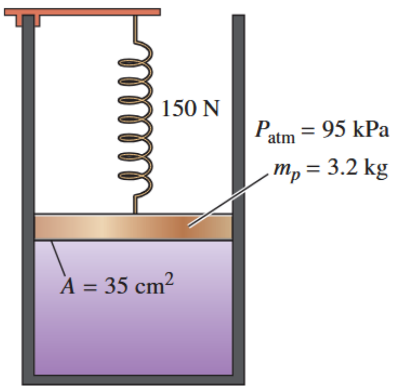
1-58

1–58 A gas is contained in a vertical, frictionless piston–cylinder device. The piston has a mass of 3.2 kg and a cross-sectional area of 35 cm². A compressed spring above the piston exerts a force of 150 N on the piston. If the atmospheric pressure is 95 kPa, determine the pressure inside the cylinder. *Answer:* 147 kPa



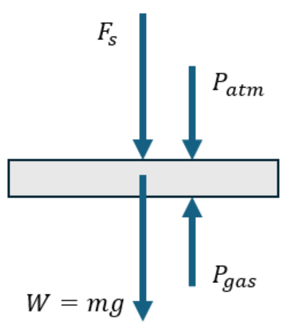
Given:

- Spring force, $F_s = 150\,\text{N}$
- Mass of piston, $m = 3.2\,\text{kg}$
- Area of piston, $A = 35\,\text{cm}^2$
- Atmospheric pressure, $P_{atm} = 95\,\text{kPa}$

Find:

- Pressure of gas inside cylinder, P_{gas}

Drawing a FBD of the piston:



Using the formula for pressure: $\boxed{P = F/A}$, we can find the force exerted by the gas on the piston and write the vertical force balance:

$$\sum F_y = P_{gas}A - F_s - mg - P_{atm}A = 0$$

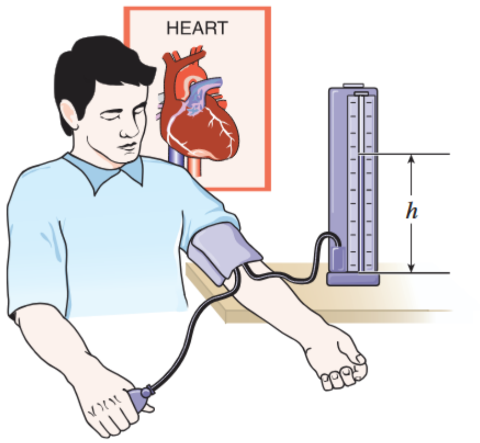
$$\implies P_{gas} = \frac{F_s + mg}{A} + P_{atm}$$

Plugging in the values:

$$P_{\text{gas}} = \frac{[150\,\text{N}] + [3.2\,\text{kg}]\,[9.81\,\text{m/s}^2]\left[\frac{\text{N}}{\text{kg}\cdot\text{m/s}^2}\right]}{[35\,\text{cm}^2]\left[\frac{(10^{-2}\text{m})^2}{\text{cm}^2}\right]} + [95\,\text{kPa}]\left[\frac{10^3\text{Pa}}{\text{kPa}}\right] = 146826.28\,\text{Pa} \approx \boxed{147\,\text{kPa}}$$

1-70

1–70 The maximum blood pressure in the upper arm of a healthy person is about 120 mmHg. If a vertical tube open to the atmosphere is connected to the vein in the arm of the person, determine how high the blood will rise in the tube. Take the density of the blood to be 1050 kg/m^3.



Given:

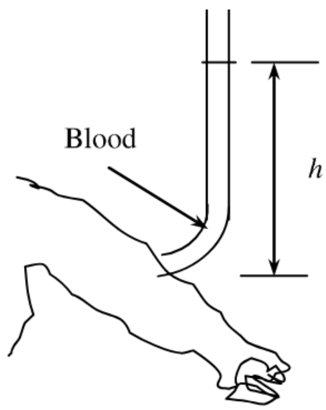
- The gauge pressure of blood is measured with a column of mercury of height

$$h_{Hg} = 120\,\text{mm}$$

- $\rho_{blood} = 1050\,\text{kg/m}^3$
- $\rho_{Hg} = 13600\,\text{kg/m}^3$

Find:

- Height of blood column, h_{blood}



For a given gauge pressure, we can find the height/depth of a fluid column using the hydrostatic pressure formula:

$$P = \rho g h$$

Since the pressure P exerted by the blood is the same regardless of whether we measure it using a column of mercury or a column of blood, we can set the two hydrostatic pressure equations equal to each other:

$$P = \rho_{Hg} g h_{Hg} = \rho_{blood} g h_{blood}$$

$$\implies h_{blood} = \frac{\rho_{Hg} h_{Hg}}{\rho_{blood}}$$

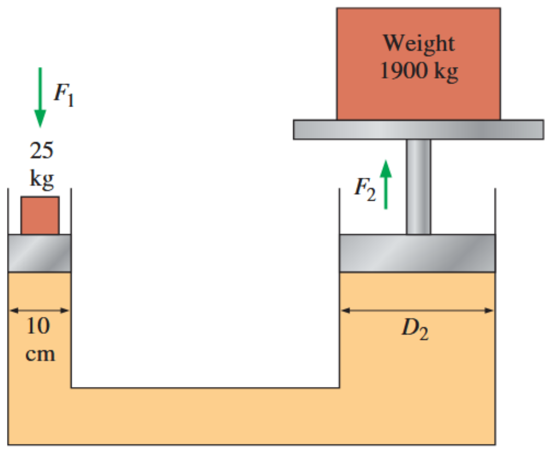
Plugging in the values:

$$h_{blood} = \frac{[13600\,\text{kg/m}^3][0.12\,\text{m}]}{[1050\,\text{kg/m}^3]} = 1.554\,\text{m} \approx \boxed{1.55\,\text{m}}$$

<u>Note:</u> The pressures are gauge pressures because they are measured relative to atmospheric pressure, so we don't have to account for atmospheric pressure in our calculations.

1-90

1–90 A hydraulic lift is to be used to lift a 1900-kg weight by putting a weight of 25 kg on a piston with a diameter of 10 cm. Determine the diameter of the piston on which the weight is to be placed.



Given:

- $m_1 = 25\,\text{kg}$
- $m_2 = 1900\,\text{kg}$
- $D_1 = 10\,\text{cm}$

Find:

- D_2 such that m_1 lifts m_2

Pascal's Principle states that the pressure applied to a confined fluid increases the pressure throughout the fluid by the same amount. Thus, the pressure applied on piston 1 is equal to the pressure applied on piston 2 ($P_1 = P_2$). Solving this equation will give us the minimum diameter D_2 such that m_1 can lift m_2.

$$P_1 = \frac{F_1}{A_1} = \frac{m_1 g}{\frac{1}{4}\pi D_1^2}, \quad P_2 = \frac{F_2}{A_2} = \frac{m_2 g}{\frac{1}{4}\pi D_2^2}$$

$$\implies \frac{m_1 g}{\frac{1}{4}\pi D_1^2} = \frac{m_2 g}{\frac{1}{4}\pi D_2^2}$$

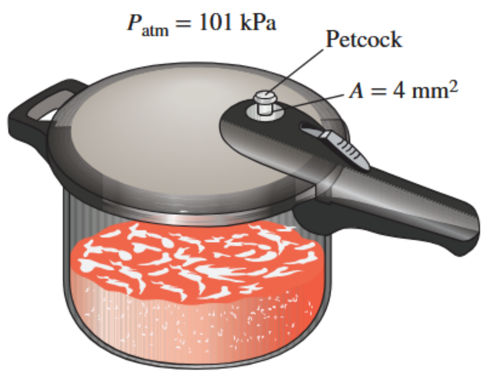
$$\implies D_2 = D_1\sqrt{\frac{m_2}{m_1}}$$

Plugging in the values:

$$D_2 = [10\,\text{cm}]\sqrt{\frac{[1900\,\text{kg}]}{[25\,\text{kg}]}} = 87.177\,\text{cm} \approx \boxed{87.2\,\text{cm}}$$

1-105

1–105 A pressure cooker cooks a lot faster than an ordinary pan by maintaining a higher pressure and temperature inside. The lid of a pressure cooker is well sealed, and steam can escape only through an opening in the middle of the lid. A separate metal piece, the petcock, sits on top of this opening and prevents steam from escaping until the pressure force overcomes the weight of the petcock. The periodic escape of the steam in this manner prevents any potentially dangerous pressure buildup and keeps the pressure inside at a constant value. Determine the mass of the petcock of a pressure cooker whose operation pressure is 100 kPa gage and has an opening cross-sectional area of 4 mm^2. Assume an atmospheric pressure of 101 kPa, and draw the free-body diagram of the petcock. *Answer:* 40.8 g



Pressure cooker

Given:

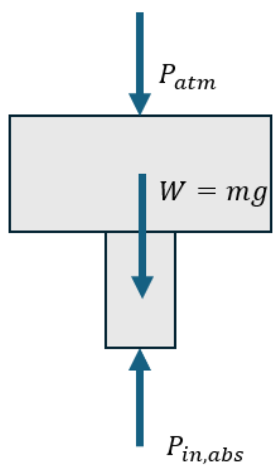
- Gauge pressure inside pressure cooker, $P_{in,gauge} = 100\,\text{kPa}$
- The opening area of the valve, $A = 4\,\text{mm}^2$
- Atmospheric pressure, $P_{atm} = 101\,\text{kPa}$

Find:

- Mass of petcock required to open at pressure $P_{in,gauge}$

Assuming that the atmospheric pressure acts on an area equal to A.

FBD of the petcock:



Recall: $P_{gauge} = P_{abs} - P_{atm} \implies P_{abs} = P_{gauge} + P_{atm}$

The vertical force balance on the petcock is:

$$\sum F_y = P_{in,abs}A - P_{atm}A - mg = 0$$

$$\implies (P_{in,gauge} + P_{atm})A - P_{atm}A - mg = 0$$

$$\implies P_{in,gauge}A - mg = 0 \implies m = \frac{P_{in,gauge}A}{g}$$

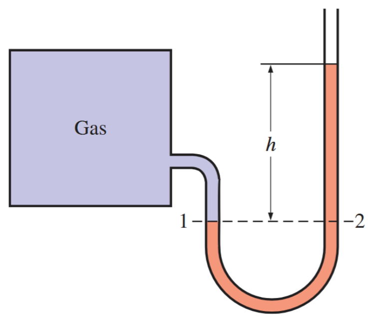
Plugging in the values:

$$m = \frac{[100\,\text{kPa}]\left[\frac{10^3\text{Pa}}{\text{kPa}}\right][4\,\text{mm}^2]\left[\frac{(10^{-3}\text{m})^2}{\text{mm}^2}\right]}{[9.81\,\text{m/s}^2]} = 0.04077\,\text{kg} \approx \boxed{40.8\,\text{g}}$$

1-110

How measuring with a manometer works:

- **Basic single fluid manometer:**



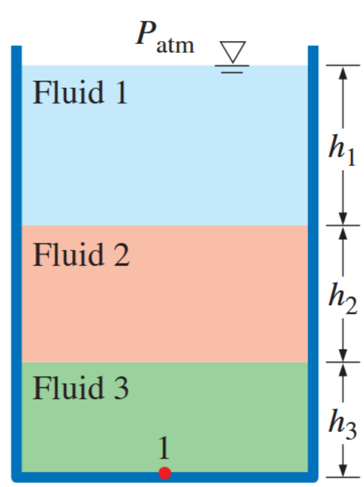
The pressure in a fluid does not change with horizontal position (equal depth), so the pressure at points 1 and 2 are equal:

$$P_1 = P_2$$

Where we use the hydrostatic pressure formula to express the pressures at points 1 and 2:

$$P_1 = P_{gas}, \quad P_2 = P_{atm} + \rho g h$$

- **Pressure with multiple layers of fluid:**



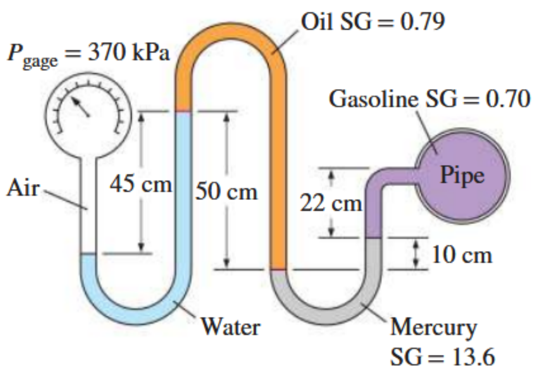
We use the following rules to find the pressure at different points in a fluid with multiple layers:

1. The pressure change across a fluid layer is given by the hydrostatic pressure formula: $\Delta P = \rho g h$
2. Pressure increases downward (+) and decreases upward (-).
3. The pressure at points of equal depth in a fluid are equal (Pascal's Principle).

Ex: At point 1 in the figure, $P_1 = P_{atm} + \rho_1 g h_1 + \rho_2 g h_2 + \rho_3 g h_3$

Solving 1-110:

1–110 A gasoline line is connected to a pressure gage through a double-U manometer, as shown in Fig. P1–110. If the reading of the pressure gage is 370 kPa, determine the gage pressure of the gasoline line.



Given:

- $P_{gauge} = 370\,\text{kPa}$
- Specific gravities
  - Oil: $SG_{oil} = 0.79$
  - Mercury: $SG_{Hg} = 13.6$
  - Gasoline: $SG_{gas} = 0.70$
- Height differences:
  - $h_{water} = 45\,\text{cm}$
  - $h_{oil} = 50\,\text{cm}$
  - $h_{Hg} = 10\,\text{cm}$
  - $h_{gas} = 22\,\text{cm}$

Find:

- Gauge pressure of gas line.

Specific gravity is defined as a relative density compared to water (at 4°C) where $\rho_{water} = 1000\,\text{kg/m}^3$:

$$\boxed{SG = \frac{\rho_{fluid}}{\rho_{water}} \implies \rho_{fluid} = SG \cdot \rho_{water}}$$

We will apply the pressure rules for multiple layers of fluid to the manometer:

1. We will begin at a known pressure point (gauge or atmospheric pressure) and follow the fluid layers to the unknown pressure point.

2. Sign convention: add when going down, subtract when going up.

3. **Horizontal jump:** We can "jump" horizontally across bends in the tube if both sides of the jump are within the **same continuous fluid**. This is because pressure is identical at the same horizontal level within a single static fluid. *Any pressure decrease*

from moving upward is perfectly balanced by an equal pressure increase when moving back down to that same level on the other side.

4. Thus, we only calculate vertical heights between **interfaces**.

Therefore:

$$P_{gauge} - \rho_{water} g h_{water} + \rho_{oil} g h_{oil} - \rho_{Hg} g h_{Hg} - \rho_{gas} g h_{gas} = P_{gas}$$
$$\implies P_{gas} = P_{gauge} + \rho_{water} g(-h_{water} + SG_{oil} h_{oil} - SG_{Hg} h_{Hg} - SG_{gas} h_{gas})$$

Plugging in the values:

$$P_{gas} = [370\,\text{kPa}] + [1000\,\text{kg/m}^3][9.81\,\text{m/s}^2]\Big(-[0.45\,\text{m}] + [0.79][0.5\,\text{m}] - [13.6][0.1\,\text{m}] - [0.70][0.22\,\text{m}]\Big)$$

$$P_{gas} = [370\,\text{kPa}] - \left[15391.89\,\frac{kg}{m \cdot s^2}\right]\left[\frac{N}{kg \cdot m/s^2}\right]\left[\frac{Pa}{N/m^2}\right]$$
$$= [370\,\text{kPa}] - [15.391\,\text{kPa}] = 354.609\,\text{kPa} \approx \boxed{354.6\,\text{kPa}}$$

1-118

1–118 During a heating process, the temperature of an object rises by 10°C. This temperature rise is equivalent to a temperature rise of
(*a*) 10°F (*b*) 42°F (*c*) 18 K (*d*) 18 R (*e*) 283 K

List of relevant temperature conversions:

- Absolute temperature conversions
  - $T_K = T_{\circ C} + 273.15$
  - $T_{\circ R} = T_{\circ F} + 459.67$
  - $T_{\circ F} = \frac{9}{5} T_{\circ C} + 32$
  - $T_{\circ R} = \frac{9}{5} T_K$
- Temperature difference conversions
  - $\Delta K = \Delta ^\circ C$
  - $\Delta ^\circ R = \Delta ^\circ F$
  - $\Delta ^\circ F = \frac{9}{5} \Delta ^\circ C$
  - $\Delta ^\circ R = \frac{9}{5} \Delta K$

Note: Fahrenheit and Celsius are relative temperature scales (based on the freezing/boiling points of water), while Rankine and Kelvin are absolute temperature scales (starting at absolute zero).

Plug and chug for 1-118 gives $\boxed{d)\,18\,R}$