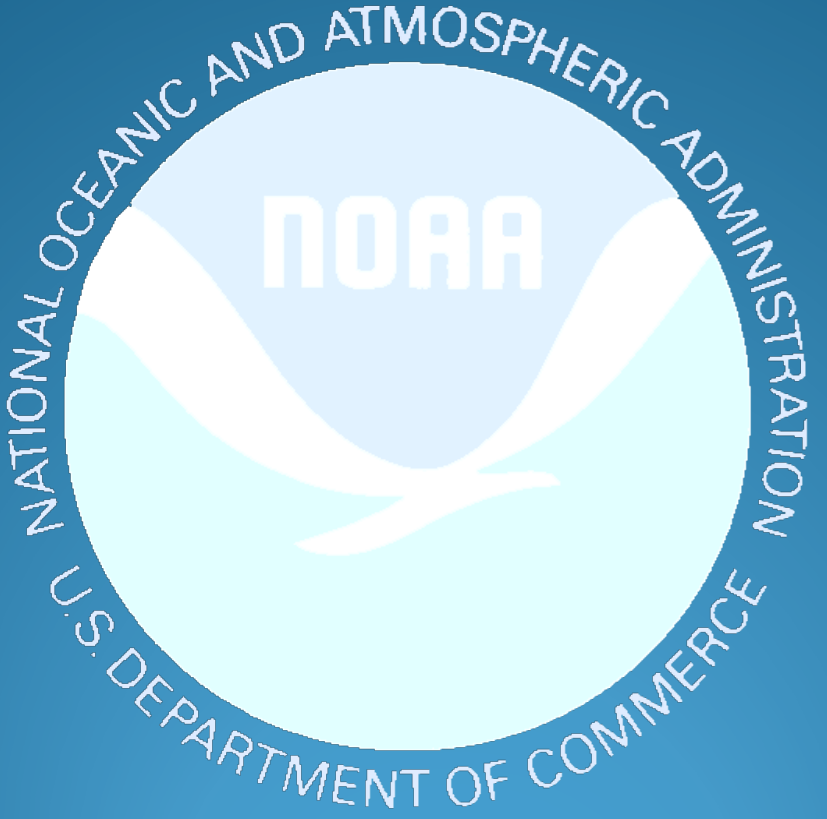
Atmospheric and Hydrostatic Pressure



Presented by the NOAA Diving Center

Seattle, Washington

Global View

- Definition
- Air pressure
- Water pressure
- Gauge and absolute pressures
- Measuring pressure
- Key Points

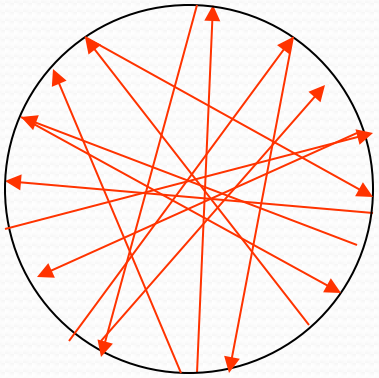
Introduction

- **Need & value**: As NOAA divers performing underwater tasks, we need to calculate pressure at depth, gas volume changes caused by changing pressure, the partial pressures of gases, and more.

- **Effect**: When we learn the fundamentals of physics and use them properly, we can solve diving problems easily and correctly. This lesson focuses on the basic principles of calculating for pressure and is a foundation for more complex calculations we will learn in future lessons.

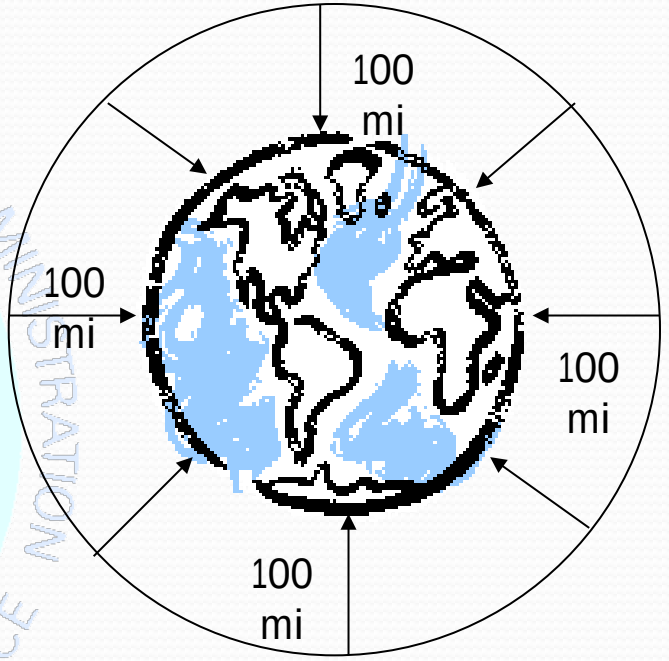
Pressure

- Pressure is defined as, “Force acting on a unit area.”
  - Force per area (l x w)
- Gases exert force, or pressure, because they are composed of billions of molecules which are always in motion
- The more molecules present and the faster they are moving, the greater the pressure
- Each time a molecule strikes another molecule or an object it exerts a force or pressure against it



Air Pressure

- Air exists in the atmosphere from sea level up to approximately 100 miles in space
  - A person at sea level experiences the full weight, or pressure, of the air molecules
- The weight of air pressure is commonly referred to as atmospheric pressure

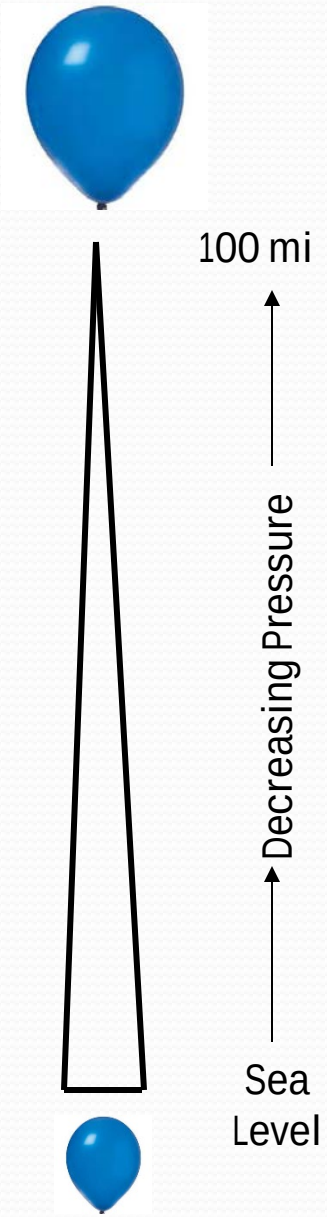


"We live submerged at the bottom of an ocean of the element air, which by unquestioned experiments is known to have weight"

Torricelli

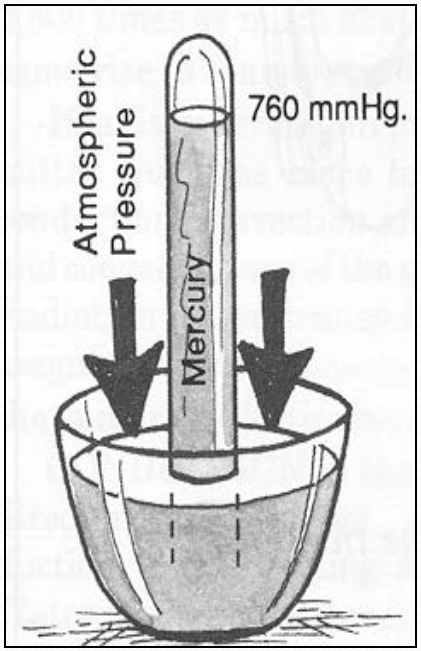
Air Pressure

- At sea level, the pressure exerted by a column of air 1” x 1” is 14.7 pounds per square inch (psi), or 1 atmosphere (ATM)
- As one ascends in altitude, there is less air on top of them equating to less pressure being exerted upon them
- A balloon filled with air at sea level will increase in size at altitude due to the decreased pressure exerted on the outside of the balloon



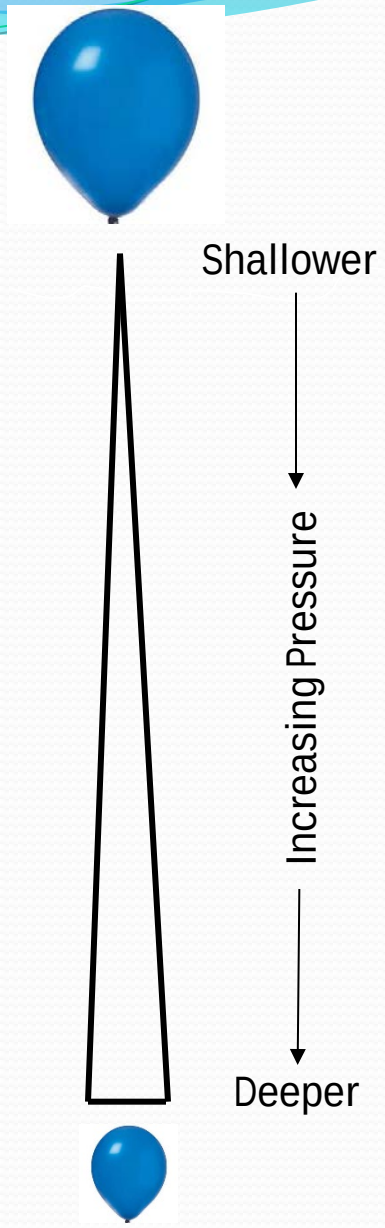
Discovery of Air Pressure

- Galileo Galilei (Italian physicist/mathematician…)
  - Weighed empty glass container, pumped air into container, and re-weighed container
- Evangelista Torricelli (Italian physicist/ mathematician)
  - In 1644, wrote a letter to a friend describing his experiment:
    - Filled a tube with Mercury, inverted it and placed it into a basin of Mercury (previous scientists had used water)
    - Concluded the weight of atmospheric pressure on the surface of the bowl kept the mercury in the tube at a height of ~760 mm



Water Pressure

- The pressure exerted by a liquid on an immersed body.
  - Commonly referred to as Hydrostatic or gauge pressure.
- As depth increases, water pressure increases
  - Marianas Trench: ~36,000ft deep, roughly 1100x atmospheric pressure or 16,000 psi (8 tons).
- Has profound effects on the human body

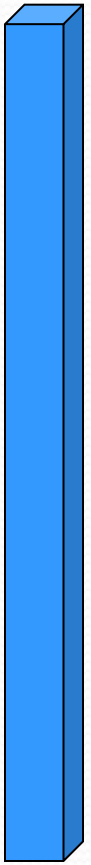


Discovery of Water Pressure

- Blaise Pascal (French physicist/ mathematician)
  - 1648, repeated Torricelli's experiment in full-scale using glass tube and mercury
- Found the weight of atmospheric pressure would offset the weight of a 1" x 1" column of fresh water 34 feet high
- Also found the weight of atmospheric pressure would offset the weight of a 1" x 1" column of sea water 33 feet high

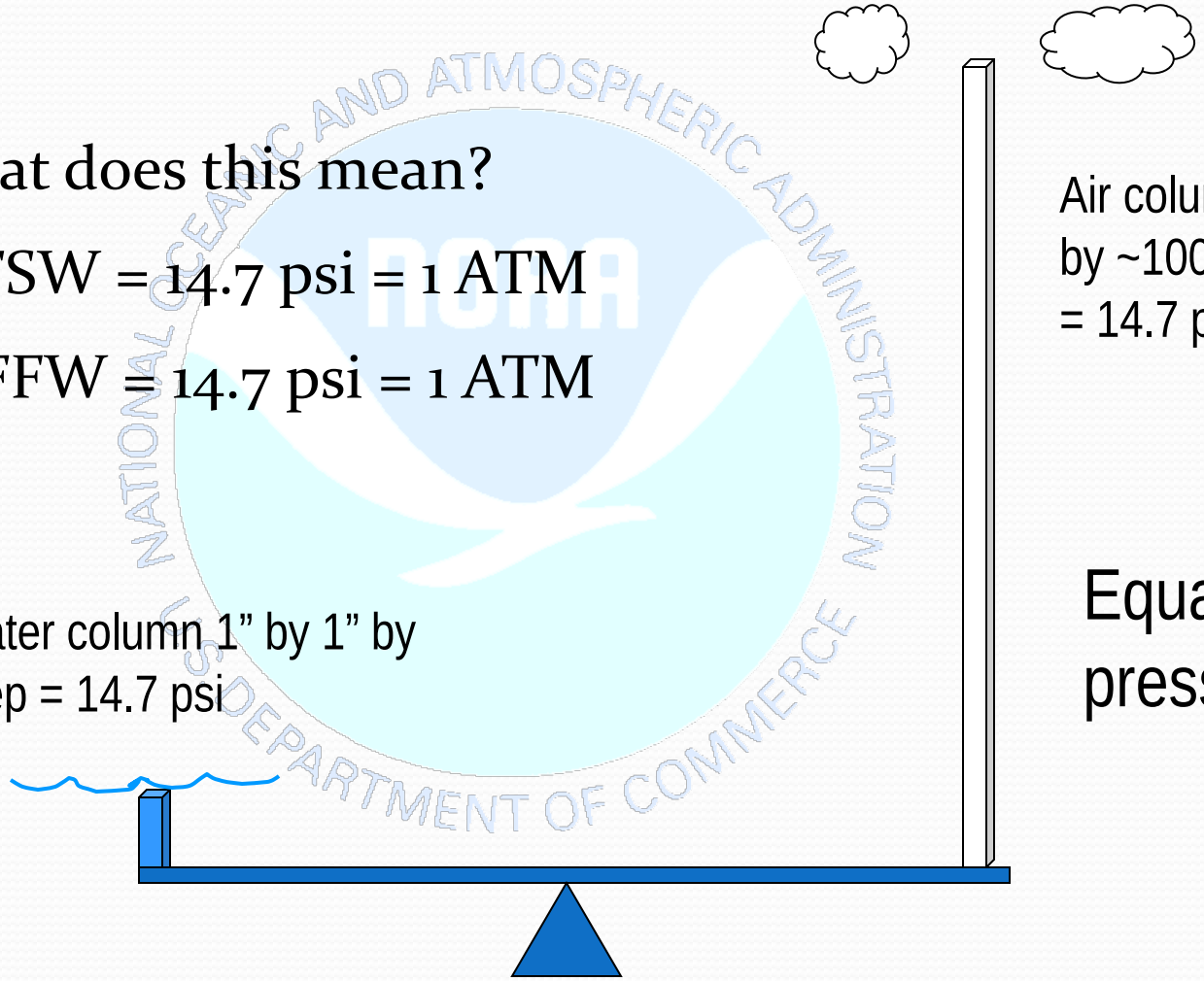
One square inch of salt water 33 feet deep weighs 14.7 lbs.

One square inch of fresh water 34 feet deep weighs 14.7 lbs.



Measuring Water Pressure

- What does this mean?
- 33 FSW = 14.7 psi = 1 ATM
- 34 FFW = 14.7 psi = 1 ATM



Measuring Water Pressure

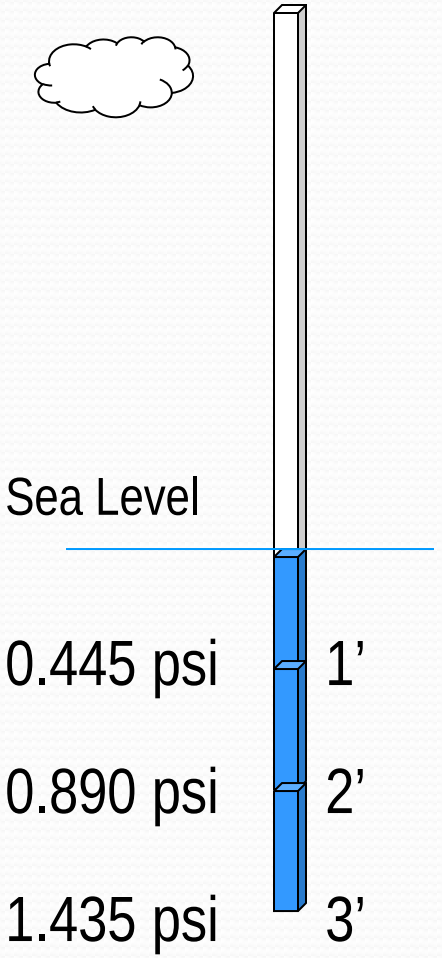
- Equivalent values:
  - 33 FSW = 14.7 psi = 1 ATM
  - 34 FFW = 14.7 psi = 1 ATM

Salt Water: pressure per foot of depth

14.7 psi / 33 feet = 0.445 psi/ft

Fresh Water: pressure per foot of depth

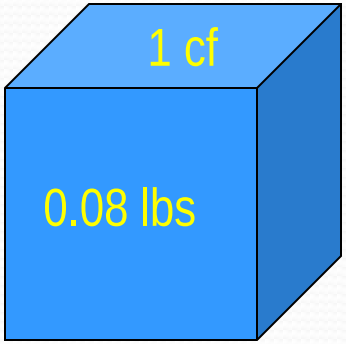
14.7 psi / 34 feet = 0.432 psi/ft



Measuring Water Pressure

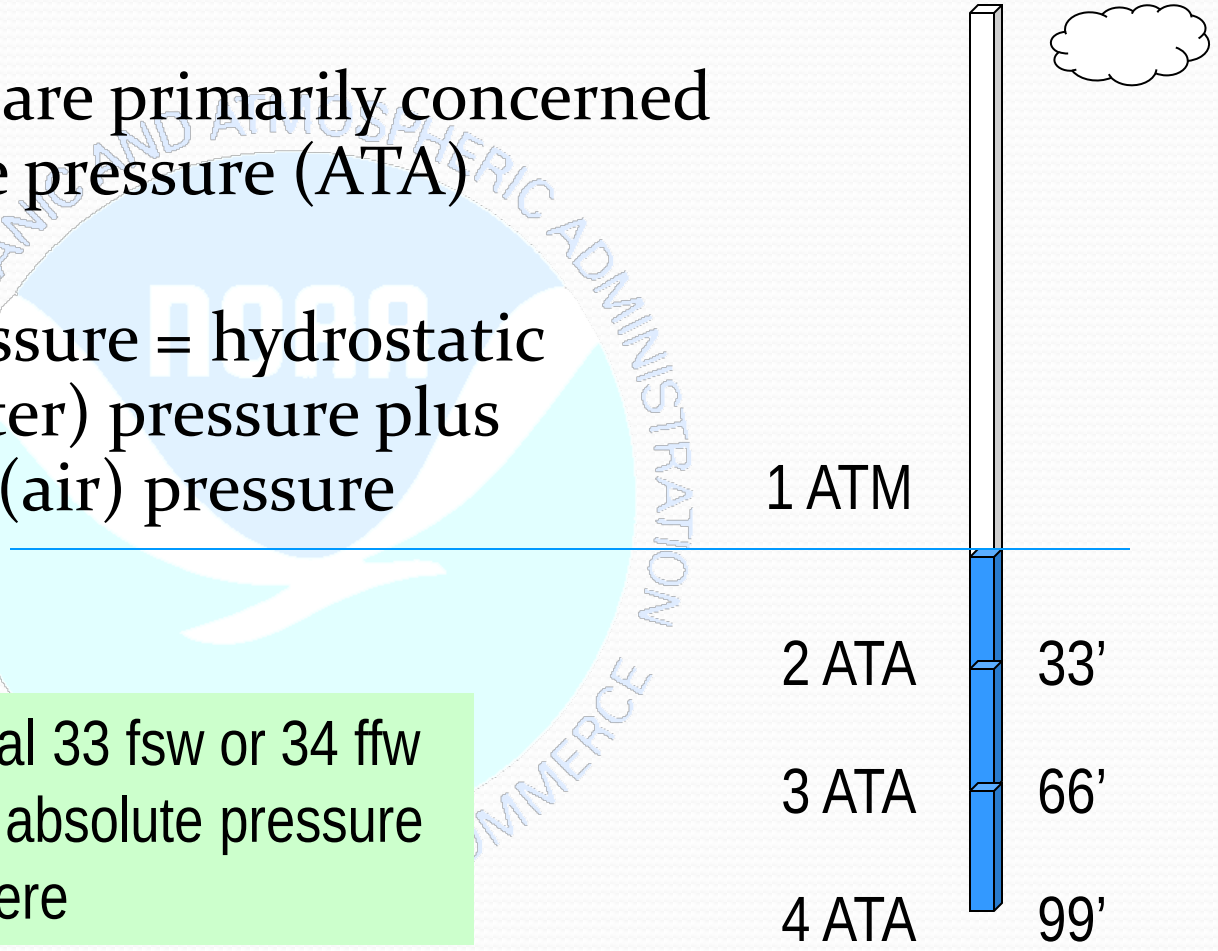
- Salt water:
  - one cubic foot weighs 64 lbs
- Fresh water:
  - one cubic foot weighs 62.4 lbs
- Air:
  - one cubic foot weighs 0.08 lbs

Pressure is force per unit area



Absolute Pressure

- As divers, we are primarily concerned with absolute pressure (ATA)
- Absolute pressure = hydrostatic (gauge or water) pressure plus atmospheric (air) pressure



Each additional 33 fsw or 34 ffw increases the absolute pressure by 1 atmosphere

Volumetric Changes By Depth

0' → 33 FSW	=	1 ATM → 2 ATA	=	100% ΔP = 50% ΔV
33' → 66 FSW	=	2 ATA → 3 ATA	=	50% ΔP = 33% ΔV
66' → 99 FSW	=	3 ATA → 4 ATA	=	33% ΔP = 25% ΔV
99' → 132 FSW	=	4 ATA → 5 ATA	=	25% ΔP = 20% ΔV

0' → 34 FFW	=	1 ATM → 2 ATA	=	100% ΔP = 50% ΔV
34' → 68 FFW	=	2 ATA → 3 ATA	=	50% ΔP = 33% ΔV
68' → 102 FFW	=	3 ATA → 4 ATA	=	33% ΔP = 25% ΔV
102' → 136 FFW	=	4 ATA → 5 ATA	=	25% ΔP = 20% ΔV

Like Units

- Pressure can be measured in several units:
  - FSW, FFW, psi, psia, psig, ATM, ATA, mmHG
- Always use absolute pressure for gas law calculations
- When converting from Gauge to Absolute Pressure you must use Like Units of Measurement

Gauge:	Absolute:
FSW	Add 33
PSI	Add 14.7
ATM	Add 1
mm Hg	Add 760

Pressure Conversions

Units	PSIG	PSIA	ATM	ATA	FSW	FSWA	FFW	FFWA
PSIG	*	Add 14.7	Divide by 14.7	Add 14.7, divide 14.7	Divide by .445	Divide by .445 + 33	Divide by .432	Divide by .432 + 34
PSIA	Minus 14.7	*	Minus 14.7, divide 14.7	Divide by 14.7	Minus 14.7, divide .445	Divide by .445	Minus 14.7, Divide .432	Divide by .432
ATM	Times 14.7	Times 14.7, add 14.7	*	Add 1	Times 33	Times 33 + 33	Times 34	Times 34 + 34
ATA	Minus 1, times 14.7	Times 14.7	Minus 1	*	Times 33, minus 33	Times 33	Times 34, minus 34	Times 34,
FSW	Times .445	Times .445, add 14.7	Divide by 33	Add 33, divide 33	*	Add 33	Times 1.03	Times 1.03 + 34
FSWA	Minus 33, times .445	Times .445	Minus 33, Divide 33	Divide by 33	Minus 33	*	Minus 33, times 1.03	Times 1.03
FFW	Times .432	Times .432, add 14.7	Divide by 34	Add 34, divide 34	Times .97	+ 34, Times .97	*	Add 34
FFWA	Minus 34, times .432	Times .432	Minus 34, Divide 34	Divide by 34	Minus 34, times .97	Times .97	Minus 34	*

* = Knowns

Calculating Pressure

- Question #1:
  - What is the pressure at 60 fsw expressed in psia?
  - (depth) x (psi/fsw) = psig + 14.7 psi = psia
- Answer:

  1) (60 fsw) x (0.445 psi/fsw) = 26.7 psig

  2) 26.7 psig + 14.7 psi =

  = 41.4 psia

Note: 14.7 psi divided by 33 fsw = 0.445 psi/fsw

Calculating Pressure

- Question #2:
  - What is the pressure at 60 fsw expressed in ATA?
  - $\frac{\text{(Depth + 33 fsw)}}{\text{33 fsw}}$
- Answer:

$$= \frac{\text{(60 fsw+ 33 fsw)}}{\text{33 fsw}} =$$

$$= 2.82 \text{ ATA}$$

Calculating Pressure

- Question #3:
  - At what depth (fsw) will the pressure be 73.425 psig?
  - psig / (psi/fsw)
- Answer:

  = 73.425 psig / (0.445 psi/fsw)

  = 165 fsw

Note: Unless advised otherwise, calculate depth in gauge pressure, not absolute.

Key Points

- Gasses (e.g. air) are compressible; liquids are not
- Water is 800 times more dense than air
  - Light travels slower in water; sound travels faster
  - Objects appear 25% larger and 33% closer underwater
  - Water conducts heat 22-24 times faster than in air
- There are three states of buoyancy: positive, negative, and neutral
- Pressure is weight or force per unit area

Key Points

- Pressure decreases with altitude and increases with depth
- Air weighs 0.08 lbs/ft^3 & exerts 14.7 psi or 760 mm Hg
- Sea water weighs 64 lbs/ft^3 & exerts 0.445 psi/fsw
- Fresh water weighs 62.4 lbs/ft^3 & exerts 0.432 psi/ffw
- 33 FSW = 14.7 psi = 1 ATM = 760 mmHG = 34 FFW
- Pressure has many units: psi, psia, psig, ATM, feet of depth, ATA, mmHG