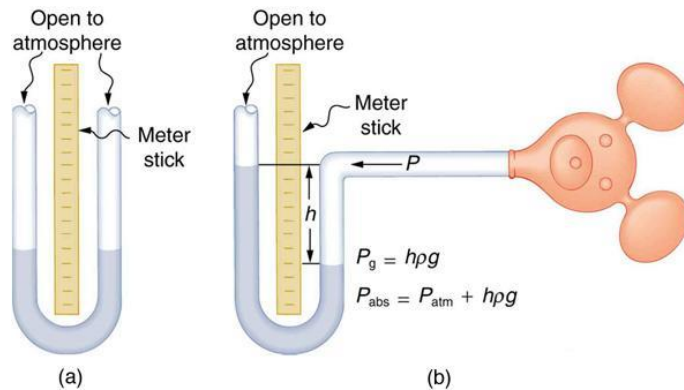
$$A_1 v_1 = A_2 v_2 \text{ continuity}$$

PASCAL PRINCIPLE

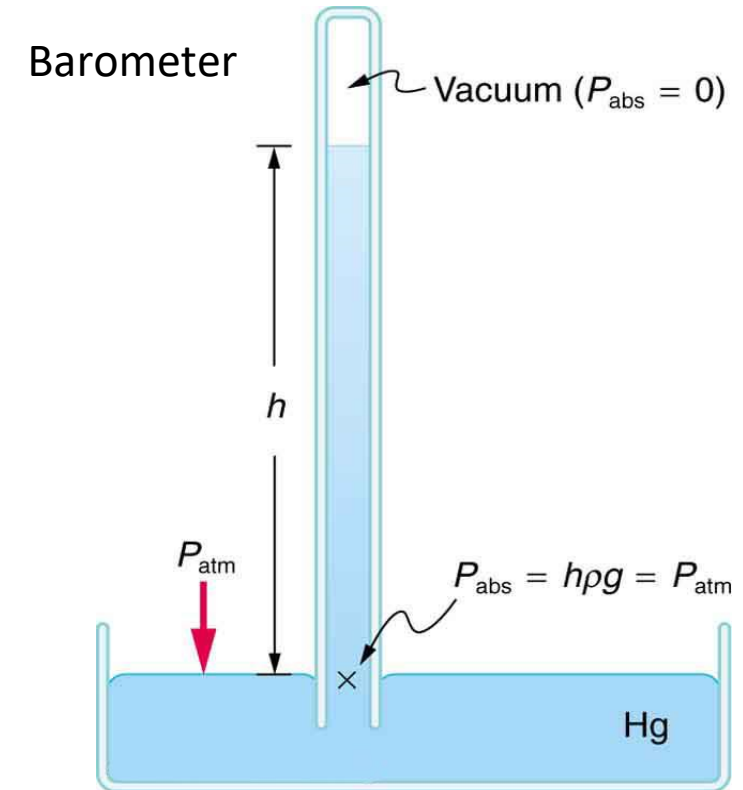
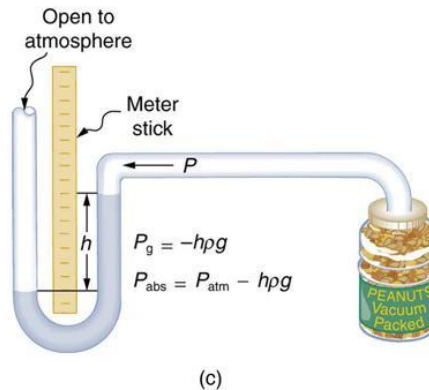
Depth Variance of Pressure in Static Fluids



Hydraulic Press



Manometers

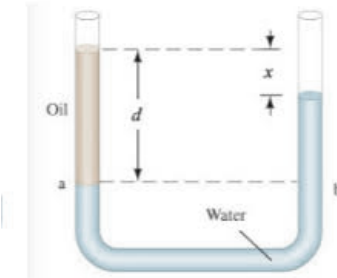


Barometer

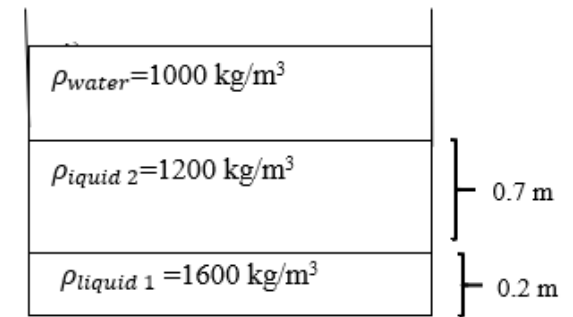
CLASSWORK FOR PASCAL PRINCIPLE

Q1) A 10,000 N car is on a circular hydraulic press plate with radius 2 meters. A smaller plate with radius 0.4 meters is used for lifting the car. What is the force required to hold the car in equilibrium?

Q2) A U-tube manometer is filled with water. Oil with density 950 kg/m^3 is poured on one side to the height of 0.10 m. What is the level difference between the two sides of u-tube? ($P_a = P_b$)



Q3) 3 layers of liquid is poured on top of each other. What should be the height of water at the top so that the pressure at the bottom of the container is 120 kPa.



Q4) What is the level of the liquid in a Barometer under normal Atmospheric conditions if

A) Liquid water is exposed to air and the other side is a vacuum

B) Liquid mercury is exposed to air and the other side is a vacuum

C) Liquid mercury is exposed to air and the other side is closed, containing gas with pressure 90,000 Pascal

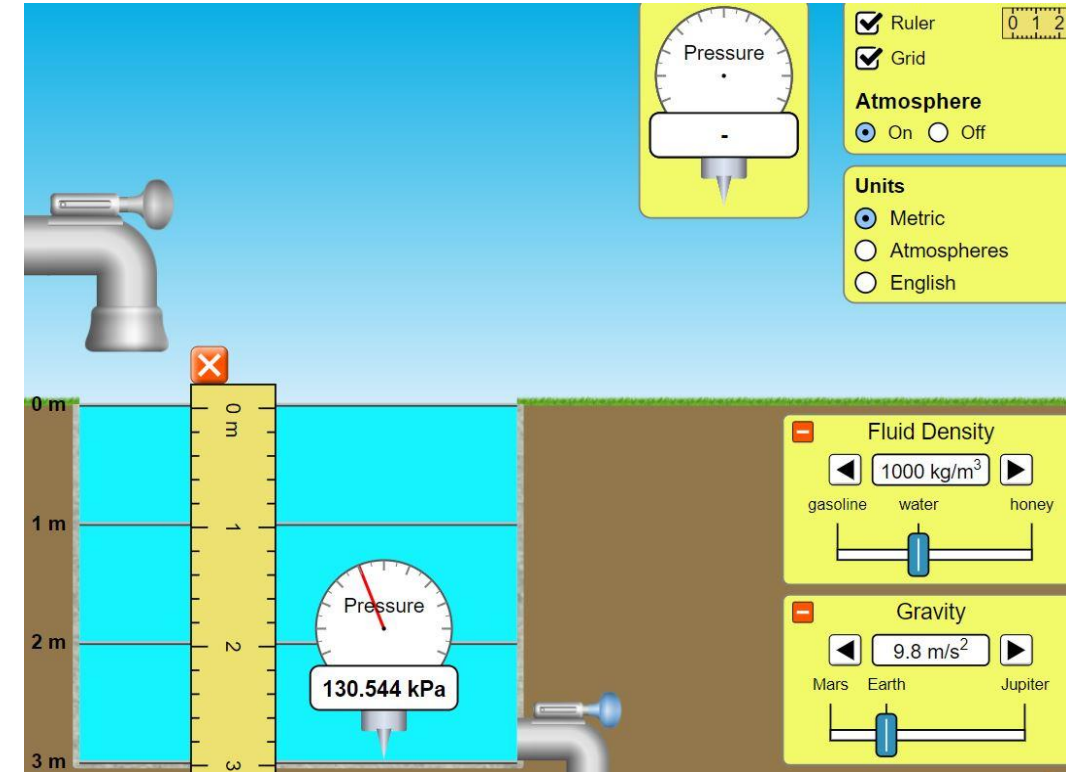
ACTIVITY FOR DEPTH VARIANCE OF PRESSURE

- Open the under pressure app at PhET
<https://phet.colorado.edu/en/simulations/under-pressure>

- Choose the first option. Click on ruler and grid.
- Start with water as your liquid. Set gravity to 9.8 m/s^2
- Fill the tank by opening the faucet
- Drag the pressure gauge, record its value at various depths
- Calculate the pressure at various depths and compare
- Fill the table below. Repeat the activity using different liquids and different gravity.

DATA: Density: Gravity: Po:

Depth (meters)	Pressure measured (units)	Pressure Calculated (units)
1		
2		
3		



ACTIVITY FOR PASCAL PRINCIPLE

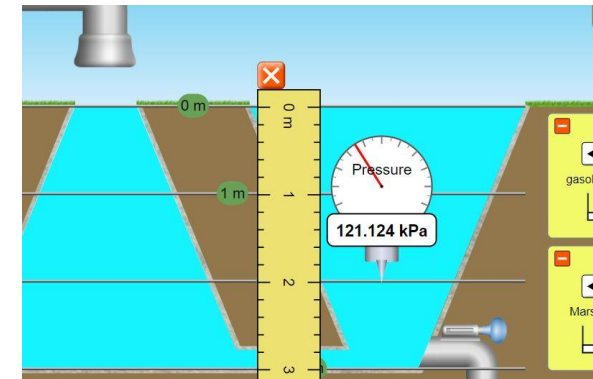
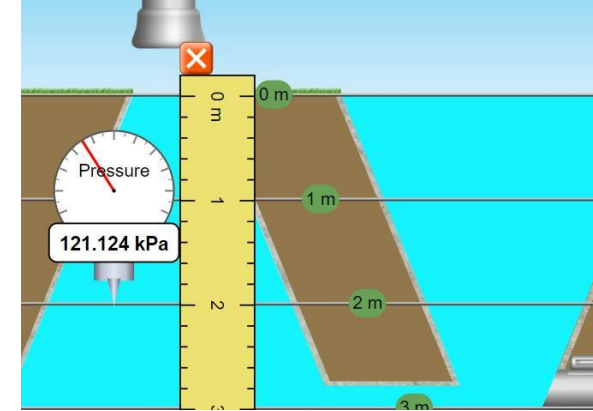
- Open the under pressure app at PhET
<https://phet.colorado.edu/en/simulations/under-pressure>
- Choose the second option. Click on ruler and grid.
- Fill the tank by opening the faucet
- Drag the pressure gauge, record its value at various depths
- For each depth record pressure on the left and on the right
- Fill the table below. Repeat the activity using different liquids and different gravity.

DATA: Density:

Gravity:

Po:

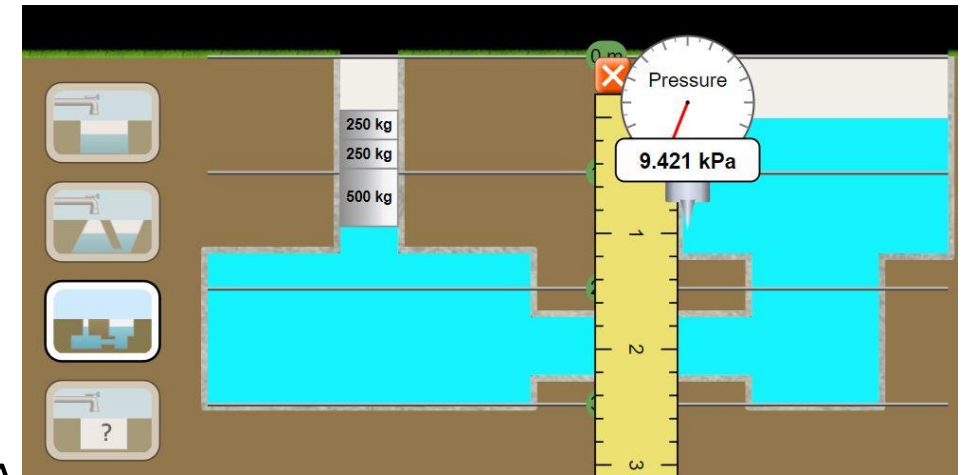
Depth (meters)	Pressure Left (units)	Pressure Right (units)
1		
2		
3		



ADVANCED ACTIVITY FOR PASCAL PRINCIPLE

1000 kg mass is placed on the left side of a u-shaped tank as shown in the graph. As a result, left side is pushed down by 0.96 meters relative to the right side. Using the Pascal principle and depth variance of pressure calculate the surface area of the 1000 kg mass.

- Open the under pressure app at PhET
<https://phet.colorado.edu/en/simulations/under-pressure>
- Choose the third option.
- Place all the masses on the left side
- Turn off the atmospheric pressure.
- Find the pressure of right from the depth
- Find the force on the left using $W=mg$
- Find the expression for the Pressure on the left using $P=F/A$
- Set $P(\text{left})=P(\text{right})$ solve for the unknown area.
- Change liquid density, gravity and mass and repeat the activity. Level difference between the left and the right side can be measured using the ruler tool or calculated using the pressure on the right.



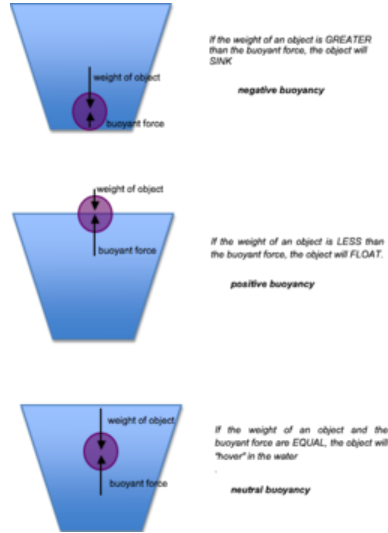
CLASSWORK FOR ARCHIMEDES PRINCIPLE

Floating Objects

Q1) 0.12 kg cork with 0.05 m^3 Volume is floating inside water. What is the volume inside the water?

Q2) A piece of wood is in sea water. What is the density of the log if 60% of the log is inside the water? (salt water density is 1030 kg/m^3)

Q3) Watermelon is floating inside a liquid with 100% of its volume is inside. What is the condition for this float?



Floating

$$\rho_o/\rho_l = V(\text{in})/V_o$$

$$\rho_o/\rho_l = h(\text{in})/h_o$$

Sinking

$$\text{Apparent Weight} = mg - F_B$$

$$F_B = W_{\text{displaced}}$$

$$F_B = \rho(\text{liquid}) V(\text{object}) g$$

Sinking Objects

Q4) 7 kg Iron is placed inside water. What is the normal force acted on it? (Density of Iron is 7900 kg/m^3)

A) Find its weight

B) Find its volume

C) Find F_B and Apparent Weight

Q5) Aluminum with 0.2 m^3 volume is placed inside the water on a triple beam scale. What is the tension on the wire that holds the aluminum. (Density of Aluminum is 2700 kg/m^3)

A) Find its mass and its weight

B) Find F_B and Apparent weight

KEY STRATEGIES FOR BERNOULLI'S EQUATION

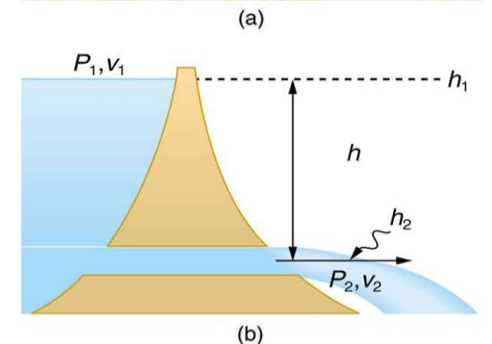
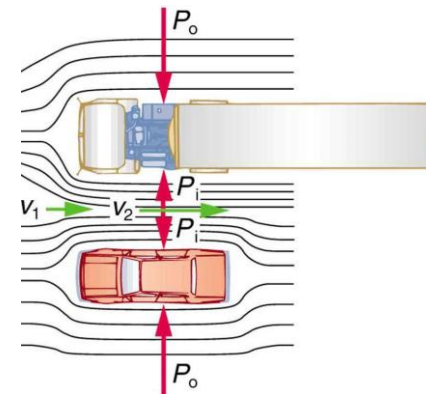
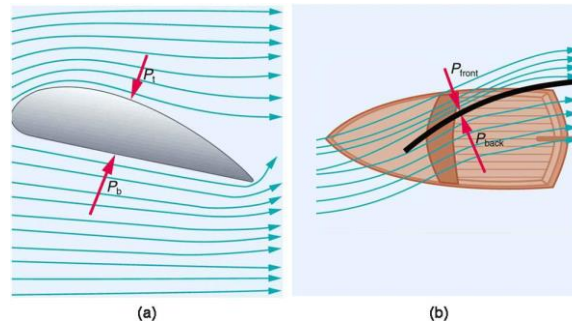
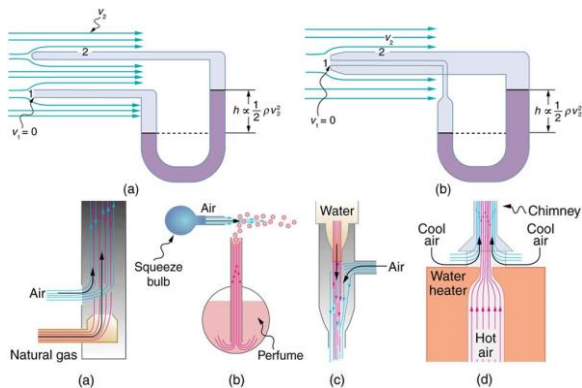
$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$$

Bernoulli's equation $A_1 v_1 = A_2 v_2$ continuity equation

- Find two reference points with either different speeds, different heights or pressure
- Label them with the index 1 and index 2
- From the word problem and/or graph identify $P_1, v_1, y_1, P_2, v_2, y_2$
- Identify your unknown
- Write the Bernoulli's equation and solve for the unknown using the numbers given in the problem

SPECIAL CASES

- If the pressure difference is asked, solve for either $P_2 - P_1$ or $P_1 - P_2$
- If pipe is vertical $y_1 = y_2$, cross them out
- If both sides are open to air $P_1 = P_2$, cross them out
- If the pipe size doesn't change, $v_1 = v_2$ cross them out



CLASSWORK FOR BERNOUILLI'S EQUATION

Q1) A water tank is 5 meters tall. At the base of the tank there is hole. What is the velocity of the water coming from the hole? Consider that the water speed at the top is negligible.

Q2) Water is flowing from a wide vertical pipe with $v=3$ m/s. At one point the pipe narrows due to build up and as a result water's velocity becomes $v= 7$ m/s. What is the pressure difference between the narrow point and wider point?

Q3) Water is flowing from a Z-shaped tube with constant cross-sectional area. The height difference between the top and the bottom is 0.50 meters and water pressure at the top is 6000 Pa. What is the water pressure at the bottom?

Q4) Water is flowing from a diagonal tube. At the ground level of the tube the speed of 4 m/s and the pressure is 70000Pa. What is the pressure in the tube 5 meters above the ground, if the water flows with speed of 6 m/s due to narrowing? Find the ratio of the areas at the bottom to the top

REFERENCES

- Slide 1, 6, 12 Open Stax College Physics online textbook
- Slide 7: Gen-Ed-Phys-I Workbook by M.Tabanli and J. Meenu and Open Stax College Physics online textbook
- Slides 8-9-10 Screenshot from PhET Interactive Simulations University of Colorado Boulder
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