

AP[®]

Pressure

Unit: Fluids & Pressure

NGSS Standards/MA Curriculum Frameworks (2016): HS-PS2-10(MA), HS-PS2-1

AP[®] Physics 1 Learning Objectives/Essential Knowledge (2024): 8.2.A, 8.2.A.1, 8.2.A.2, 8.2.A.3, 8.2.B, 8.2.B.1

Mastery Objective(s): (Students will be able to...)

- Calculate pressure as a force applied over an area.

Success Criteria:

- Pressures are calculated correctly and have correct units.

Language Objectives:

- Understand and correctly use the terms “force”, “pressure” and “area” as they apply in physics.
- Explain the difference between how “pressure” is used in the vernacular vs. in physics.

Tier 2 Vocabulary: fluid, pressure

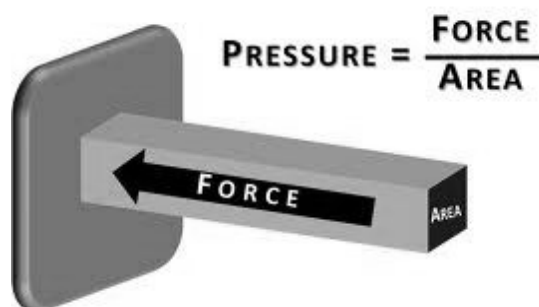
Labs, Activities & Demonstrations:

- Balloon.
- Pinscreen (pin art) toy.
- Balloon & weights on small bed of nails.
- Full-size bed of nails.

Notes:

pressure: the exertion of force upon a surface by an object, fluid, etc. that is in contact with it.

Mathematically, pressure is defined as force that is perpendicular to a surface divided by area of contact:



$$P = \frac{F_{\perp}}{A}$$

AP®

The S.I. unit for pressure is the pascal (Pa).

$$1 \text{ Pa} \equiv 1 \frac{\text{N}}{\text{m}^2} \equiv 1 \frac{\text{kg}}{\text{ms}^2}$$

(Note that Pa is a two-letter symbol.)

Some other common pressure units are:

- bar: $1 \text{ bar} \equiv 100\,000 \text{ Pa}$
- pound per square inch (psi or $\frac{\text{lb.}}{\text{in.}^2}$)
- atmosphere (atm): the average atmospheric pressure on Earth at sea level.
 $1 \text{ atm} \equiv 101\,325 \text{ Pa} \equiv 1.01325 \text{ bar} = 14.696 \text{ psi}$

In this course, we will use the approximation that $1 \text{ atm} \approx 1 \text{ bar}$, meaning that standard atmospheric pressure is $1 \text{ bar} \equiv 100\,000 \text{ Pa}$.

Air pressure can be described relative to a total vacuum (absolute pressure), but is more commonly described relative to atmospheric pressure (gauge pressure):

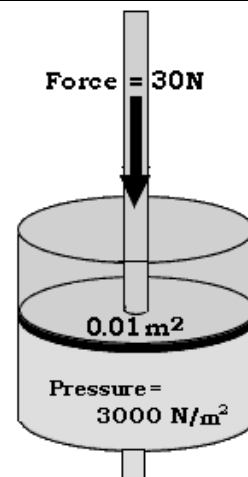
- absolute pressure: the total pressure on a surface. An absolute pressure of zero means there is zero force on the surface.
- gauge pressure: the difference between the pressure exerted by a fluid and atmospheric pressure. A gauge pressure of zero means the same as atmospheric pressure. The pressure in car tires is measured as gauge pressure. For example, a tire pressure of 30 psi (30 pounds per square inch, or $30 \frac{\text{lb.}}{\text{in.}^2}$) would mean that the air inside the tires is pushing against the air outside the tires with a pressure of 30 psi.

A flat tire would have a gauge pressure of zero and an absolute pressure of about 1 bar.

Sample Problem

Q: What is the pressure caused by a force of 25 N acting on a piston with an area of 0.05 m^2 ?

A:
$$P = \frac{F_{\perp}}{A} = \frac{25 \text{ N}}{0.05 \text{ m}^2} = 500 \text{ Pa}$$



AP®

Homework Problems

1. **(M)** A person wearing snowshoes does not sink into the snow, whereas the same person without snowshoes sinks into the snow. Explain.



2. **(S)** A balloon is inflated to a pressure of 0.2 bar. A 5.0 kg book is balanced on top of the balloon. With what surface area does the balloon contact the book? (*Hint: Remember that 1 bar = 100 000 Pa.*)

Answer: 0.0025 m²

3. **(S)** A carton of paper has a mass of 22.7 kg. The area of the bottom is 0.119 m². What is the pressure between the carton and the floor?

Answer: 1908 Pa

4. **(S)** A 1000 kg car rests on four tires, each inflated to 2.2 bar. What surface area does *each* tire have in contact with the ground? (Assume the weight is evenly distributed on each wheel.)

Answer: 0.0114 m²

AP®

5. **(A)*** A student with a mass of 75.0 kg is sitting on 4-legged lab stool that has a mass of 3.0 kg. Each leg of the stool is circular and has a diameter of 2.50 cm. Find the pressure under each leg of the stool.
(Hints: (1) Remember to convert cm^2 to m^2 for the area of the legs of the stool. (2) Remember that the stool has four legs. (3) Note that the problem gives the diameter of the legs of the stool, not the radius.)

Answer: 397 250 Pa

6. **(M)** A student has a mass of 75 kg.
- a. **(M)** The student is lying on the floor of the classroom. The area of the student that is in contact with the floor is 0.6 m^2 . What is the pressure between the student and the floor? Express your answer both in pascals and in bar.

Answer: 1 250 Pa or 0.0125 bar

- b. **(M)** The same student is lying on a single nail, which has a cross-sectional area of $0.1 \text{ mm}^2 = 1 \times 10^{-7} \text{ m}^2$. What is the pressure (in bar) that the student exerts on the head of the nail?

Answer: $7.5 \times 10^9 \text{ Pa} = 75\,000 \text{ bar}$

- c. **(M)** The same student is lying on a bed of nails. If the student is in contact with 1 500 nails, what is the pressure (in bar) between the student and each nail?

Answer: $5 \times 10^6 \text{ Pa} = 50 \text{ bar}$

* This is a nuisance problem, not a difficult problem.