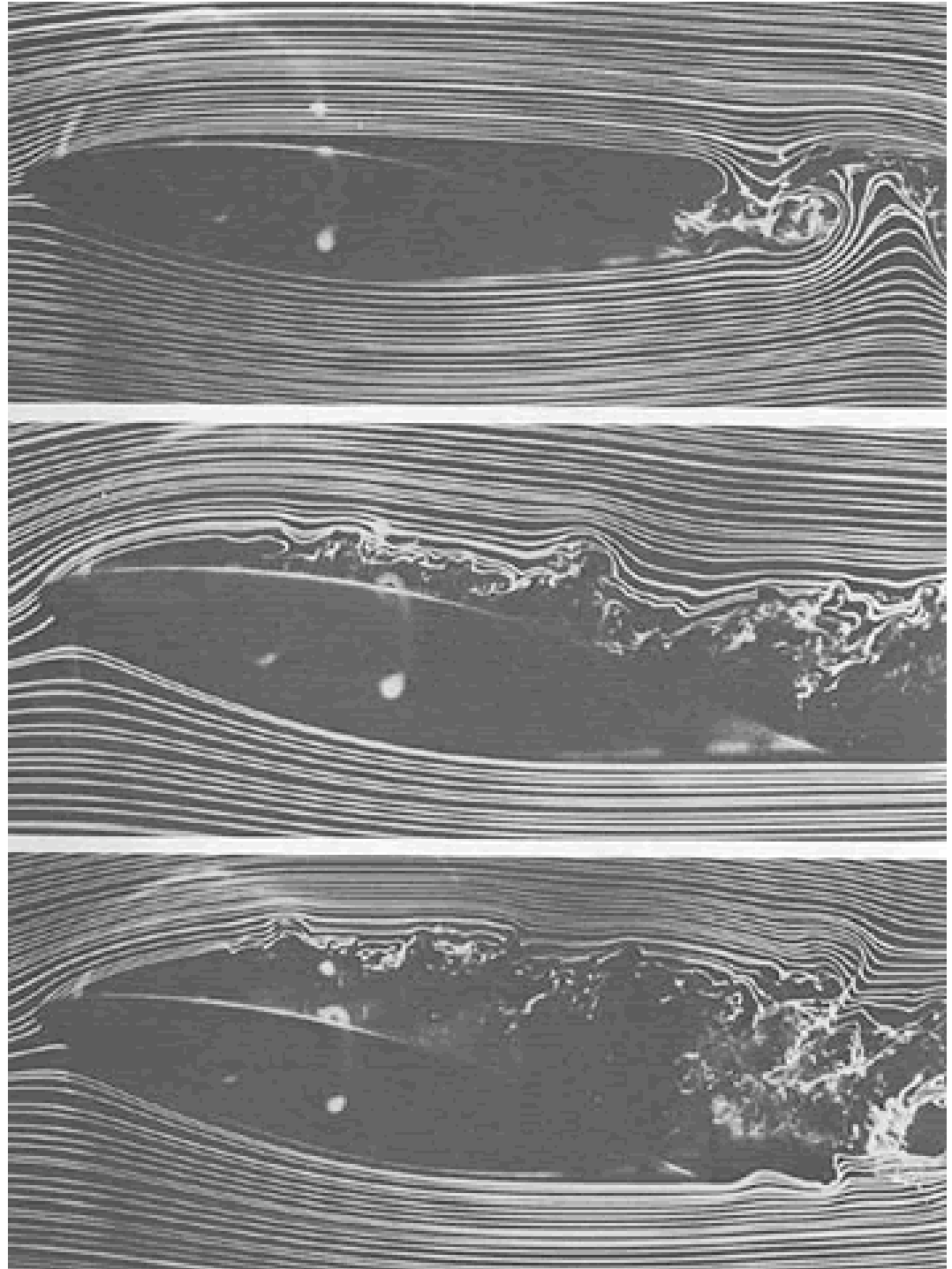
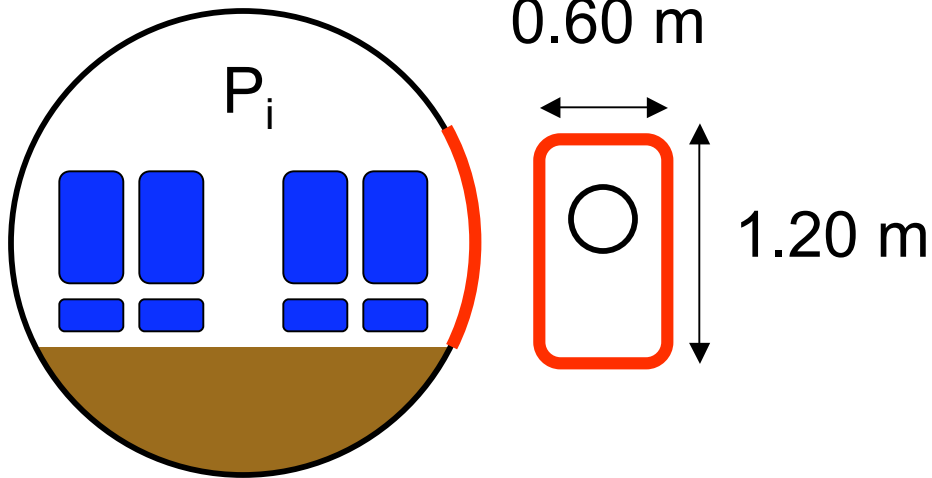


# Fluid Mechanics



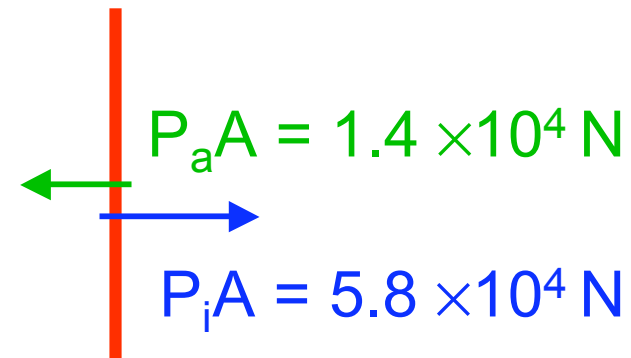
# Emergency Exit

$$P_a = 0.2 P_o$$



what is the force on the exit door due to the pressures

$$A = 0.72 \text{ m}^2$$

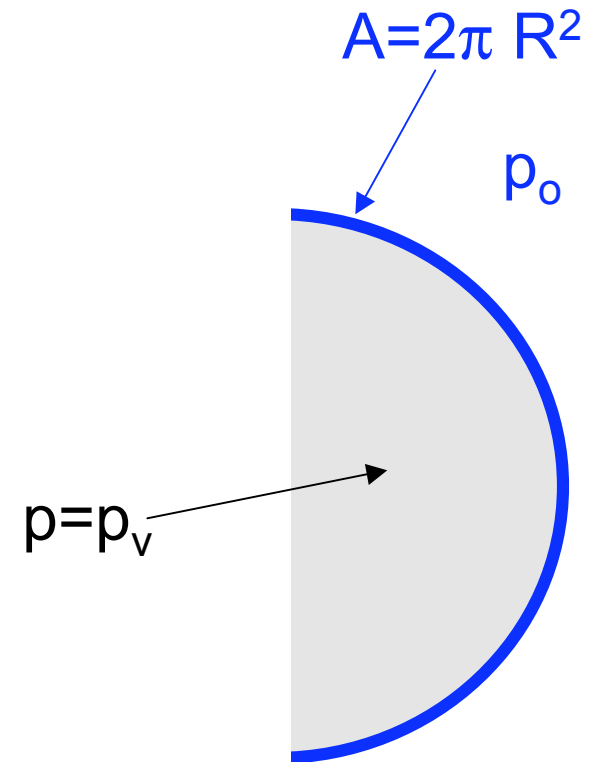
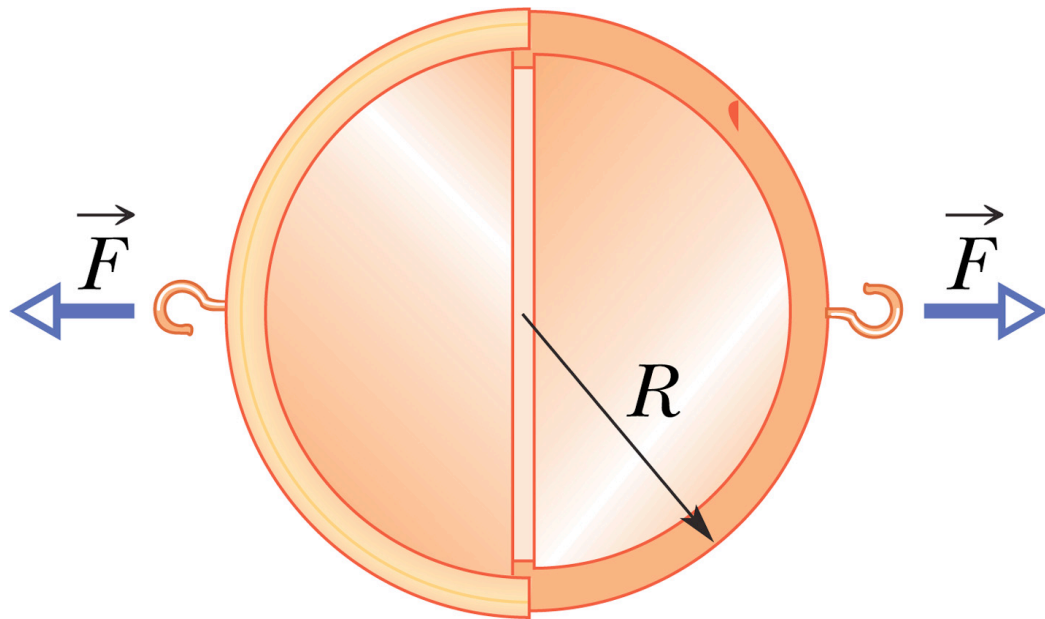


$$P_a = 0.2 P_o = 2 \times 10^4 \text{ N/m}^2$$

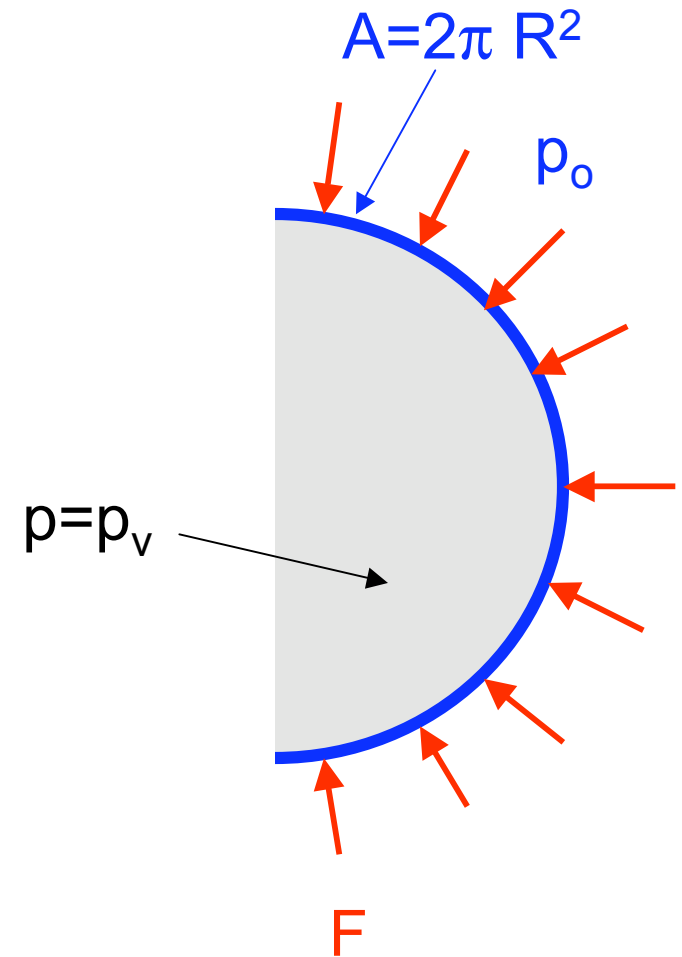
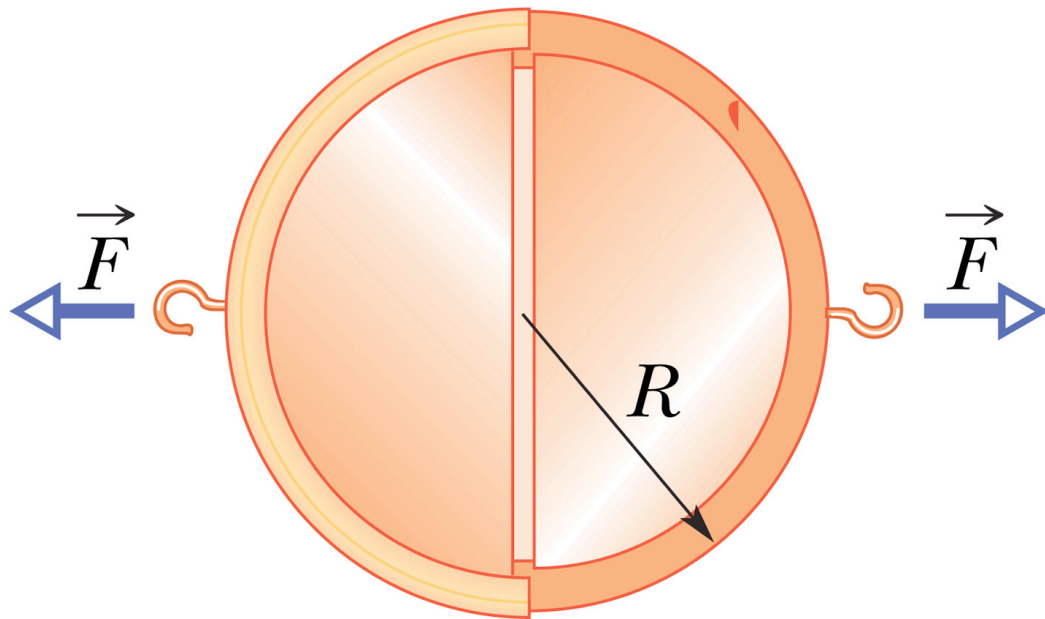
$$P_i = 0.8 P_o = 8 \times 10^4 \text{ N/m}^2$$

$$F = 4.4 \times 10^4 \text{ N} = 44 \text{ tonnes}$$

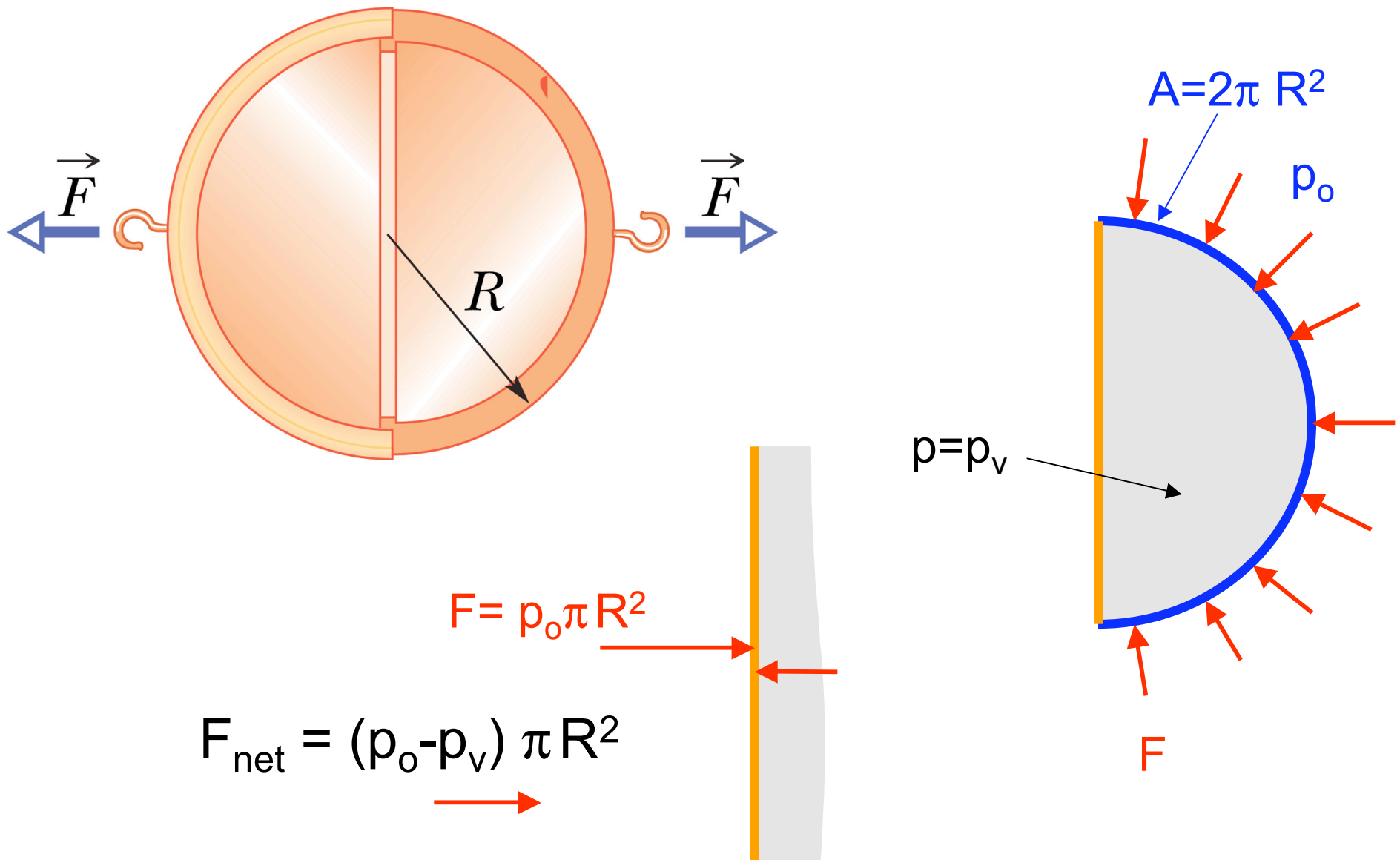
# The power of nothing



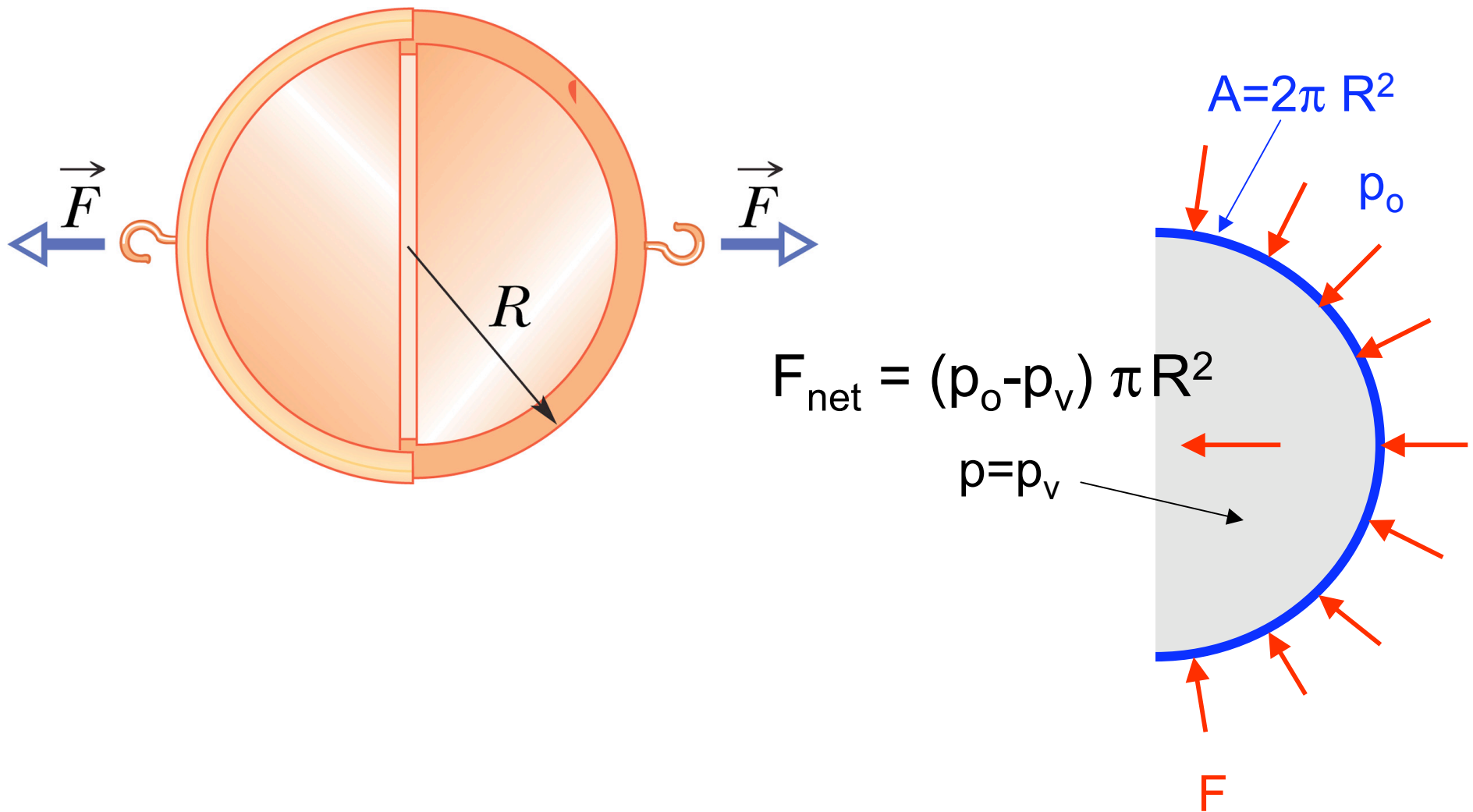
# The power of nothing



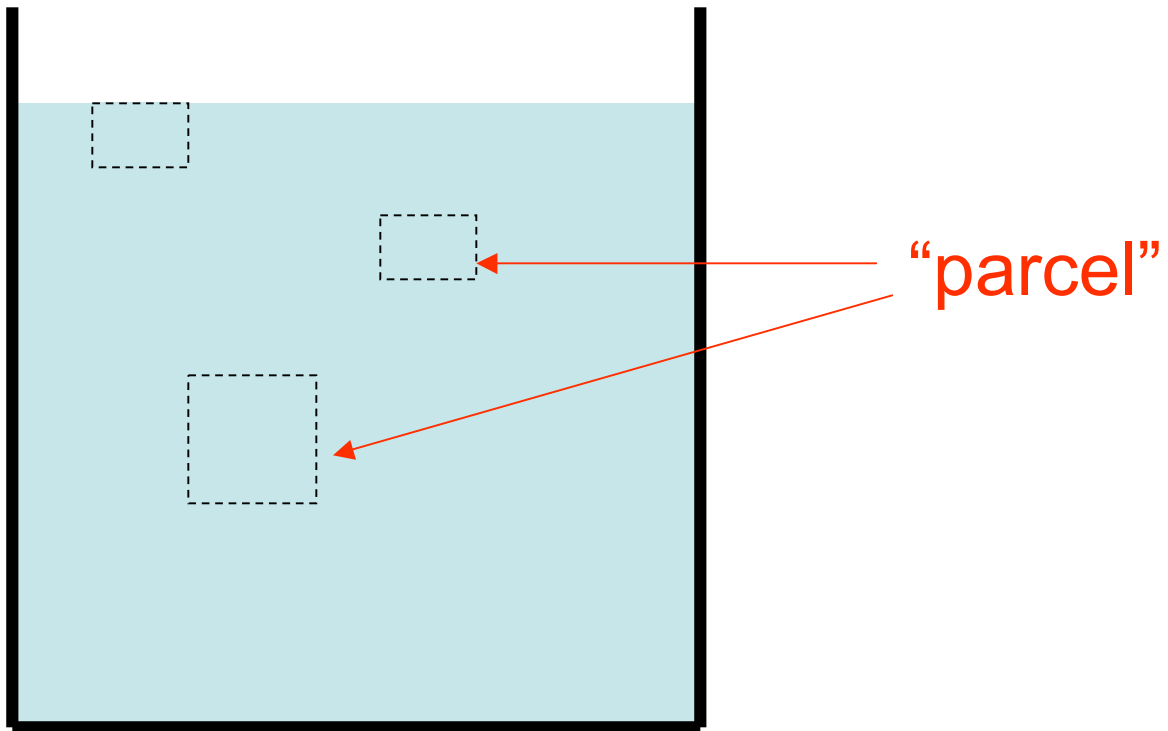
# The power of nothing



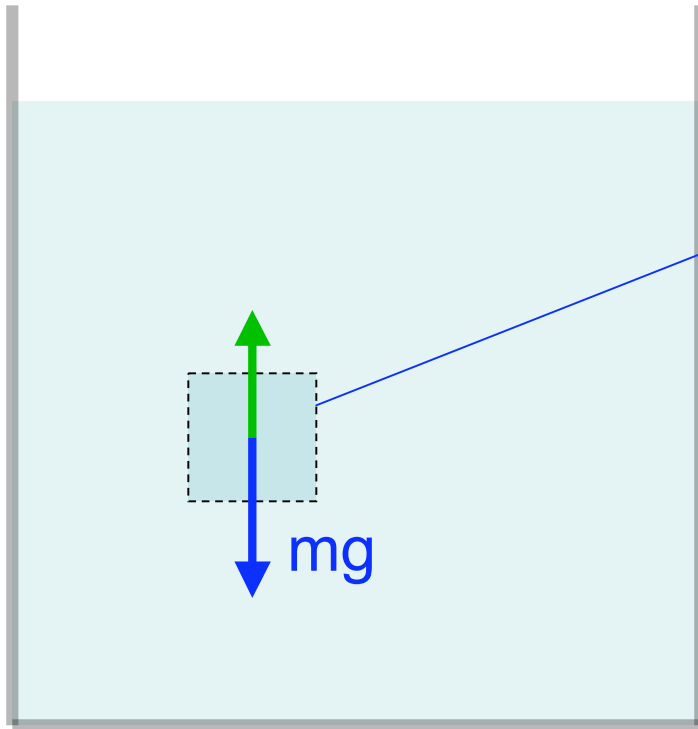
# The power of nothing



# Fluid Mechanics



# Fluid Mechanics

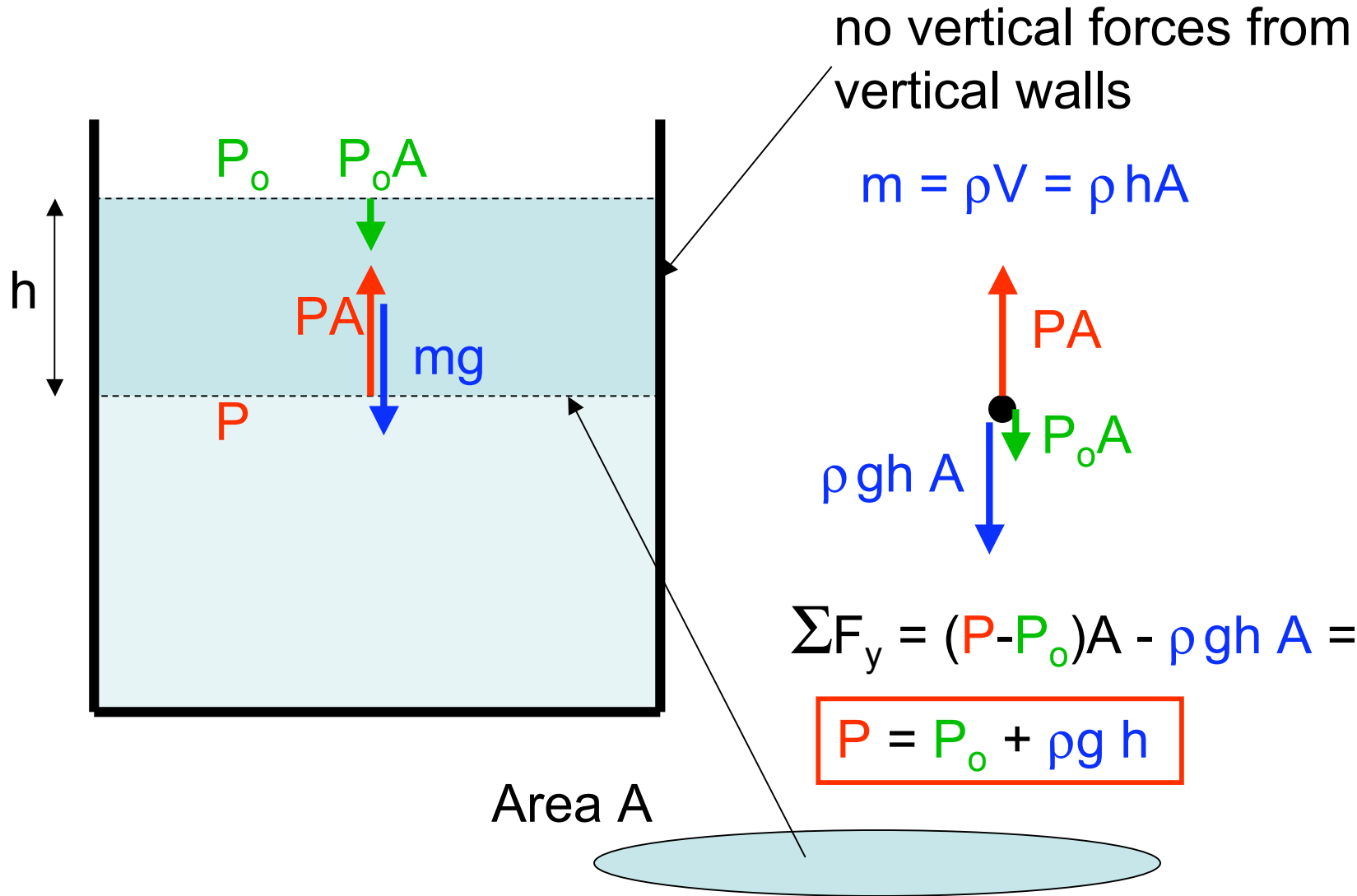


$$m = \rho V$$

but that parcel is not falling...

... must be upward force on its walls from surrounding fluid

from pressure



$P_o$

$P_o A$

$h$

$PA$

$mg$

$P$

$PA$

$P_o A$

$\rho g h A$

$$\Sigma F_y = (P - P_o)A - \rho g h A = 0$$

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

Area A

Q: at what depth is the pressure 2 atm.?

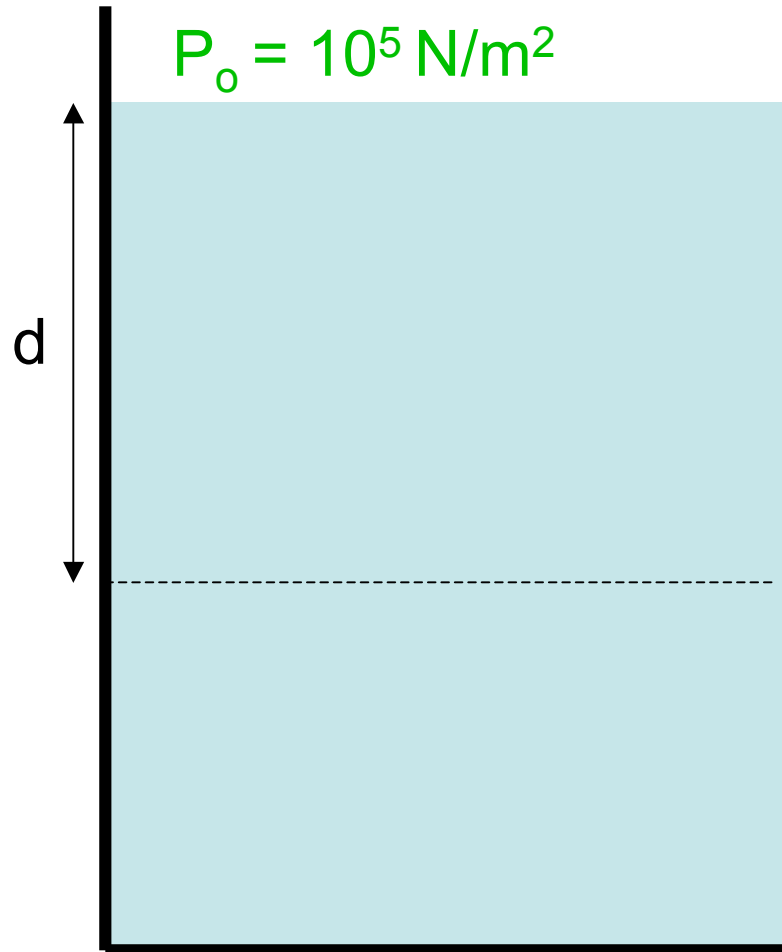
$$P = P_o + \rho g d = 2P_o$$

$$\rho_{\text{water}} = 10^3 \text{ kg/m}^3$$

$$g = 10 \text{ m/s}^2$$

$$\rho_{\text{water}}g = 10^4 \text{ N/m}^3$$

$$P = 2P_o = P_o + \rho g d$$



$$d_2 = P_o / \rho g = (10^5 \text{ N/m}^2) / (10^4 \text{ N/m}^3) = 10 \text{ m (30 ft)}$$

Q:  $P = 3P_o$  (3 atm.)?

A:  $d = 20 \text{ m (60 ft)}$

How much lower is the pressure at the ceiling of the room than at the floor?

A 0.03 Pa

B 0.3 Pa

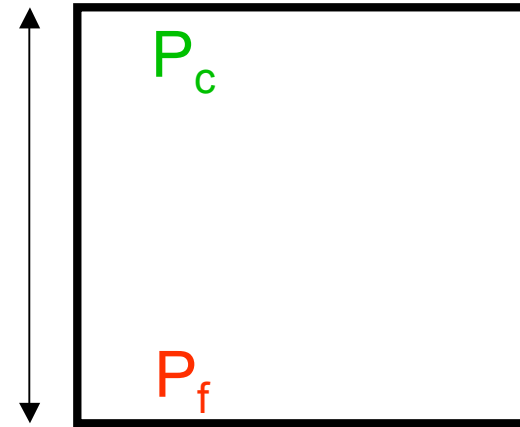
C 3 Pa

**D 30 Pa**

E 300 Pa

$$h = 3\text{m}$$

$$P_f = P_c + \rho gh$$



i.e. 0.03% of an atm.

$$\rho_{\text{air}} = 1 \text{ kg/m}^3$$

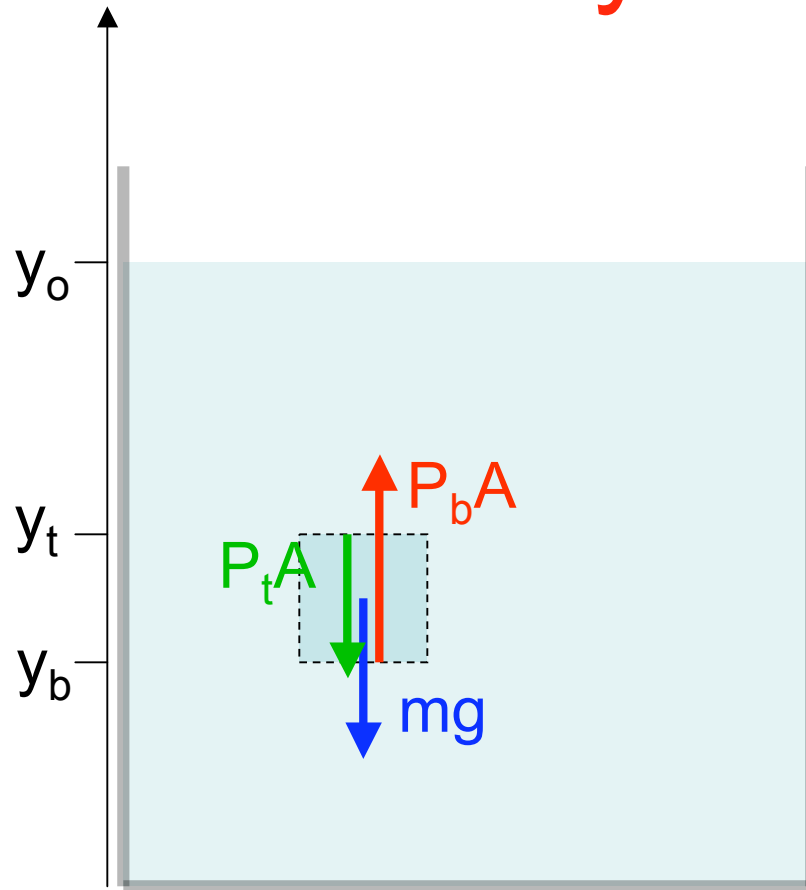
$$g = 10 \text{ m/s}^2$$

$$\rho_{\text{air}}g = 10 \text{ N/m}^3$$

$$\rho_{\text{air}}gh = 30 \text{ N/m}^2$$

@ 300 m (1000 ft)  
pressure will have fallen  
3% of an atm.  
(altimeter)

# Buouyancy force



$$P_b = P_o + \rho g ( y_o - y_b )$$

$$P_t = P_o + \rho g ( y_o - y_t )$$

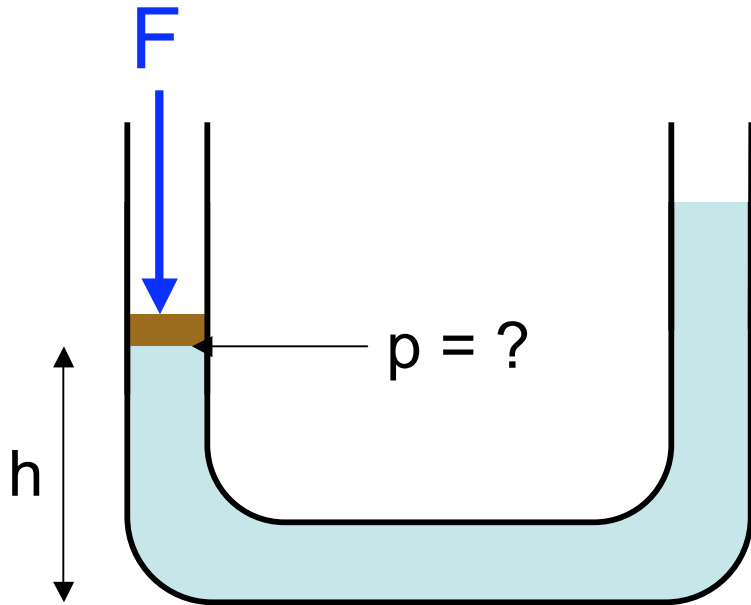
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$$P_b - P_t = - \rho g ( y_b - y_t )$$

pressure at bottom  
exceeds pressure at top  
just enough to keep  
parcel balanced

$$\Sigma F_y = (P_b - P_t)A - \rho g ( y_t - y_b ) A = 0$$

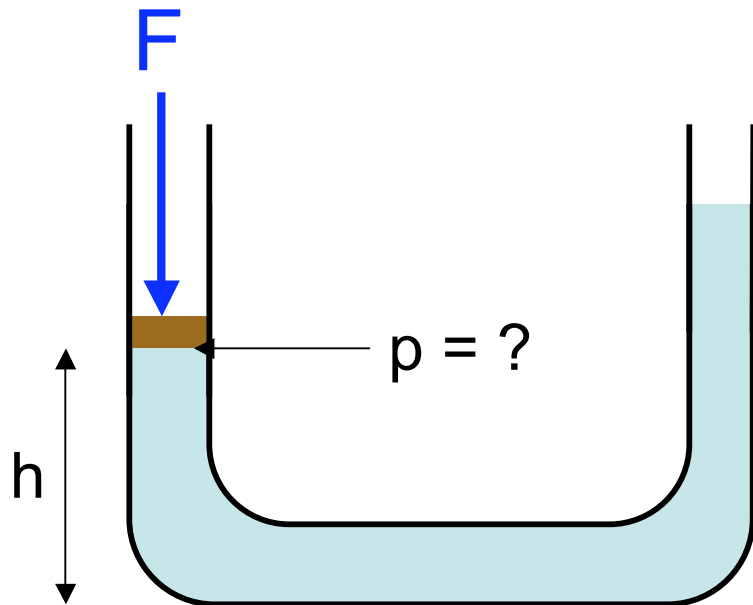
# The original U-tube



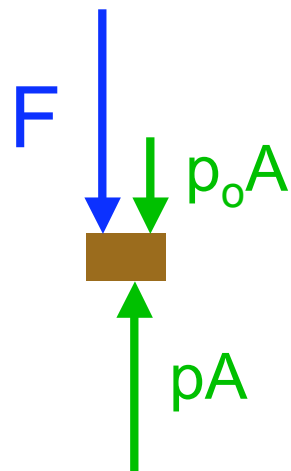
A light piston head of area  $A=0.04 \text{ m}^2$  is open to atmospheric pressure  $p_0$  and pushed down by addition force  $F=8 \text{ N}$ . The pressure just beneath the piston is

- A  $p_0$
- B  $F/A$
- C  $F/A + p_0$
- D  $\rho gh$
- E  $\rho gh + p_0$

# The original U-tube



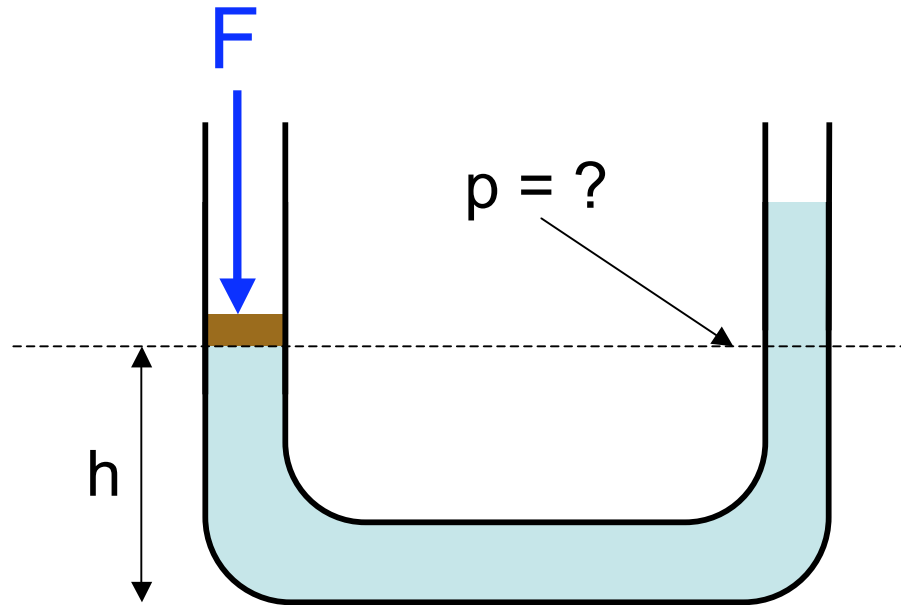
A light piston head of area  $A=0.04 \text{ m}^2$  is open to atmospheric pressure  $p_o$  and pushed down by addition force  $F=8 \text{ N}$ . The pressure just beneath the piston is



$$\sum F_y = 0$$

- A  $p_o$
- B  $F/A$
- C  $F/A + p_o$**
- D  $\rho gh$
- E  $\rho gh + p_o$

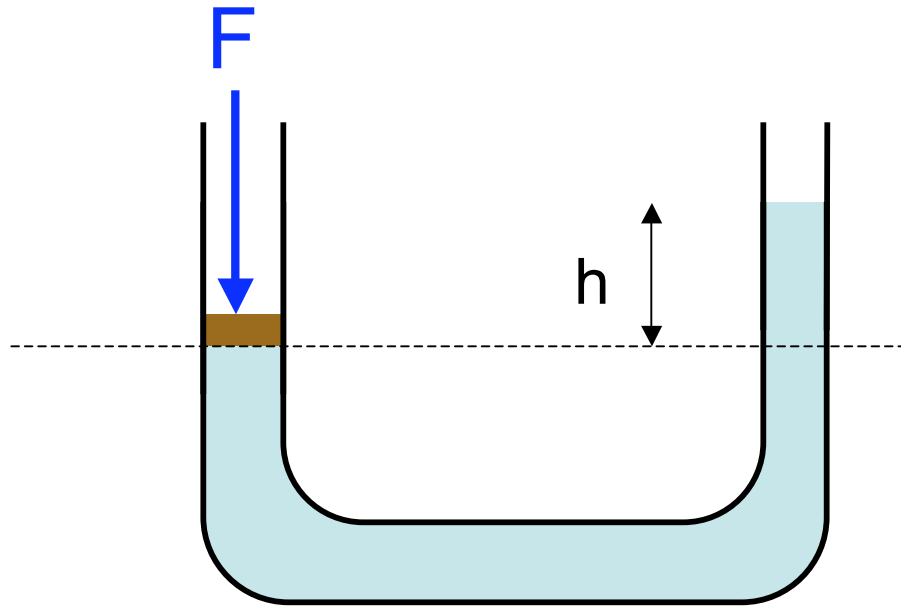
# The original U-tube



A light piston head of area  $A=0.04 \text{ m}^2$  is open to atmospheric pressure  $p_0$  and pushed down by addition force  $F=8 \text{ N}$ . The pressure at the same level of the other tube is

- A  $p_0$
- B  $F/A$
- C  $F/A + p_0$**
- D  $\rho gh$
- E  $\rho gh + p_0$

# The original U-tube

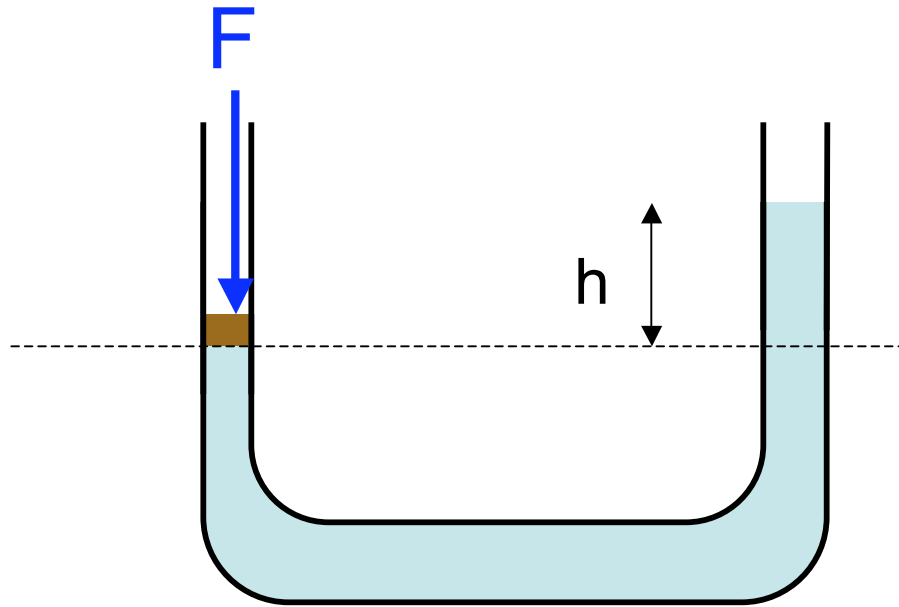


A light piston head of area  $A=0.04 \text{ m}^2$  is open to atmospheric pressure  $p_0$  and pushed down by addition force  $F=8 \text{ N}$ . height of the column above the piston level is

$$p = F/A + p_0 = \rho gh + p_0$$

$$h = F/\rho gA$$

# The original U-tube

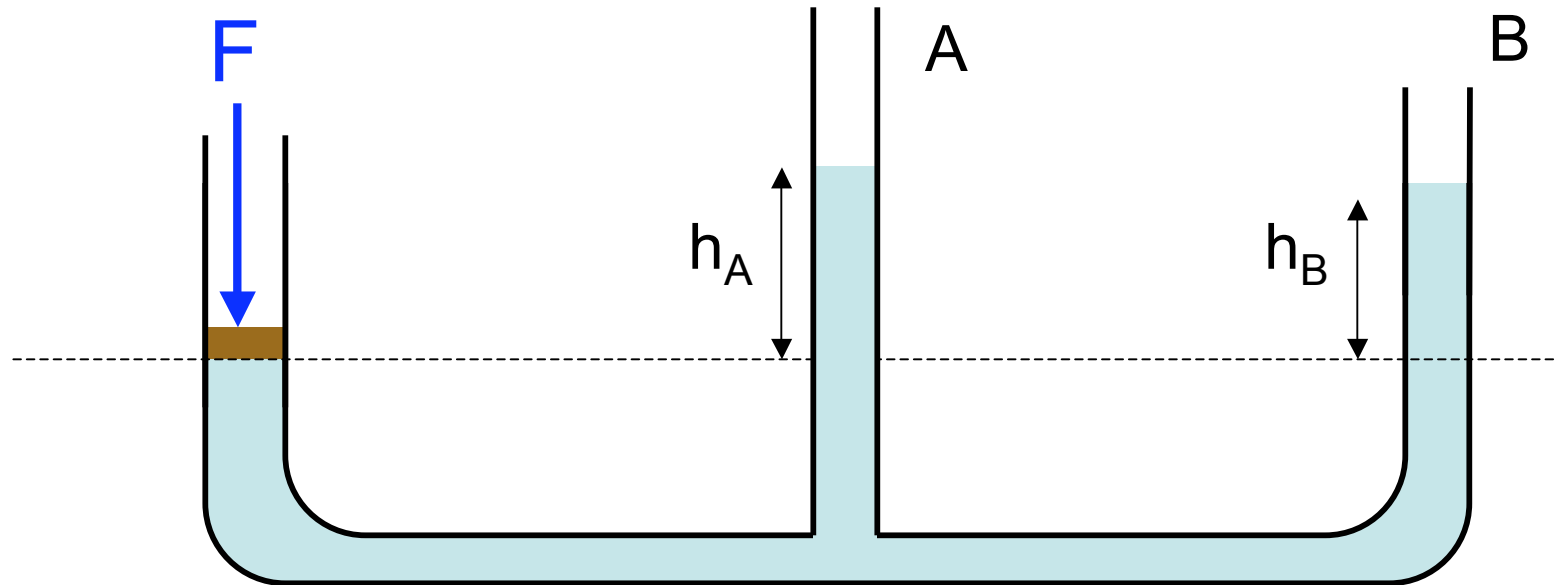


The same force is now applied to a **smaller** piston. Compared to the previous case the column in the opposite tube is

- A higher
- B lower
- C the same

$$h = F/\rho g A$$

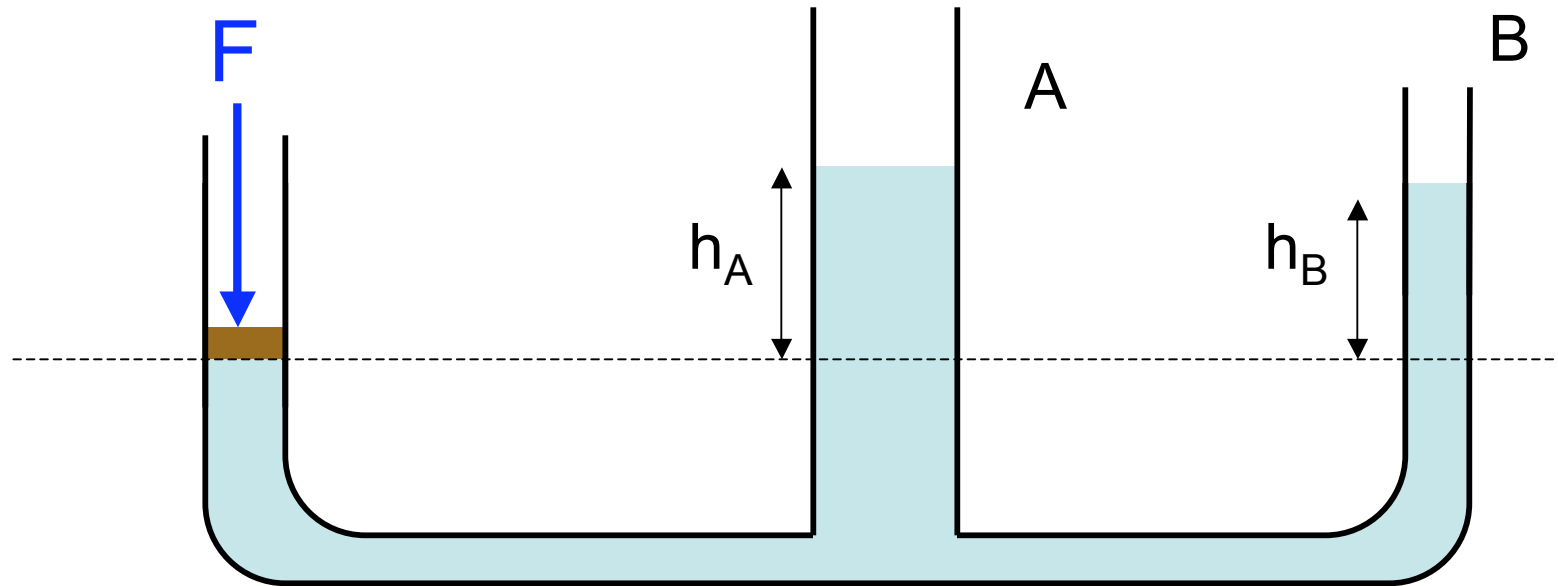
# The original U-tube



Columns have the same area. Which is higher?

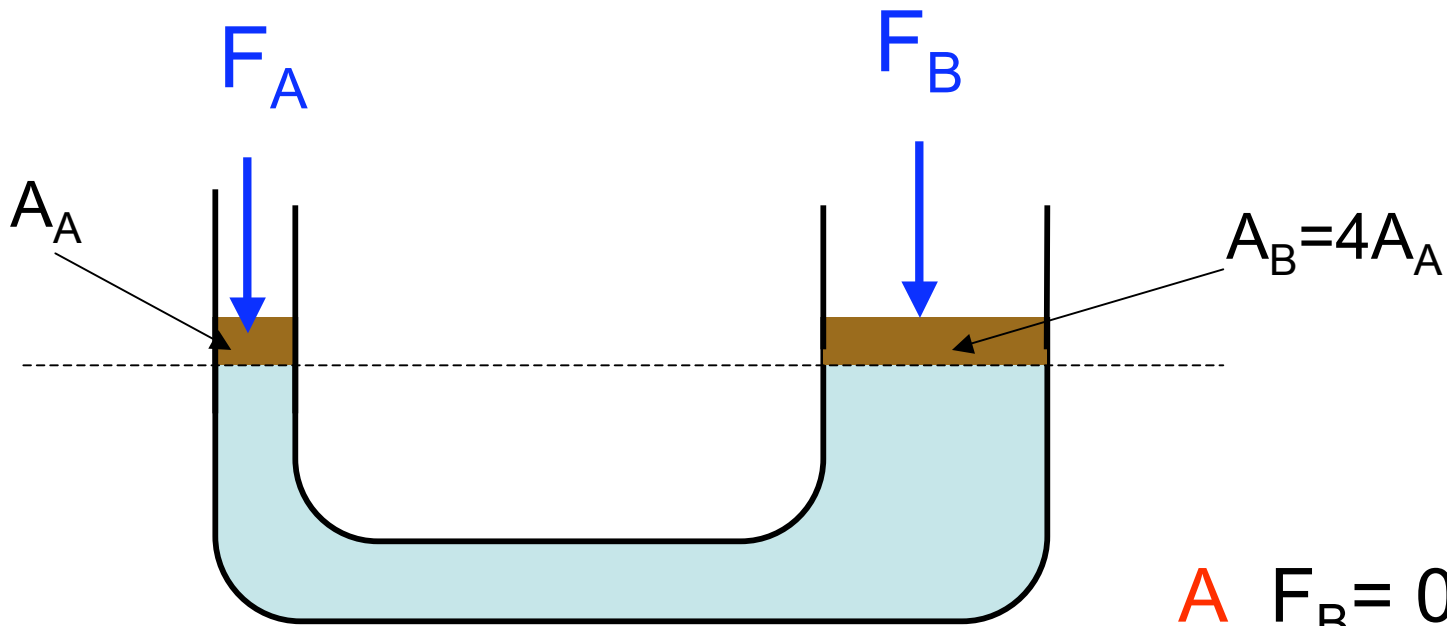
- A A
- B B
- C the same

# The original U-tube



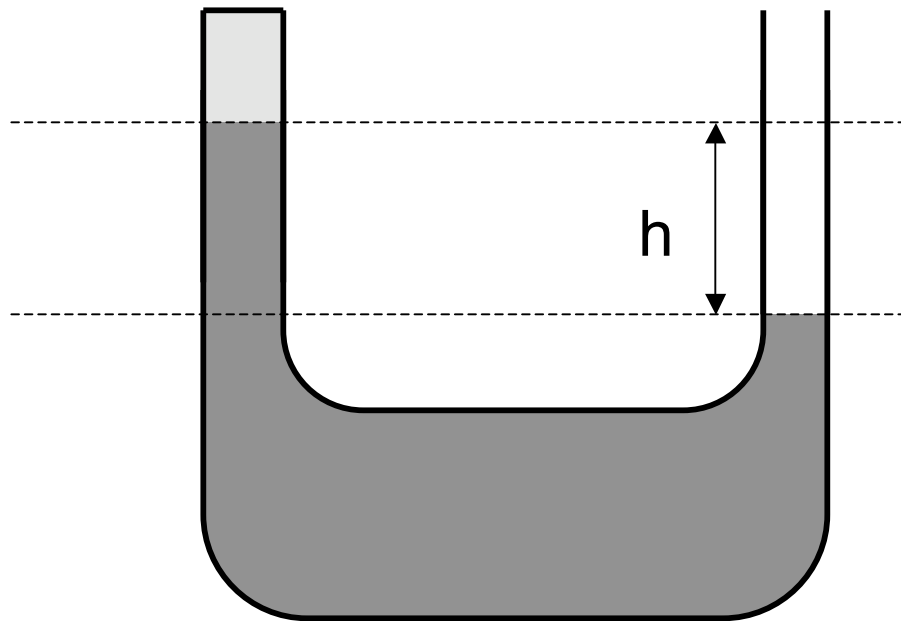
A is fatter. Which is higher?

- A A
- B B
- C the same



- A  $F_B = 0.25 F_A$
- B  $F_B = 0.5 F_A$
- C  $F_B = F_A$
- D  $F_B = 2 F_A$
- E  $F_B = 4 F_A$

# The original U-tube



bath & tubes filled with mercury

( $\rho = 13.6 \times 10^3 \text{ kg/m}^3$ )

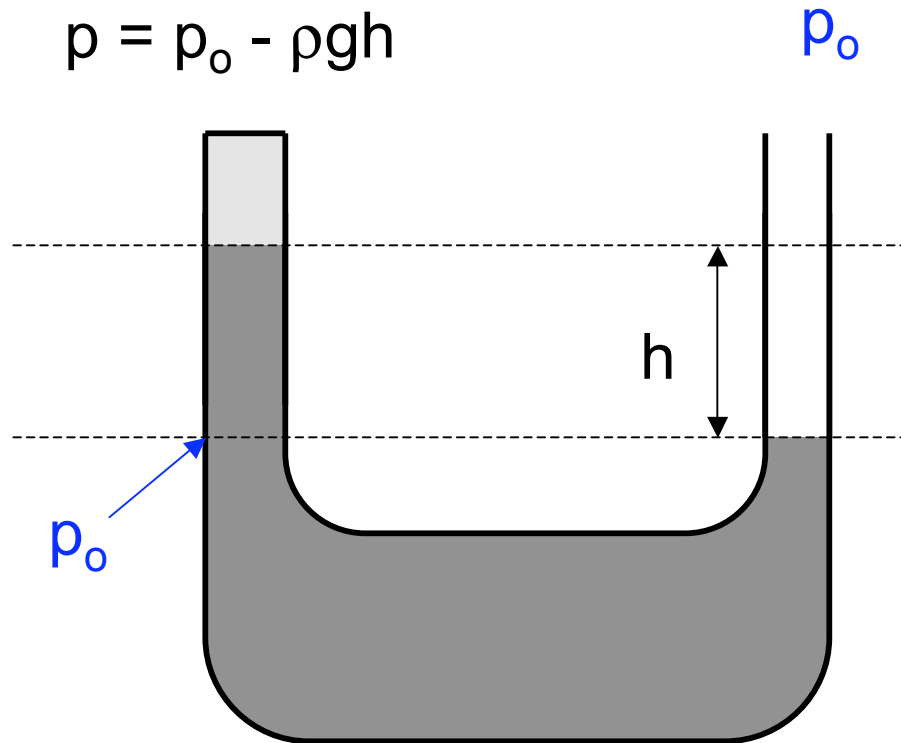
column rises to  $h=20$

cm. What is the

pressure in closed end?

- A  $2.0 \times 10^3 \text{ Pa}$
- B  $2.6 \times 10^4 \text{ Pa}$
- C  $7.4 \times 10^4 \text{ Pa}$
- D  $9.8 \times 10^4 \text{ Pa}$
- E  $1.3 \times 10^5 \text{ Pa}$

# The original U-tube



bath & tubes filled with mercury

( $\rho = 13.6 \times 10^3 \text{ kg/m}^3$ )

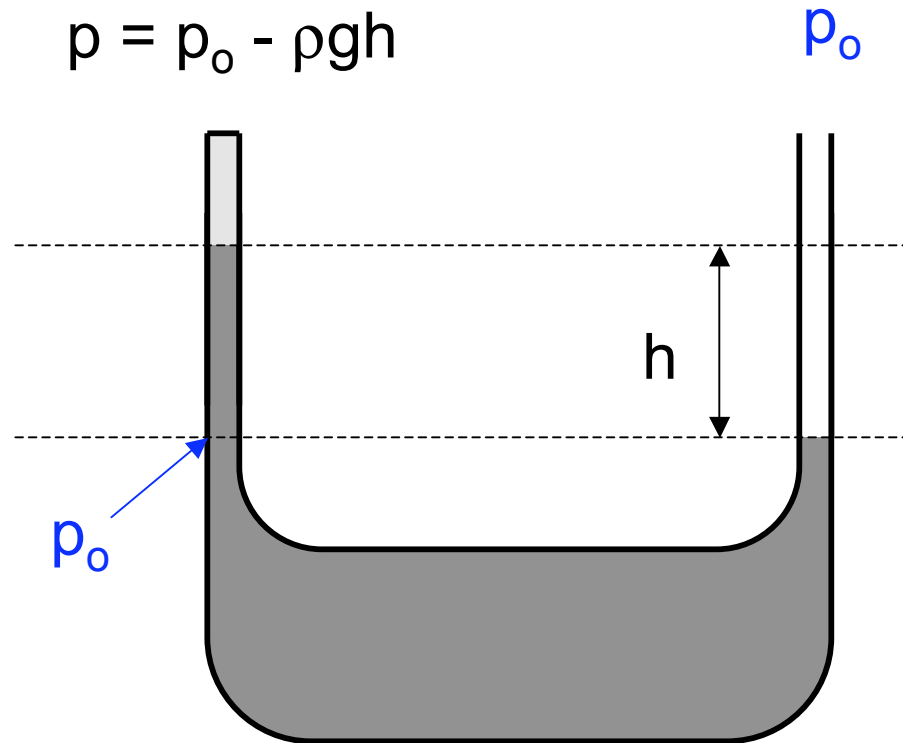
column rises to  $h=20$

cm. What is the

pressure in closed end?

- A  $2.0 \times 10^3 \text{ Pa}$
- B  $2.6 \times 10^4 \text{ Pa}$
- C  $7.4 \times 10^4 \text{ Pa}$
- D  $9.8 \times 10^4 \text{ Pa}$
- E  $1.3 \times 10^5 \text{ Pa}$

# The original U-tube



How high is the column if the closed end is a perfect vacuum (and the open end is at sea-level?)

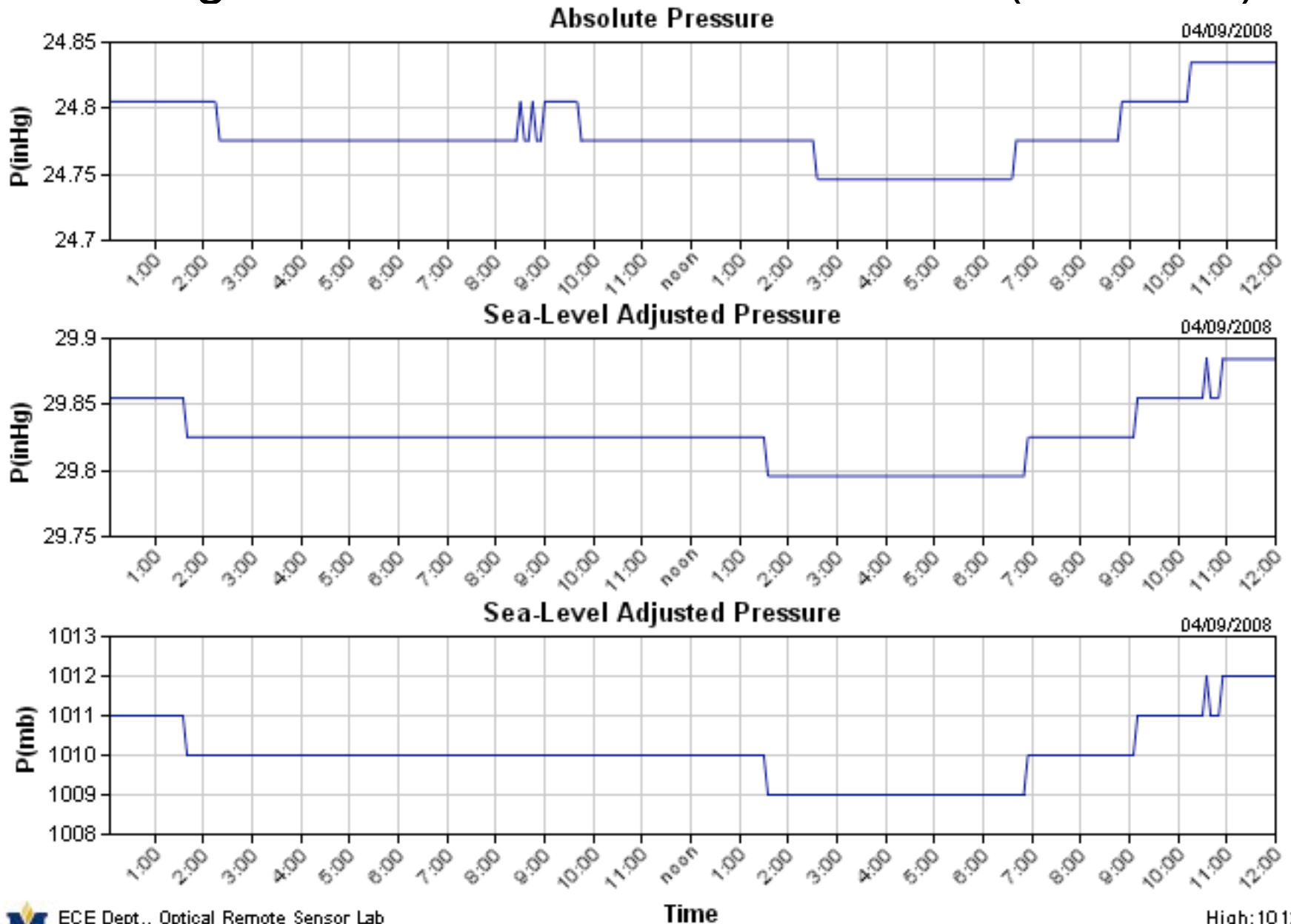
$$p_o = 1.01 \times 10^5 \text{ Pa}$$

$$p = p_o - \rho gh = 0$$

$$h = p_o / \rho g =$$

$$= 0.76 \text{ m} = 30 \text{ inches}$$

# Readings from the EPS weather station (4/9/2008)



# Current Surface

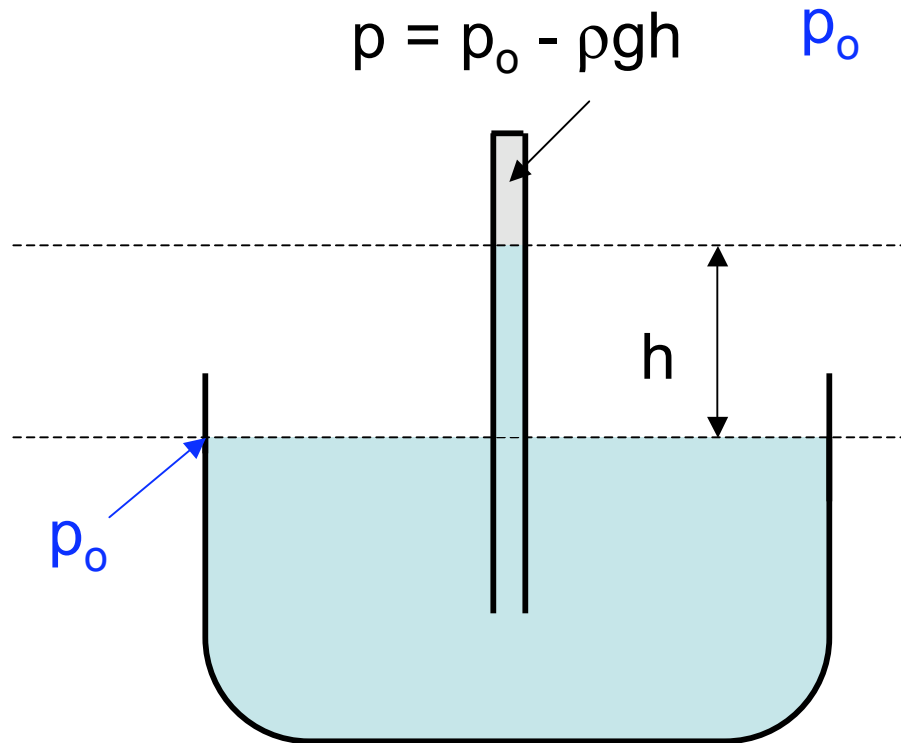
LT RAIN/DRIZZLE MOD/HVY RAIN RAIN/ICE/SNOW LT SNOW/FLUR MOD/HVY SNOW FOG



10 Apr 2008 14:07 GMT / 10 Apr 2008 10:07 AM EDT

The Weather Channel

weather.com



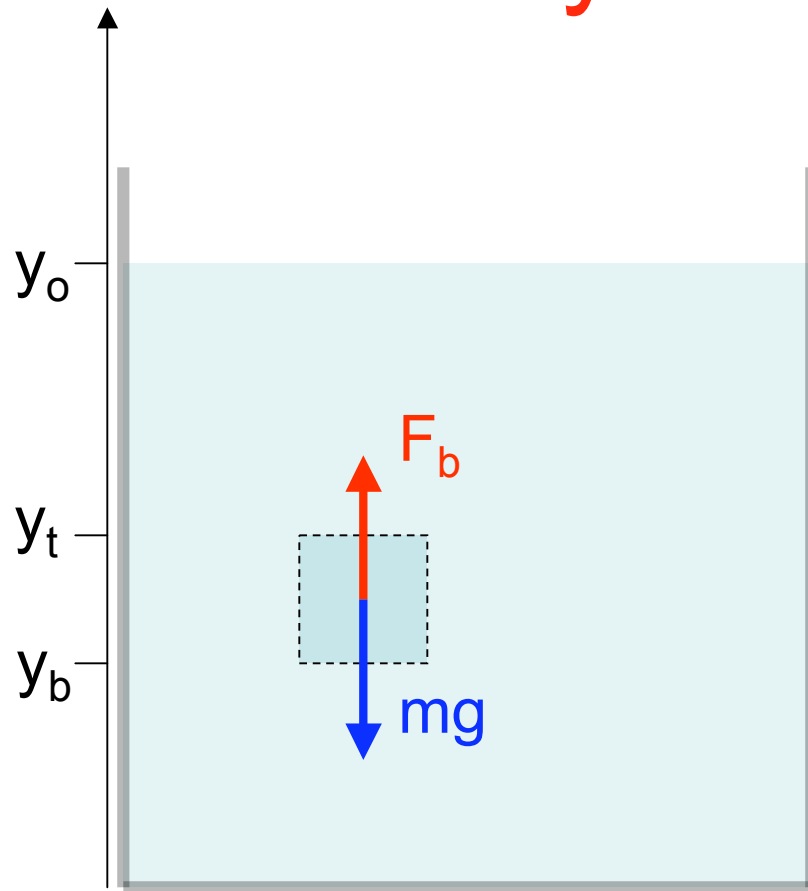
How high is the column if the closed end is a perfect vacuum (and the open end is at sea-level & the fluid is water?)

$$p_0 = 10^5 \text{ Pa}$$

$$p = p_0 - \rho g h = 0$$

$$h = p_0 / \rho g = 10.2 \text{ m}$$

# Buoyancy force



$$P_b = P_o + \rho g ( y_o - y_b )$$

$$P_t = P_o + \rho g ( y_o - y_t )$$

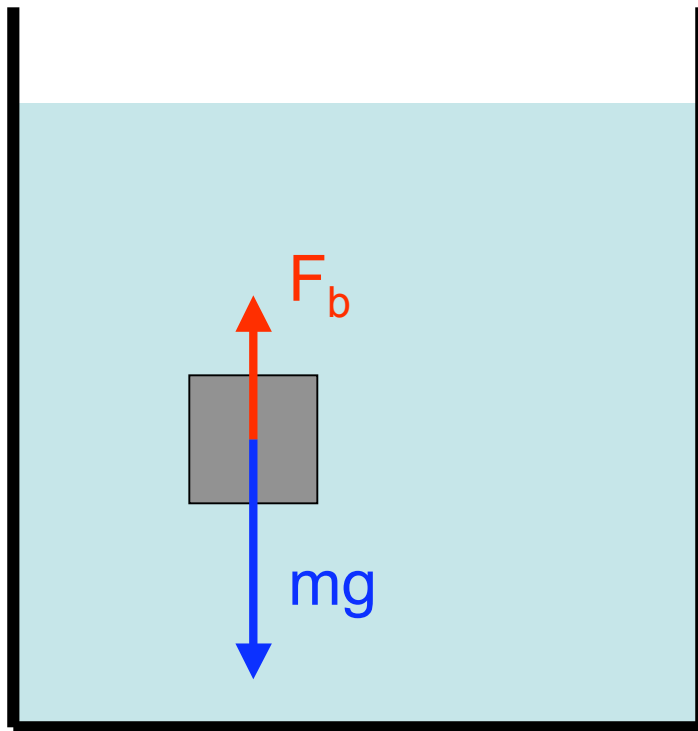
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$$P_b - P_t = - \rho g ( y_b - y_t )$$

net force of outside fluid  
called Buoyancy force

Exactly  
balances weight  
force on water  
of same volume

# Buoyancy force



$$P_b = P_o + \rho g (y_o - y_b)$$

$$P_t = P_o + \rho g (y_o - y_t)$$

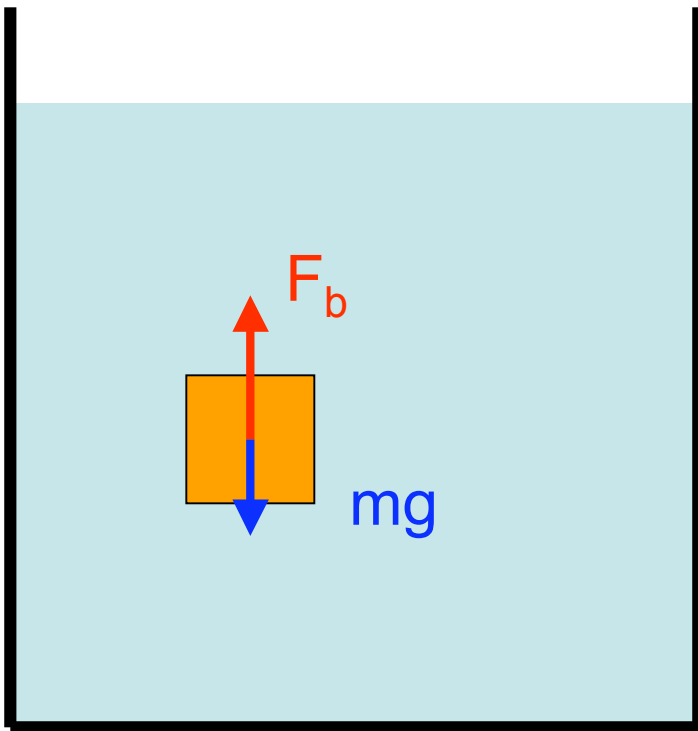
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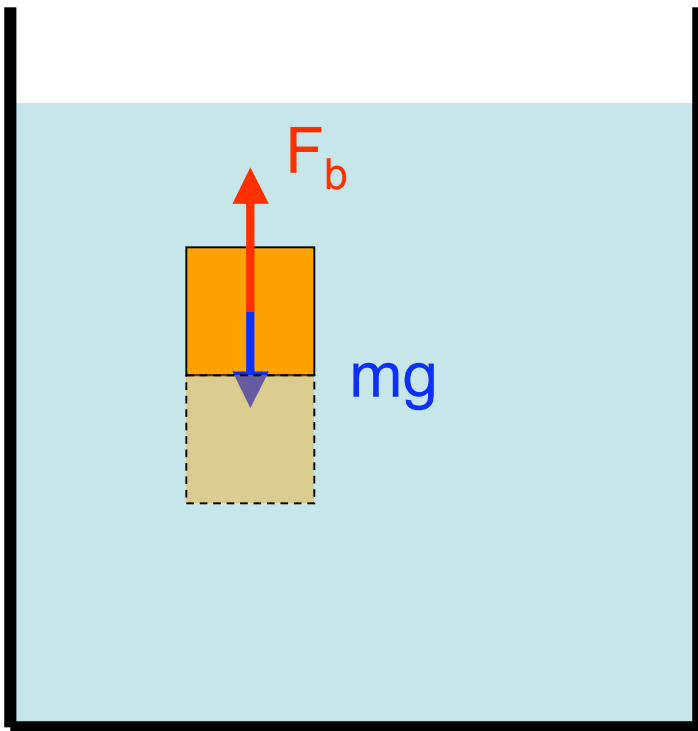
$$P_b - P_t = -\rho g (y_b - y_t)$$

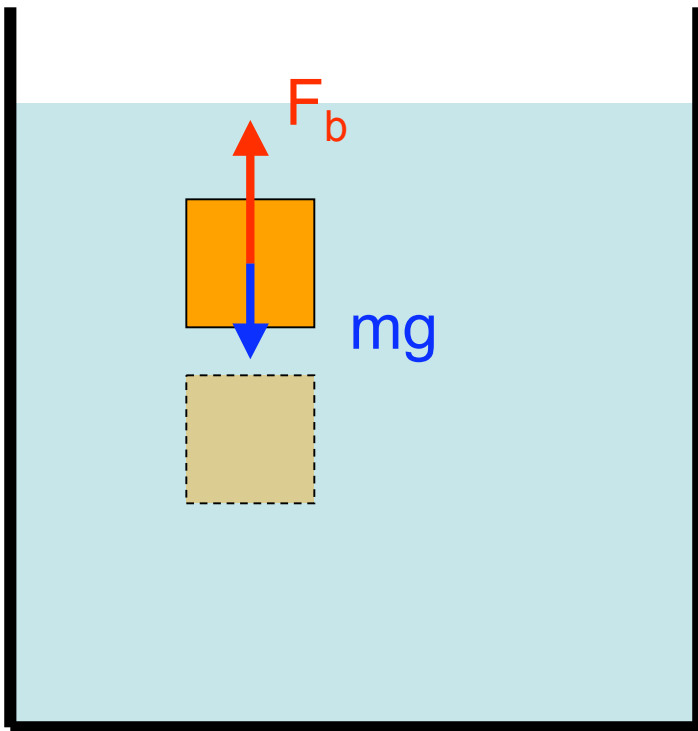
net force of outside fluid  
called Buoyancy force

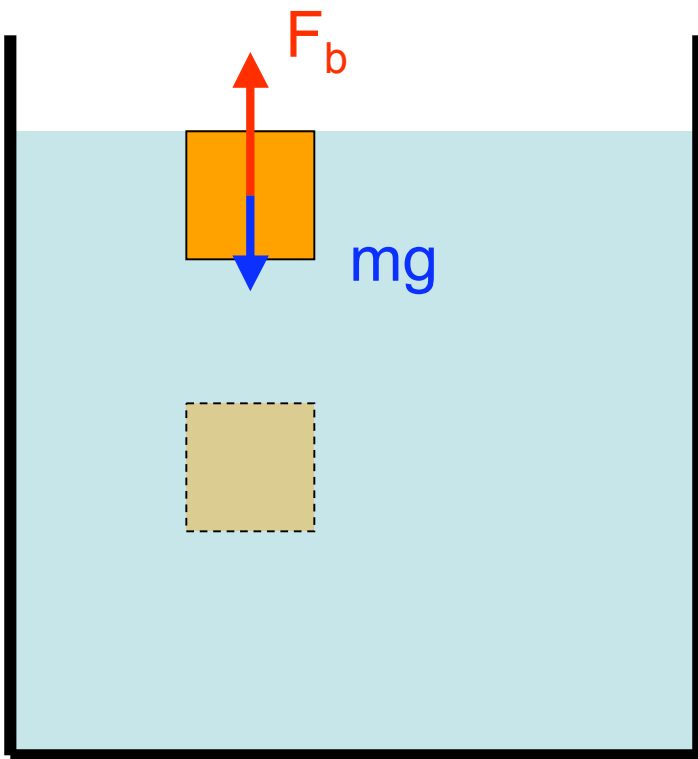
Exactly  
balances weight  
force on water  
of same volume

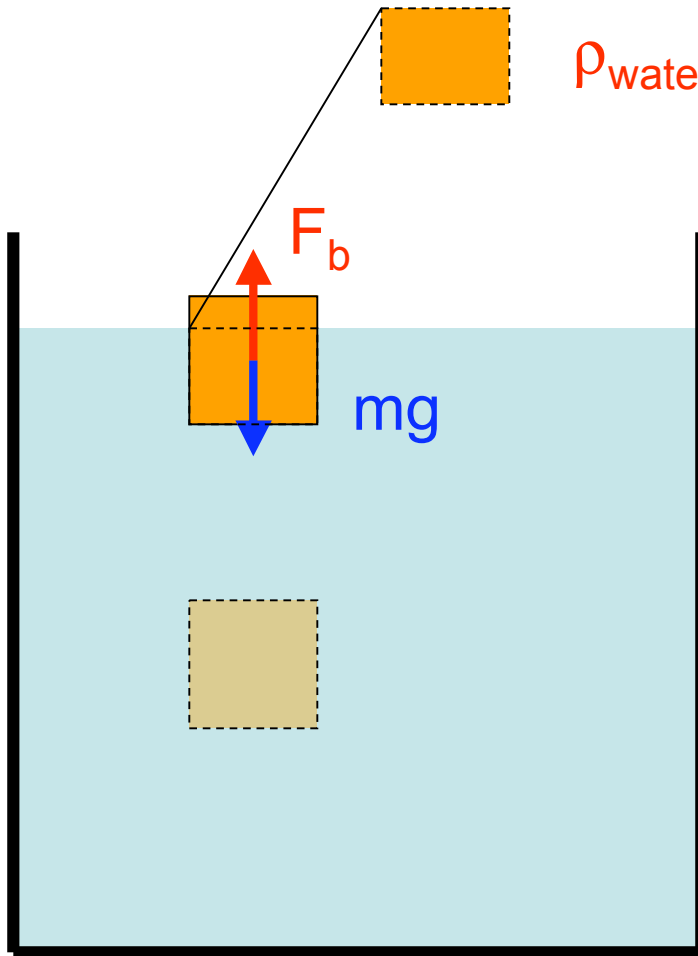
even when volume is filled with something else











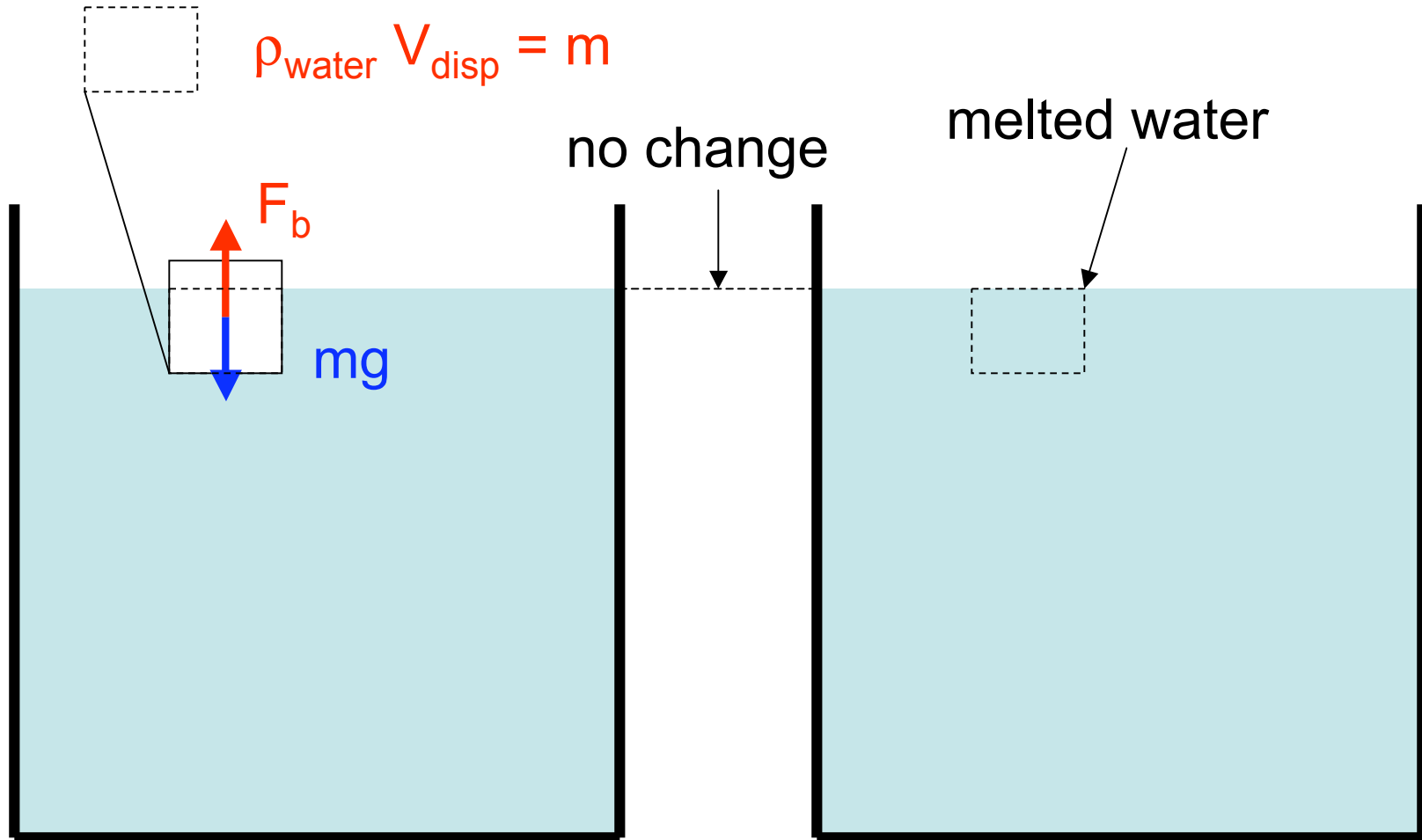
$$\rho_{\text{water}} V_{\text{disp}} = m$$

$$V_{\text{disp}} = m / \rho_{\text{water}}$$

$$< V_{\text{obj}} = m / \rho_{\text{obj}}$$

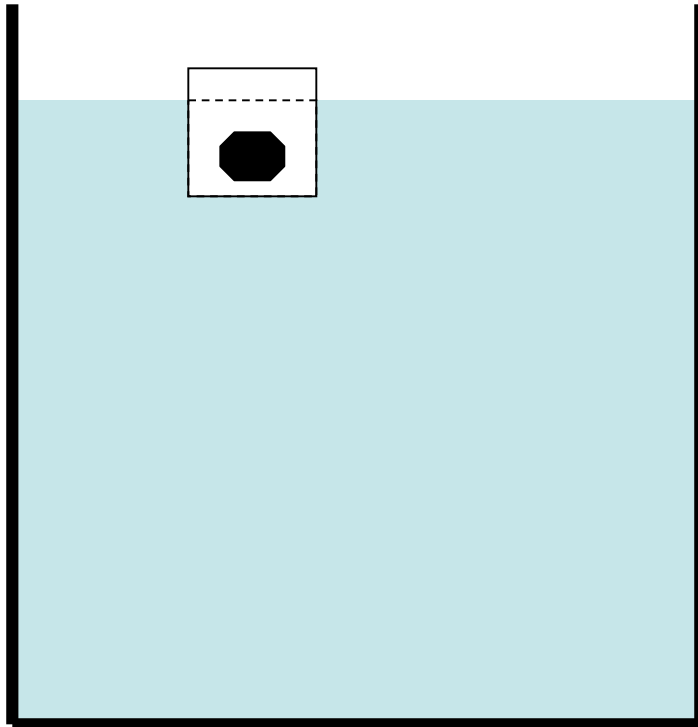
# floating ice cube

$$V_{\text{disp}} = m/\rho_{\text{water}} < V_{\text{ice}} = m/\rho_{\text{ice}}$$



# floating ice cube w/ pebble

When ice melts the water level will



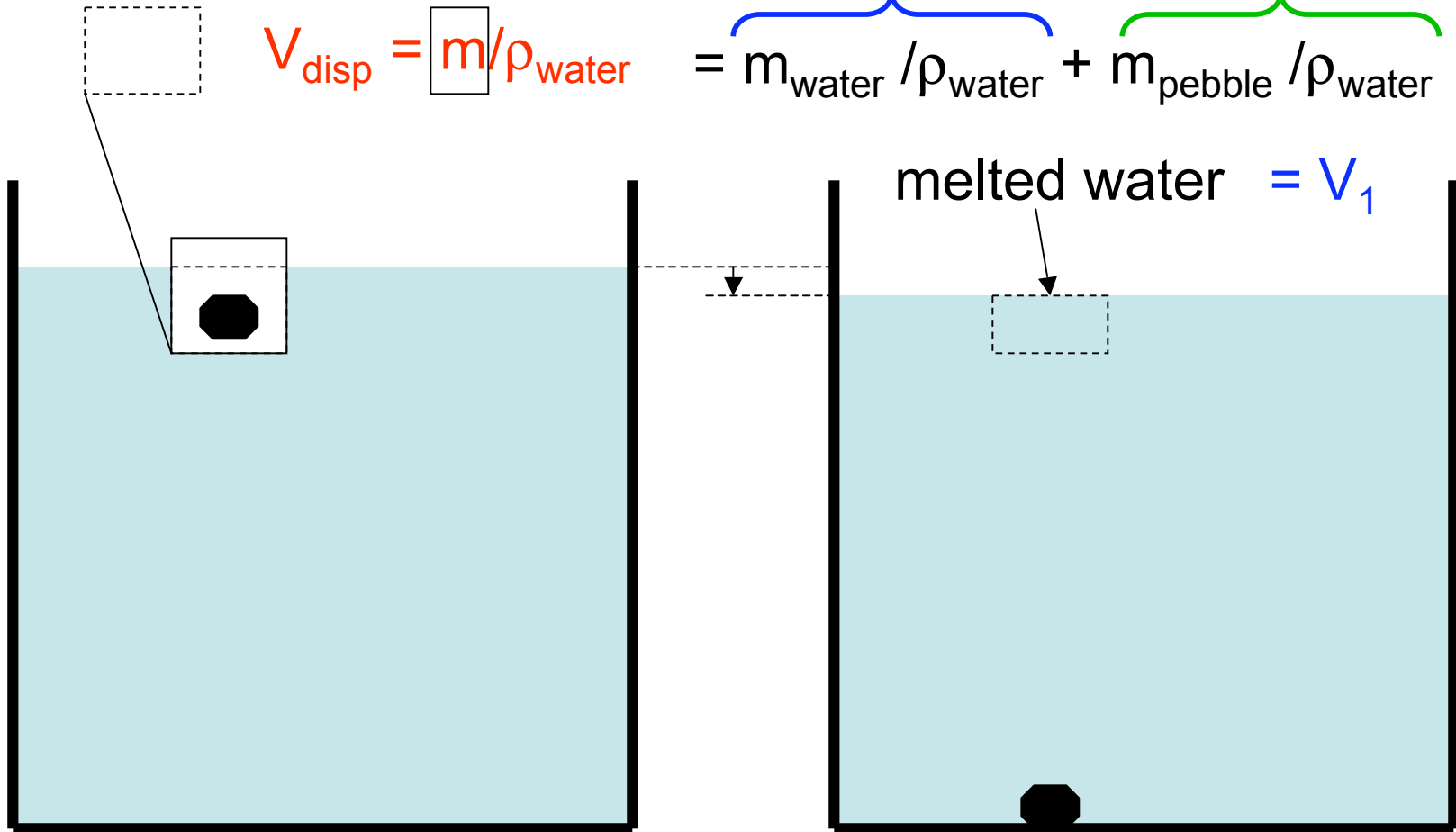
- A rise
- B stay the same
- C go down
- D depends on other things

# floating ice cube w/ pebble

$$= m_{\text{water}} + m_{\text{pebble}}$$

$$V_{\text{disp}} = \boxed{m} / \rho_{\text{water}}$$

$$= \overbrace{m_{\text{water}} / \rho_{\text{water}}}^{V_1} + \overbrace{m_{\text{pebble}} / \rho_{\text{water}}}^{V_2}$$



$$V_{\text{pebble}} = m_{\text{pebble}} / \rho_{\text{rock}} < V_2$$

Q: Is there a buoyancy force on you now?

How large (approximately)?

A 0.01 N

B 0.1 N

C 1 N

D 10 N

E 100 N

$$V = m/\rho = 10^2 \text{ kg}/10^3 \text{ kg/m}^3 = 10^{-1} \text{ m}^3$$

$$m_{\text{air}} = V \rho_{\text{air}} = (10^{-1} \text{ m}^3)(1 \text{ kg/m}^3) \\ = 10^{-1} \text{ kg} \quad (= 3 \text{ oz})$$

$$F_b = m_{\text{air}}g = (10^{-1} \text{ kg}) (10 \text{ m/s}^2) = 1 \text{ N}$$