Week 11 - Monday - PHYS 107

* Buoyancy:

$$F_B = W_{\text{displaced liquid}}$$

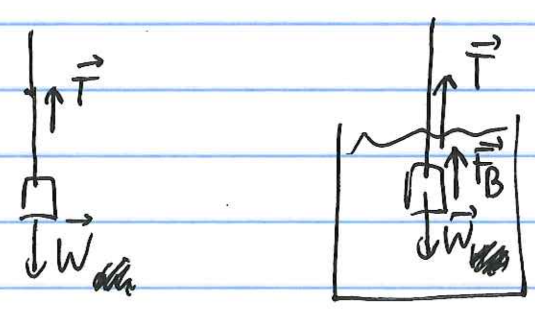
F_B ↑ buoyant force upward

↑ weight of displaced liquid (number, would be downward)

$F_B > W_{\text{object}}$ → float because net force up when submerged

$F_B < W_{\text{object}}$ → sinks because net force down

Example: Archimedes measured the weight of the King's crown in air and in water



$T = W_{air}$

$T = W - F_B < W$

↓

scale reads lower number

* Galileo thermometer (image)

Floating bells have constant V and constant m → ρ is constant inside bell

What changes? ρ_{H_2O}!

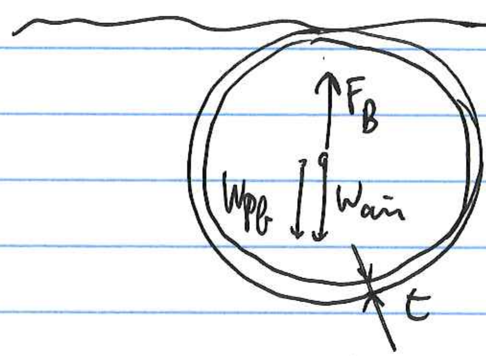
As temperature increases → ρ_{H_2O} will increase → $F_B = \rho_{H_2O} V_{bell}$ increases

↓

bells start to rise one by one

* Example: lead balloon, $\rho = 11.3 \times 10^3\ kg/m^3$

How thin do the walls have to be for this air-filled balloon to ~~ff~~ float in water? $R = 10\ cm$



$$0 = F_B - W_{Pb} - \underbrace{\cancel{W_{air}}}_{\text{very small}}$$

$$0 = \rho_{H_2O}\left(\frac{4}{3}\pi R^3\right)g - \rho_{Pb}(4\pi R^2)tg$$

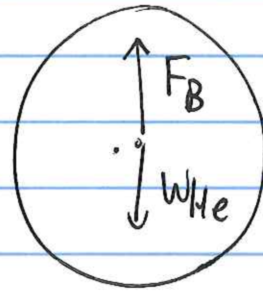
↓

$$t = \frac{\rho_{H_2O} R}{3\rho_{Pb}} = 3 \times 10^{-3}\ m = 3\ mm$$

* Example: Can 42 He-filled balloons (5' diameter) lift a person (70 kg)?

$F_{lift} = F_B - W_{He}$

$F_B = W_{air}$



F_{lift} = net force that is then used to lift person

$F_{lift} = W_{air} - W_{He}$

$= V \rho_{air} g - V \rho_{He} g = V(\rho_{air} - \rho_{He}) g$

5' diameter → $R = 0.76\,m$ → $V = \frac{4}{3}\pi R^3 = 1.85\,m^3$

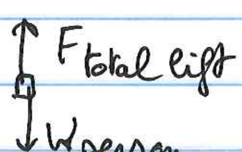
For each balloon: $F_{lift} = (1.85\,m^3)\left(1.29\frac{kg}{m^3} - 0.18\frac{kg}{m^3}\right)g$

$= 20.2\,N$

Total lift $= (42)(20.2\,N) = 850\,N$ → yes, person is lifted

$> \underbrace{(70\,kg)g}_{686\,N}$

What is the acceleration?



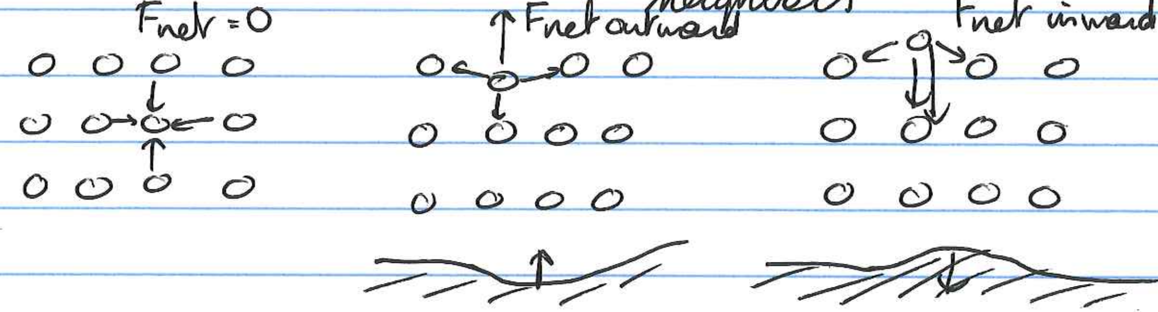
$\rightarrow ma = F_{total\ lift} - W_{person}$

$a = \frac{F_{total\ lift} - W_{person}}{m} = +2.3\,m/s^2$

Balloon flight video

* Surface tension : cohesive forces between molecules of the same type in a liquid

Consider surface of a liquid : molecules exert forces on neighbors



Surface of liquid "wants" to be as smooth as possible

For suspended liquid → droplets become spherical

Surface tension $= \gamma = \frac{F}{\ell}$ in units $\frac{N}{m}$

where ℓ is the circumference of the contact area

Water strider

Example : what is the angle at the contact with the water?

$R = 1.5 \times 10^{-4}\ m$ → $F = \gamma \ell = \gamma (2\pi R)$

$m = 2 \times 10^{-5}\ kg$

$\gamma = 0.0728\ N/m$ $\qquad F_y = F \cos\theta \times 6$ (legs)

$F_{net} = F_y - W = 0 \rightarrow \cos\theta = \frac{mg}{12\pi\gamma R} = 0.47 \rightarrow \theta = 62°$

what happens when $\cos\theta > 1$? bug sinks

* Surfactants : substances in liquid that reduces γ,
e.g. detergent in H_2O makes it "stick" / cling more to grease

In the lungs : pulmonary alveoli (mucus liquid)
tiny sacs with $r = 10^{-2}$ cm

inhalation: muscles expand chest cavity ⇒ negative pressure of ~ -3 mmHg

surfactant of long lipoproteins in mucus
when extended: γ increases → alveoli don't expand too much

exhalation: surface tension when extended causes alveoli to shrink again, γ decreases, alveoli don't collapse

Drowning : water in lungs : surfactant is diluted → γ is
Infants too large and can't inhale
Hyaline membrane disease

Emphysema : alveoli walls deteriorate → larger bubbles/sacs
→ reduced pressure → can't exhale