Physics 115
General Physics II

B. Pascal, 1623-1662

Session 2

Fluid statics: density and pressure

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Lecture Schedule (up to exam 1)

Date	Day	Lect.	Topic	readings in Walker
31-Mar	Mon	1	Introduction, Preview	
1-Apr	Tues	2	Density & Pressure	15.1-15.3
3-Apr	Thurs	3	Static Fluids, Buoyancy	15.4-15.5
4-Apr	Fri	4	Fluid Flow, Bernoulli	15.6-15.8
7-Apr	Mon	5	Viscosity, Flow, Capillaries	15.9
8-Apr	Tues	6	Temperature, expansion	16.1-16.3
10-Apr	Thurs	7	Heat, Conduction	16.4-16.6
11-Apr	Fri	8	Ideal gas	17.1-17.2
14-Apr	Mon	9	Heat, Evaporation	17.4-17.5
15-Apr	Tues	10	Phase change	17.6
17-Apr	Thurs	11	First Law Thermodynamics	18.1-18.3
18-Apr	**Fri**		**EXAM 1 Ch 15,16,17**	

Today

Just joined the class? See course home page
courses.washington.edu/phy115a/
for course info, and slides from previous sessions

Announcements

- You must log in to WebAssign to get your name onto the class roster for grades
  - Done automatically when you first log in, no other action required
  - BTW, you get 10 tries on each HW item
- Clicker registration is now open - Follow link on course home page: https://catalyst.uw.edu/webq/survey/wilkes/231214

  REQUIRED to let us connect your name to your clicker responses, and to create a personal screen name

Other items:

- Recommended weekly reading: *NY Times* Tuesdays: Science Section
- Recommended weekly viewing: Neil deGrasse Tyson's *Cosmos*

www.globaltv.com/cosmos/episodeguide/

- 115A sessions are recorded on Tegrity

  Go to uw.tegrity.com

Using HiTT clickers

- Older model TX3100
    - New model TX3200
- We'll use them in class next time

- Required to enter answers in quizzes
  - Be sure to get radio (RF), *not* infrared (IR)

1. Set your clicker to radio channel #01 for this room
2. Find and write down its serial number
3. Register your clicker (connects your name to the clicker serial number)

- Go to 115A class home page and click on "CLICKER PROGRAMMING: how to program (and reprogram) and register your clicker" for details on programming and registration

Topics for this week

- ✓ Fluids overview
- ✓ Density
- Pressure
- Static equilibrium in fluids
- Pressure vs depth
- Archimedes' Principle and buoyancy
- Continuity and fluid flow
- Bernoulli's equation

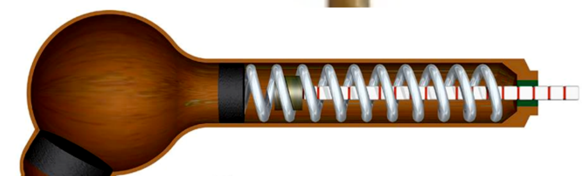
Read each day's assigned text sections <u>before</u> class

Last time:
(revised for clarity)

“Gauge” pressure

- Pressure gauges usually read P *relative to* atmospheric pressure:

  $P_g = P - P_{atm}$



Tire-pressure gauge

- Example: Tire gauge reads 35 lb/in^2

  What is the “absolute” pressure of air in the tire?

$$101.325 \text{ kPa} = 14.70 \text{ lb/in}^2 (psi)$$

Use this fact to convert units

$$35\, psig = 35\, psi \left(\frac{101.325 \text{ kPa}}{14.7\, psi} \right) = 241.25 \text{ kPa} = P_g = P - P_{ATM}$$

$$P = P_g + P_{ATM} = 101.325 \text{ kPa} + 241.25 \text{ kPa} = 342.575 \text{ kPa}$$

$$P = 342.575 \text{ kPa} \left(\frac{14.70\, psi}{101.325 \text{ kPa}} \right) = 49.7\, psia$$

Gauge pressure = “psig”
Absolute pressure = “psia”

Fluid pressure

- Fluids exert pressure on all submerged surfaces
  - Force always acts perpendicular to surface
    - Otherwise, fluid would just flow!
- Atmospheric pressure is equal on all sides of a (small) object
- If pressure inside an object is lowered, or external pressure is too great, fluid pressure may crush it
  - Examples: apply vacuum pump to a metal can
    - Styrofoam wig form submerged to 900m depth in ocean:

Standard oceanography student game: attach styrofoam to equipment being lowered to great depth: water pressure crushes it *uniformly*, so it retains shape

http://www.mesa.edu.au/deep_sea/images/styrofoamhead.jpg

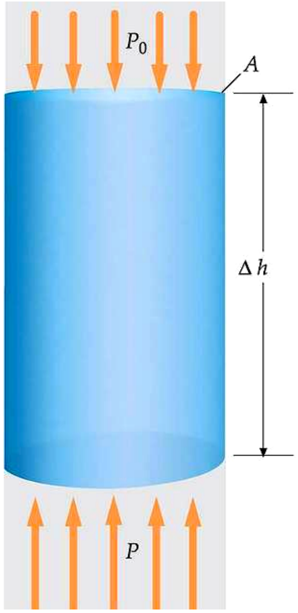
Pressure vs depth

- Force on a surface of area A at depth h = weight of fluid above: $$F_g = mg = (\rho V)g = \rho A h g$$
  - But we must take into account atmospheric pressure also!
- Force = pressure*area, so $PA - P_0 A = (\rho A h g)$

  P_0 = pressure of atmosphere at fluid surface

$$P = P_0 + \rho g h \quad \text{(assuming } \rho \text{ is constant)}$$

In general, pressure at location 2 which is h **deeper** than location 1 is: $$P_2 = P_1 + \rho g h$$



Example: diving

How far below the surface of a freshwater lake is a diver, if the pressure there is 2.0 atm?

(*Recall:* The pressure at the surface is 1.0 atm.)

$$P = P_0 + \rho g \, \Delta h$$

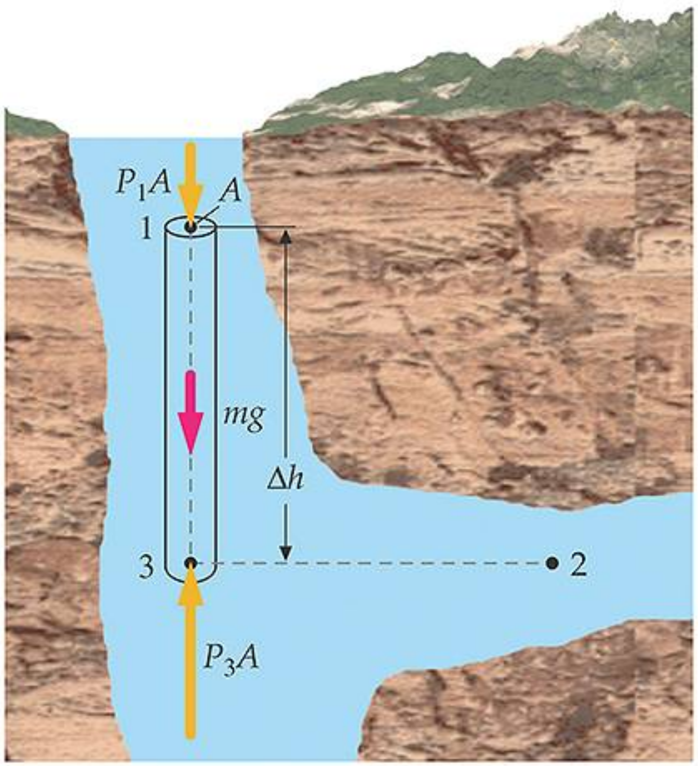
$$\Delta h = \frac{P - P_0}{\rho g}$$

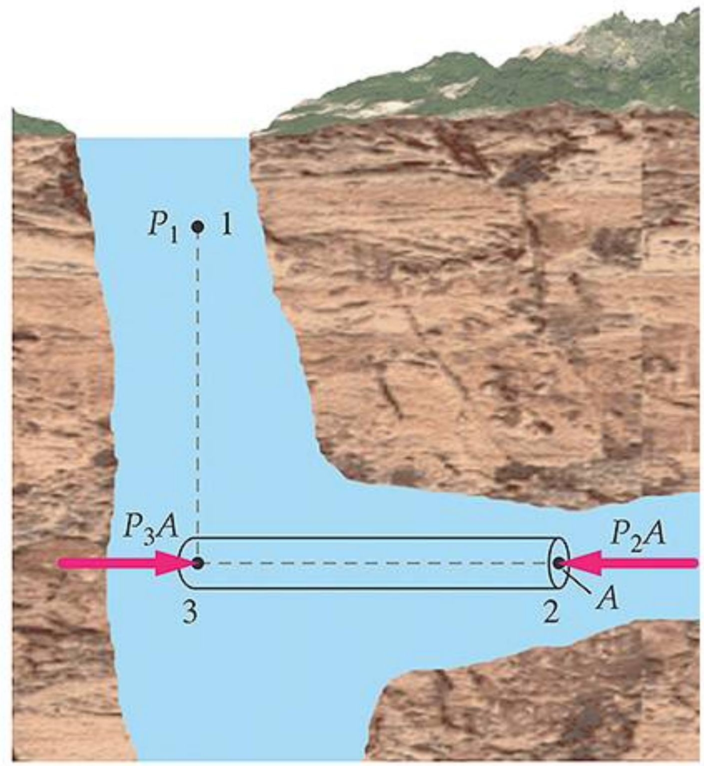
$$= \frac{\left[(2.0 \text{ atm}) - (1.0 \text{ atm})\right] 101 \text{ kPa/atm}}{(1000 \text{ kg/m}^3)(9.81 \text{ N/kg})}$$

$$= \boxed{10.33 \text{ m}}$$

Underwater cave example

- Compare pressures at points 1 and 2 (depth difference h) and 3 (*same* depth as 2):





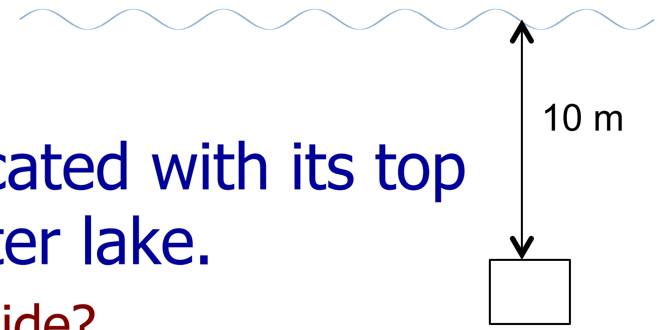
$$P_2 = P_3$$

(same depth)

$$P_3 = P_1 + \rho g \Delta h$$

$$so \quad P_2 = P_1 + \rho g \Delta h \quad also$$

Empty box underwater



- An empty box 1 m on each side is located with its top 10 m under the surface of a freshwater lake.
  - What is the (gauge) pressure on its top side?
    - "gauge" – so, subtract the atmospheric pressure and consider only pressure due to the water column

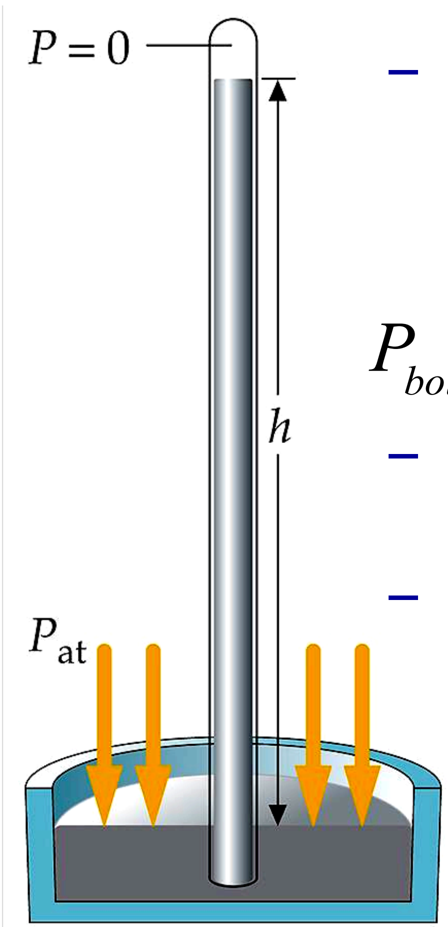
$$P_{TOP} = \rho g h = \left(1000\text{kg/m}^3\right)\left(9.8\text{m/s}^2\right)\left(10\text{m}\right) = 98kPa$$

  - Q: why use *gauge* – when would *absolute* be useful?
  - What is the *gauge* pressure on its bottom side?

$$P_{BOTTOM} = \rho g h = \left(1000\text{kg/m}^3\right)\left(9.8\text{m/s}^2\right)\left(11\text{m}\right) = 107.8kPa$$

    - Notice we measure h *downward* from the surface
  - What does the 10 kPa pressure *difference* between top and bottom imply...?

Barometers (atmospheric pressure measurement)



- Toricelli's barometer (c. 1640)
  - Fill long glass tube, 1 end closed, with mercury (Hg)
  - Invert it and put open end in a dish of Hg
    - Empty space at top is "vacuum" : *P ~ 0*

    (actually: Hg vapor, but negligible pressure)

$$P_{bottom} - P_{at} = (0 + \rho g h) - P_{at} \rightarrow P_{at} = \rho g h$$

  - Atmospheric pressure on the dish supports a column of Hg of height h
  - Column is at rest so pressures at bottom must balance:

$$P_{ATM} = \rho_{Hg} g h$$

$$h = P_{ATM} / \rho_{Hg} g$$

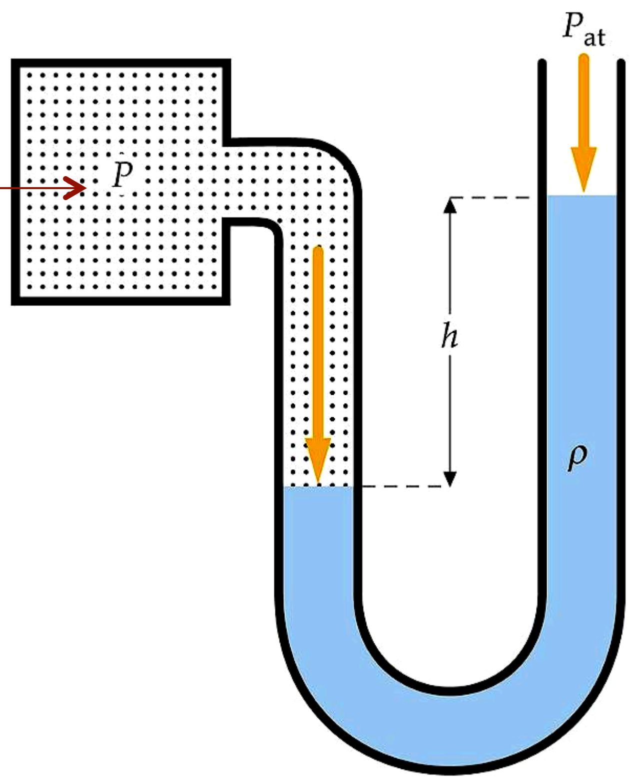
$$= (101.3kPa) / (9.8m/s^2)(13600kg/m^3)$$

$$= 0.760m$$

Manometers (fluid pressure gauges)

- Use a U-tube filled with fluid (Hg, water, etc) to measure pressure
- Height difference between sides indicates pressure P

P we want to measure



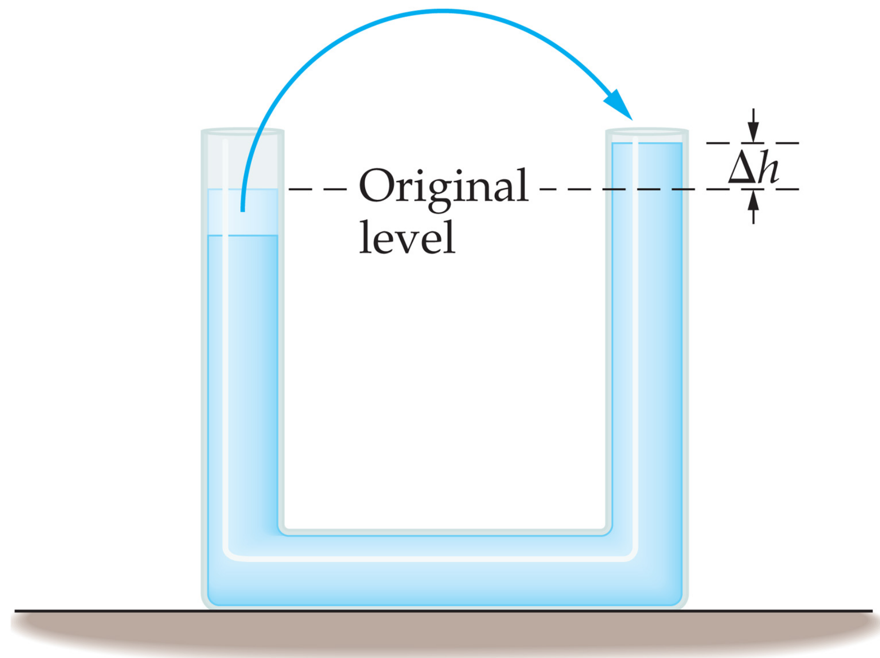
$$P - P_{at} = \rho g h$$

Deep thought

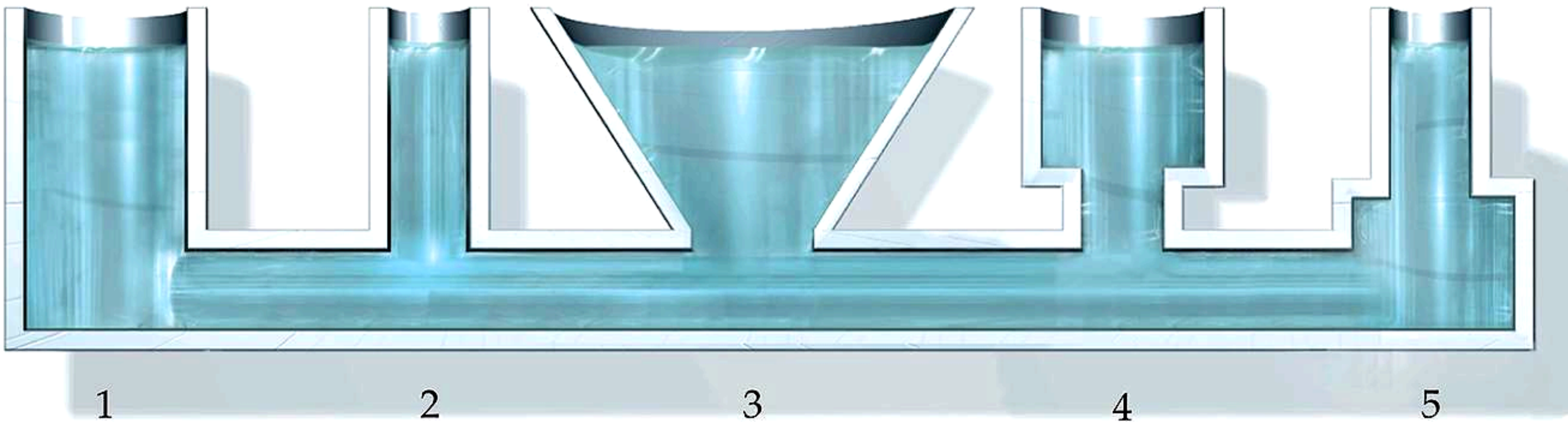
- U-tube filled with fluid : we "naturally" expect sides to be equal in height
  - We just saw this can be explained in terms of equalized P
- We can also think in terms of energy

To get unequal levels, we'd have to raise some mass of fluid: do work on it to increase its potential E

So: Equal levels represent the minimum energy arrangement for the system



Pascal's Vases: paradox?



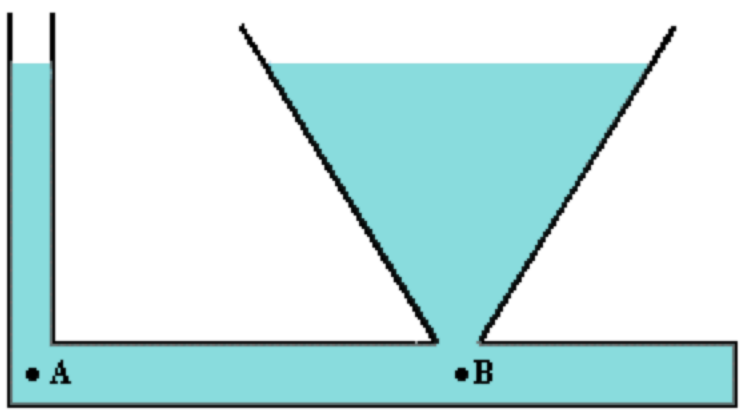
The water level in each section is the same, independent of shape.

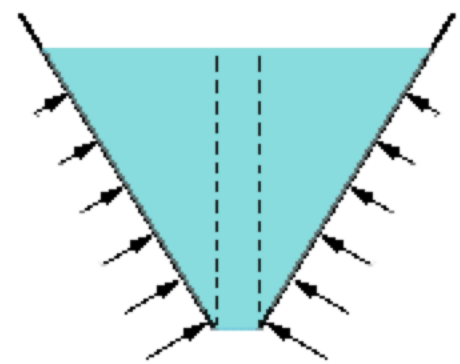
But P is the same for all - no flow! We say this must be so because h is the same at the bottom of each section

Q: What supports the extra water volume in the flared shapes?

Hydrostatic paradox resolved: apply phys 114

- Forces exerted by the sides of the cone are perpendicular to the walls (pressure direction)
  - Vertical components support the water above the sides
- Only the column of water directly above the bottom opening contributes to pressure at the base of the cone - glass structure supports the rest





http://scubageek.com/articles/wwwparad.html

Pascal's Principle (1646)

- Pressure at depth h in container

$$P = P_0 + \rho g h$$

  - P_0 = atmospheric pressure
- Increase P_0 by P_1 :

$$P' = \left(P_0 + \rho g h\right) + P_1$$

- So P anywhere in fluid is increased by P_1

"External pressure applied to an enclosed fluid is transmitted to *every point* in the fluid"

- Blaise Pascal's demonstration:
  - Put a 10m pipe into closed full barrel
  - Insert a narrow pipe, fill with water
  - Barrel bursts!

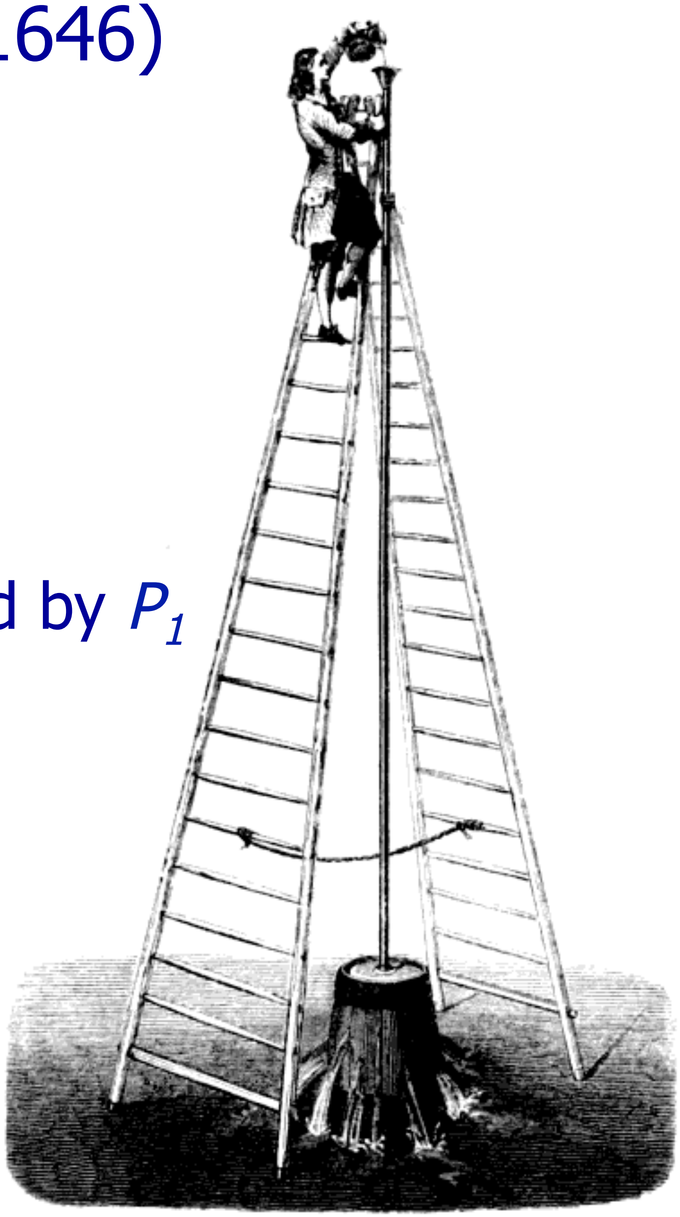


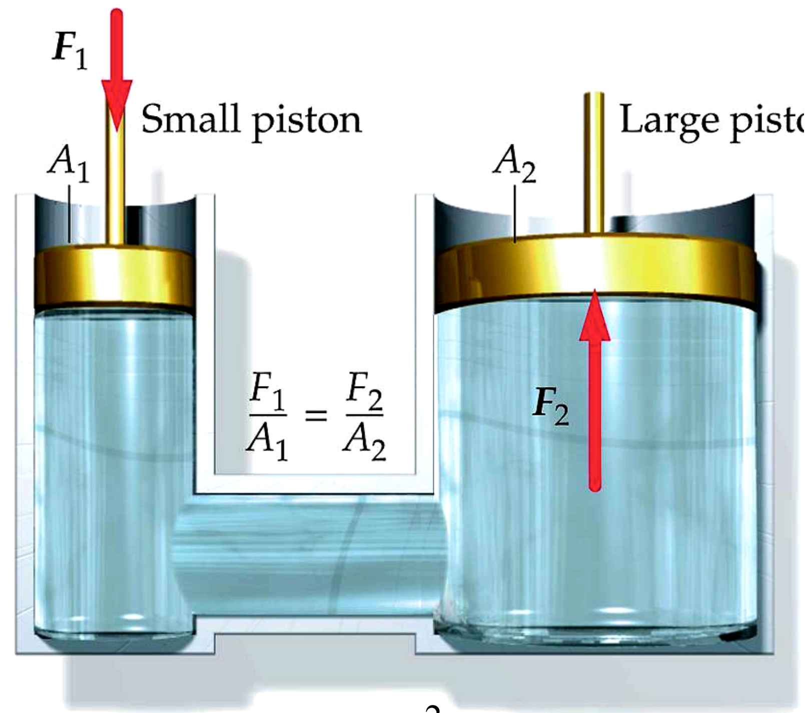
FIG. 45.—Hydrostatic paradox. Pascal's experiment.

Applying Pascal's principle: hydraulic lift

The large piston of a hydraulic lift has a radius of 20 cm.

What force must be applied to the small piston of radius 2.0 cm to raise a car of mass 1,500 kg?

(***weight*** = mg = 14,700 N)



$$PA_2 = mg \text{ so } P = \frac{mg}{A_2}$$

$$F_1 = PA_1 = mg\frac{A_1}{A_2} = mg\frac{\pi r_1^2}{\pi r_2^2} = mg(r_1/r_2)^2$$

$$= (1500 \text{ kg})(9.81 \text{ N/kg})(2.0 \text{ cm} / 20 \text{ cm})^2$$

$$= \boxed{147 \text{ N}}$$

$F_2 = 100\ F_1$