November 22, 2010   Physics 121   Prof. E. F. Redish

■ **Theme Music:** Queen
   Under Pressure
■ **Cartoon:** Bill Watterson
   Calvin & Hobbes

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Outline

■ Quiz 9: Torque and rotational energy
■ Fluids
   – Pressure
   – Fluids under gravity
■ Archimedes' Principle

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Pressure

■ What forces are exerted
   on the box imbedded in the fluid?

Pressure has
no direction!
It acts in all
directions at once!

$$p = \frac{F}{A} \qquad \vec{F} = p\vec{A}$$

The force takes its direction from A.

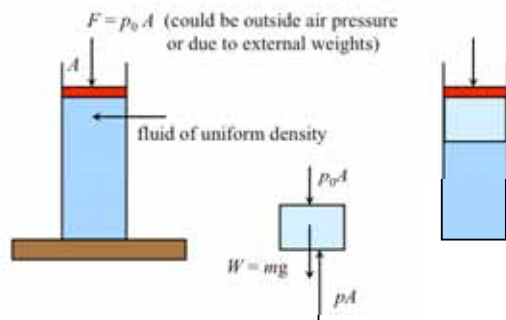11/22/10   Physics 121   3

Drawing on experience

■ What happens when an object is immersed in a fluid?
■ Examples?

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Fluids in Gravity

$F = p_0 A$ (could be outside air pressure or due to external weights)

fluid of uniform density

$p_0 A$

$W = mg$

pA

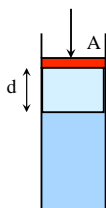11/22/10   Physics 121   **7**

Variation of Pressure with Depth*

$F^{down} = F^{up}$

$mg + p_0 A = pA$

$\rho V g + p_0 A = pA$

$\rho A d g + p_0 A = pA$

$p = p_0 + \rho g d$

* We assumed uniform density. Is this OK?
    For water ($\rho \sim 1000$ kg/m^3) yes.
    For air ($\rho \sim 1$ kg/m^3) OK for meters — not km.
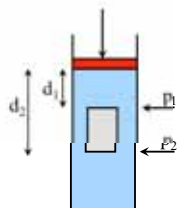
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Archimedes' Principle: 1

■ What happens when an object is immersed in a fluid?

■ The pressure at the bottom is greater than the pressure at the top so overall the fluid pushes up.

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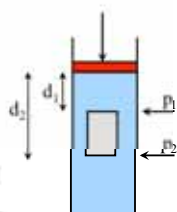
Archimedes' Principle: 2

$$F^{net} = p_2 A - p_1 A$$
$$p_1 = p_0 + \rho g d_1$$
$$p_2 = p_0 + \rho g d_2$$
$$F^{net} = (p_2 - p_1)A$$
$$F^{net} = (p_0 + \rho g d_2 - p_0 - \rho g d_1)A$$
$$F^{net} = \rho g (d_2 - d_1)A = \rho V g = mg$$

The buoyant (upward) force = the weight of the fluid displaced.

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Making sense of AP

■ Consider the forces on a bag of water the same shape as an immersed object.

■ The BF is equal to the weight of the water displaced – that's what the surrounding water can hold up!

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Measuring Pressure: Manometers

Measuring Pressure: Units

	Pascal (N/m²)	atm	mm of Hg	millibar	lb/in²
Pascal (N/m²)	1	10^{-5}	7.5×10^{-5}	0.01	1.5×10^{-4}
atm	10^5	1	760	1000	14.7
mm of Hg			1		
millibar				1	
lb/in²					1