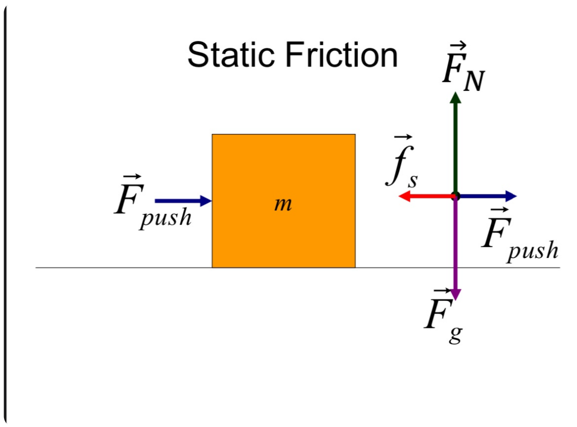
Friction

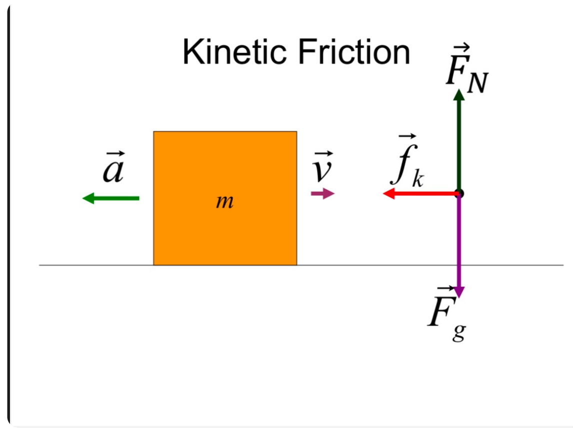
1. Definition: A frictional force that occurs between sliding an object on a rough surface

2. types of frictional forces:

- Static ⇒ $F_s \le \underbrace{\mu_s}_{\text{maximum}} \times F_n$ ⇒ μ_s : coefficent of static
- Kinetic ⇒ $F_k = \mu_k \times F_n$ ⇒ F_k : coefficent of kinetic

(($\mu_k < \mu_s$))
Values of μ_k & μ_s depends on type of material





Buoyancy

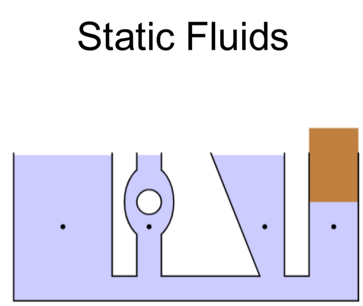
1. what is a fluid?

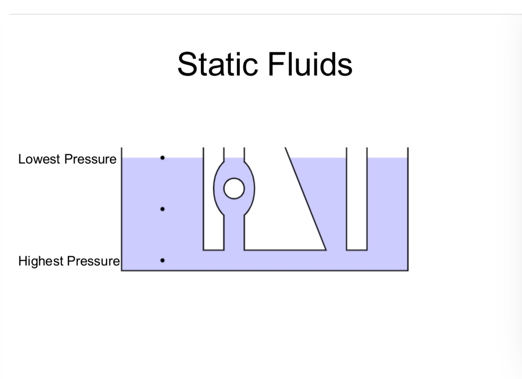
- A form of matter capable of flowing in response to forces...
- it also exerts a force per unit area on an object, which is called: ((Pressure))

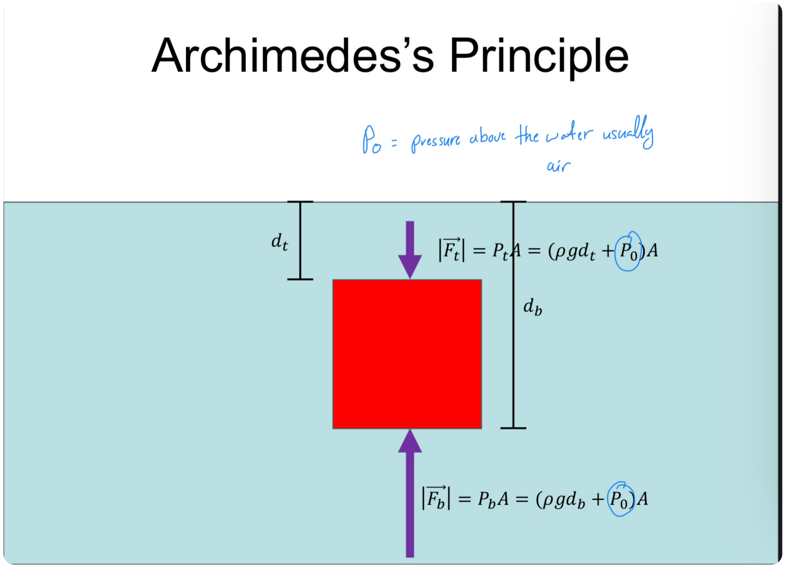
$$\boxed{P = \frac{F}{A} = \frac{N}{m^2} = Pa}$$

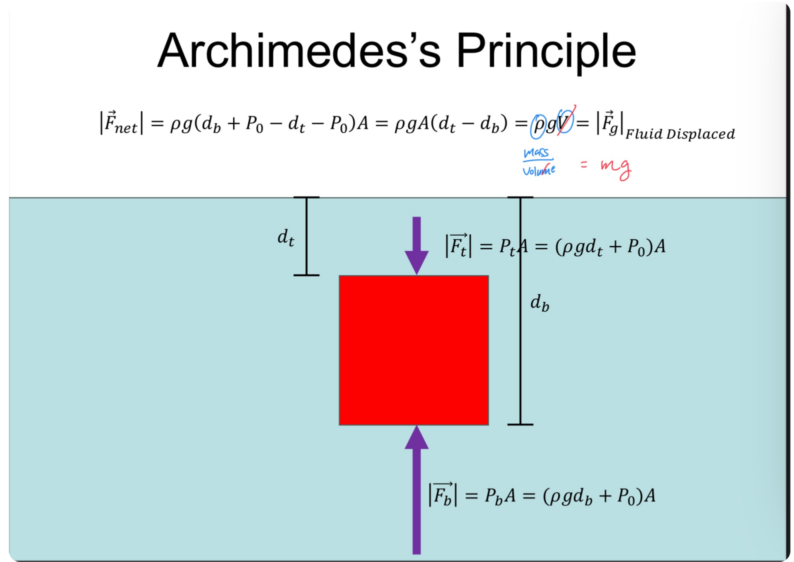
$$\boxed{\Delta P = \rho g \,\Delta d}$$ ⇒ ρ: density of fluid (mass / volume)

$$\boxed{\begin{gathered} F_{net} = (\rho g \,\underline{\Delta d})\, A = \rho g V = m_f \times g \\ \vec{F}_b = \vec{F}_g \text{ (fluid displaced)} \end{gathered}}$$







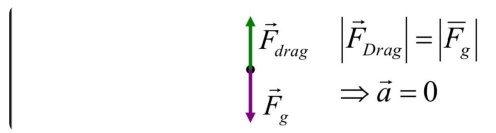


Drag

$\boxed{2}$ Object traveling through fluid experience a force opposite direction of motion...

$$\boxed{\vec{F}_{Drag} = \frac{1}{2} C \rho A v^2}$$

C: drag coefficient

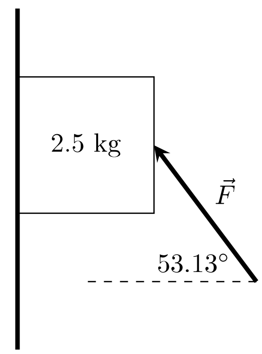


$\vec{F}_{Drag} \propto v^2 \Rightarrow$ as an object accelerates during free fall, the $\vec{F}_{Drag}$ increases until $F_{Drag} = F_g$ (($a_y = 0$))...

1.7 Friction, Buoyancy, and Drag

1.7.1 A Book Against a Wall

To hold up a 2.5 kg block against a vertical wall, Felicity finds she must exert a minimum force $\vec{F} = 25$ N against the block at an angle of 53.13° above the horizontal, as shown in the picture below. (*Note: This is a former test question!*)



1. What is the magnitude and direction of the normal force exerted on the block?
2. What is the magnitude and direction of the frictional force experienced by block? What type of frictional force is this?
3. Which coefficient of friction μ_s or μ_k between the block and the wall can Felicity now calculate? Using the information given in this problem, find a value for this coefficient of friction.
4. Based on this coefficient of friction, what is the maximum magnitude of force $\left|\vec{F}\right|$ Felicity can exert at this angle before the box starts accelerating up the wall?

1.7.2 A Balloon in an Elevator

A helium balloon of total mass $m = 12.5$ g floats at the top of an elevator. At a particular instant in time - at which point the elevator is traveling upwards at a speed of 2 m/s but accelerating downwards with a magnitude of 1 m/s^2 - it is observed that a horizontal push of magnitude $\vec{F} = 0.600$ N is necessary to slide the balloon across the roof of the elevator. The coefficient of static friction between the elevator roof and the balloon is known to be 0.56.

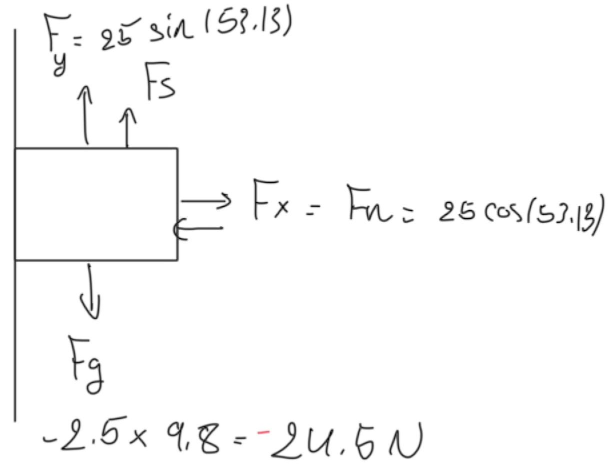
1. What is the net force acting on the balloon the moment before it is pushed? Please specify both the magnitude and the direction of this net force.
2. Draw a free body diagram showing the forces acting on the balloon, including the force of the push, the force of static friction, the force of gravity, the buoyant force, and the normal force.
3. What is the magnitude of the normal force acting on the balloon?
4. What is the magnitude of the buoyancy force acting on the balloon?
5. If the density of air is about 1.23 kg/m^3, what is the approximate volume of the helium balloon?

1.7.3 Drag on an Airplane

At flight level 280 (i.e., at an altitude where the pressure is equivalent to 28000 ft above sea level), a typical Airbus A320 airplane has a cruising speed of about 290 knots. At this cruising altitude, its CFM56-5A engines deliver approximately 5000 lbs of continuous thrust.

1. Draw and label a qualitative free body diagram for the Airbus A320 airplane. Don't forget that the airplane has mass, and that its wings are generating lift!
2. Using that 1 inch is defined to be exactly 2.54 cm, convert the airplane's altitude to SI units.
3. Using that 1 nautical mile is exactly 1852 meters, convert the airplane's speed to SI units.
4. Using that 1 pound is approximately 4.448 N, convert the airplane's thrust into SI units. (Note that pounds are units of force, not units of mass, in the British Imperial system!)

$\boxed{1.7.1}$



$\boxed{1}$ $F_n = F_x = 25\cos(53.13) = 15\,\hat{i}\,N$

$\boxed{2}$ since $F_g > F_y$, then F_s is in the positive y... it is a static frictional force

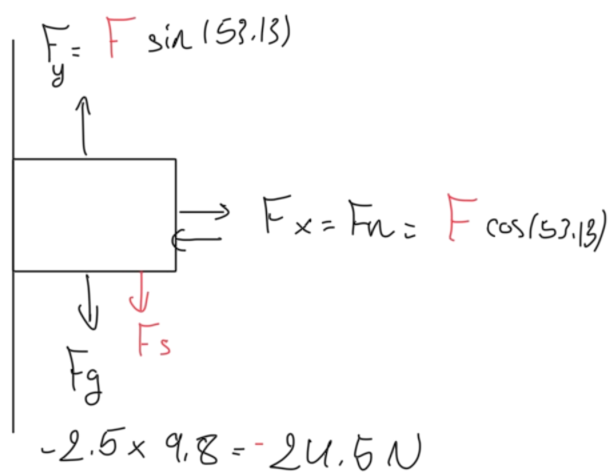
$F_g = F_y + F_s$

$24.5 = 25\sin(53.13) + F_s$

$F_s = \boxed{4.5\,N}$

$\boxed{3}$ $\mu_s = \dfrac{F_s}{F_n} = \dfrac{4.5}{15} = \boxed{0.3}$

$\boxed{4}$ $F\sin(53.13°) > F_g + F_s$



$0.8F > 24.5 + 0.3 \times F\cos(53.13)$

$0.8F > 24.5 + 0.18F$

$0.62F > 24.5$

$\boxed{F > 39.52\,N}$

$\boxed{1.7.2}$

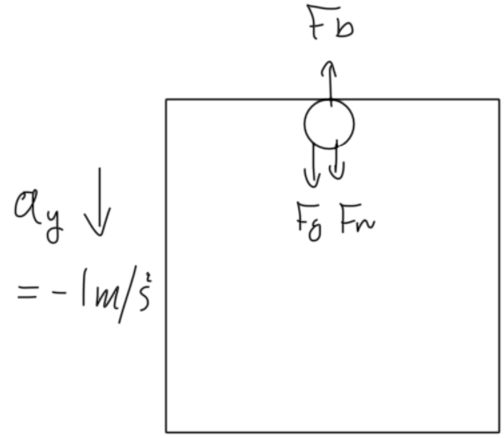
$m_{(b)} = 0.0125\ kg$

$m_s = 0.56$

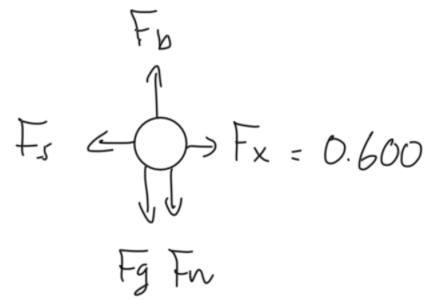
$F_x = 0.600\ N$

$a_y = -1\ m/s^2$

$\boxed{1}$



$\boxed{2}$



$\boxed{3}$ $F_s = F_x$

$\mu_s F_n = 0.6$

$0.56\ F_n = 0.6$

$F_n = \frac{0.6}{0.56} = \boxed{1.07\ N}$

$\boxed{4}$ $\sum F_{(net\text{-}y)} = m_b \cdot a_y$

$F_b - F_g - F_n = 0.0125 \times -1$

$F_b - (0.0125 \times 9.8) - 1.07 = -0.0125$

$F_b = \boxed{1.18\ N}$

$\boxed{5}$ $F_b = \rho g V$

$0.935 = 1.23 \times 9.8 \times V$

$V = \boxed{0.098\ m^3}$

$\boxed{1.7.3}$

5. For air inside the lower troposphere (i.e., the part of earth's atmosphere closest to the surface), the density of air ρ obeys (approximately) the following formula

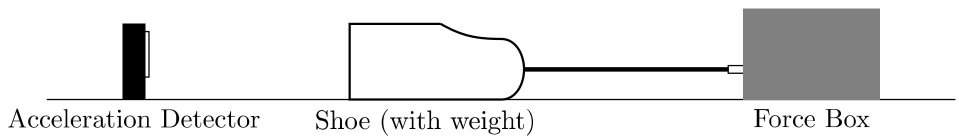
$$\rho = \rho_0 e^{-\frac{y}{H}} \tag{1.1}$$

where y is the altitude, ρ_0 is the density of air at sea level (approximately 1.23 kg/m^3 at standard temperature and pressure), and H a length scale approximately equal to 10.4 km for earth's atmospheric makeup. Use this equation to find ρ at the altitude of the A320 airplane.

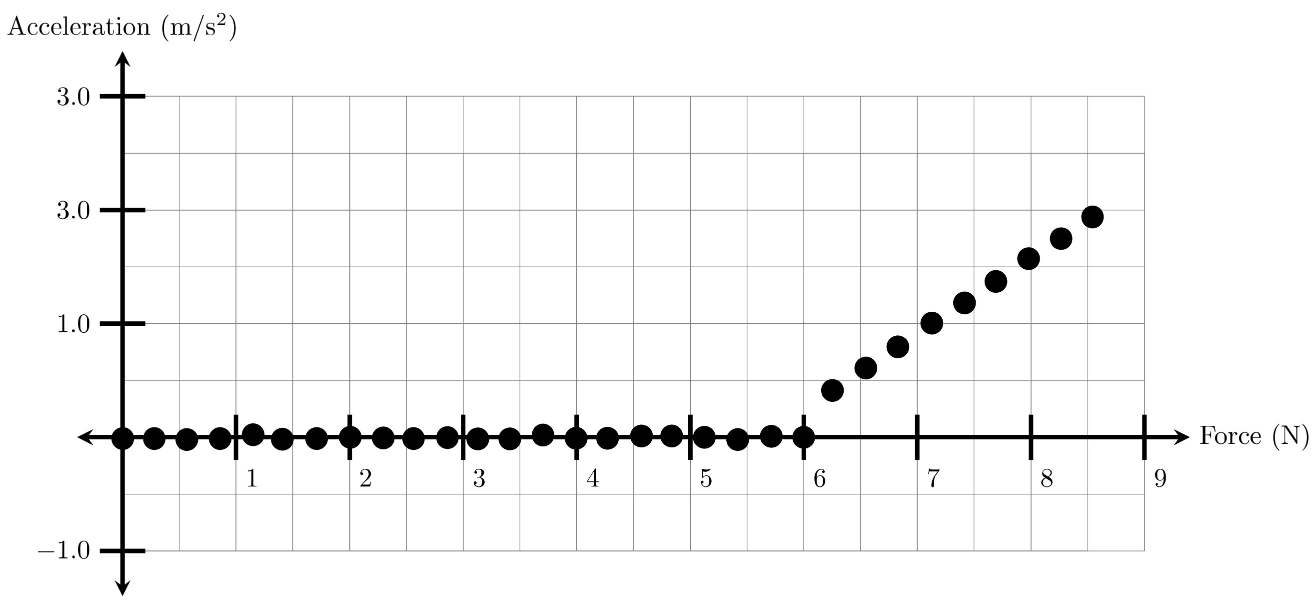
6. For an aircraft, the area term that appears in the equation for drag is very close to the area of the wing itself, which for an Airbus A320 is 122.6 square meters. Use this and your previous results to calculate C, the approximate drag coefficient of the Airbus A320.

1.7.4 Graphical Analysis

To determine the the coefficients of friction between her shoe and the ground, Maggie sets up the following experiment, in which she attaches her shoe to a force box (as shown below) that will exert progressively larger and larger forces on her shoe and then measures the acceleration of her shoe using an ultrasonic motion detector (like the ones we encountered in our second lab)! She then puts a lead weight in her shoe to increase its mass, and measures the full mass of the weighted shoe to be 1.55 kg.



She then takes the following data for the acceleration as a function of the force applied by the force box.



1. What is the approximate coefficient of static friction between Maggie's shoe and the ground?

2. What is the approximate coefficient of kinetic friction between Maggie's shoe and the ground?

$\boxed{1}$ $\sum F_{(net-y)} = \overset{0}{ma}$

$F_n = mg$

$F_n = 1.55 \times 9.8$

$F_n = 15.19\ N$

$\sum F_{(net\,x)} = \overset{0}{ma}$

$F_s = F_x$

$\mu_s \times 15.19 = 6$

$\boxed{\mu_s = 0.395}$

$\boxed{2}$ $\sum F_{(net-x)} = ma$

* $\mu_k \times 15.19 = 8.5 - 1.55 \times 2$

$\mu_k = 0.345$ … [6,7] has the same

* $\mu_k \times 15.19 = 7.5 - 1.55 \times 1.5$

$\mu_k = 0.341$

Average $\mu_k = 0.364$