Advanced Structural Geology, Fall 2022

Force and Stress

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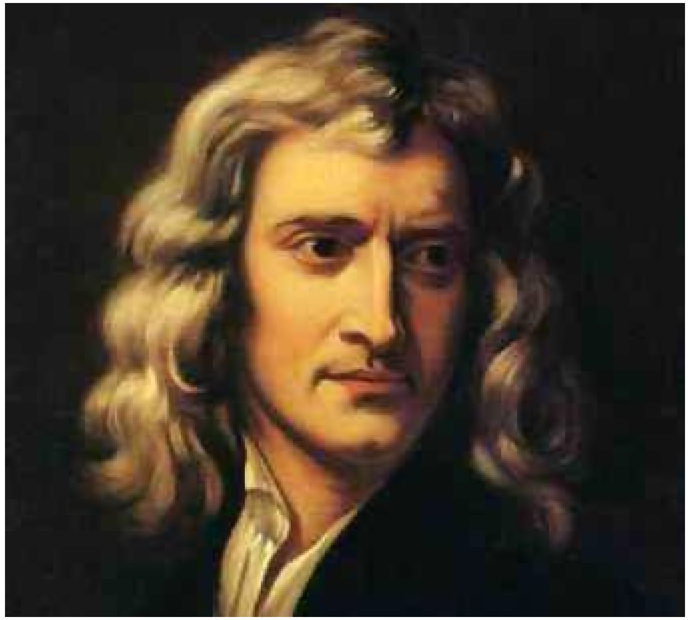
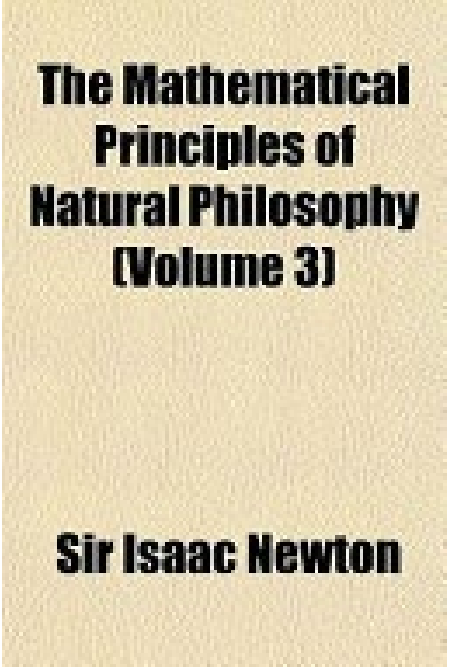




F=m**A**

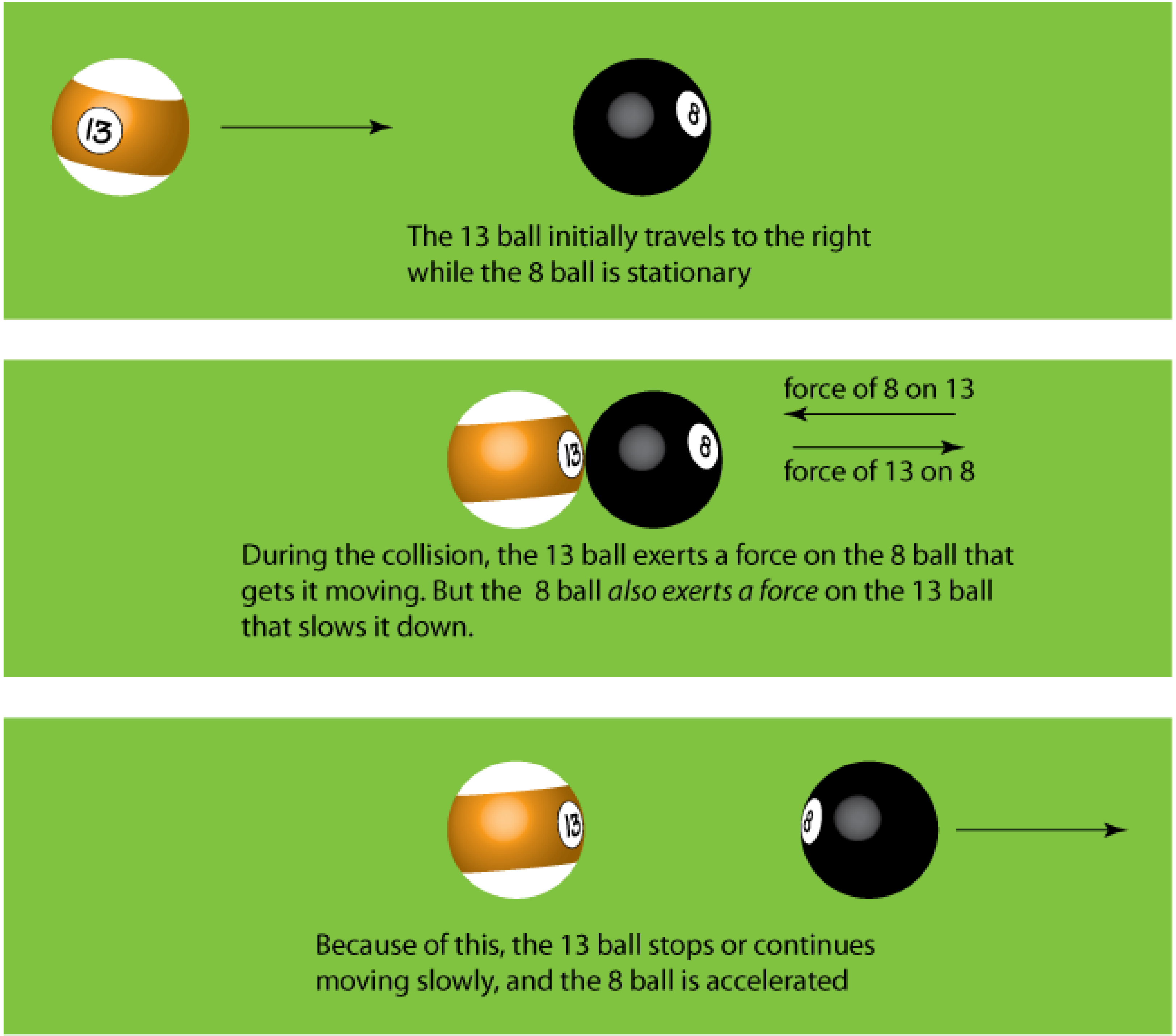
Isaac Newton

Sir Isaac Newton was an English physicist, mathematician, astronomer, natural philosopher, alchemist and theologian, who has been "considered by many to be the greatest and most influential scientist who ever lived."

Philosophiæ Naturalis Principia Mathematica, often referred to as simply the *Principia*, is a work in three books by Sir Isaac Newton, first published 5 July 1687

Force: Newton's Laws of Motion

- Law I: Every body continues in its state of rest, or in uniform motion in a straight line, unless it is compelled to change its state by forces impressed upon it.



https://sites.google.com/site/billiardballsandphysics/the-collision

Force: Newton’s Laws of Motion

- Law II: The rate of change of momentum is proportional to the impressed force and is made in the direction in which the force is impressed.

Force: Newton's Laws of Motion

m = mass
v = velocity vector
t = time
a = acceleration vector

Force: Newton's Laws of Motion

Force = rate of change of momentum (mass · velocity)

$$\vec{F} = \frac{\Delta m\vec{v}}{\Delta t} \underset{\lim \Delta t \to 0}{=} \frac{dm\vec{v}}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a}$$

m = mass

$\vec{v}$ = velocity vector (vector)

t = time

$\vec{a}$ = acceleration vector

Force: Newton's Laws of Motion

Dimensional analysis: fundamental units

Mass = amount of material in a body
Weight = Force due to gravity action on a body
1 liter of water has a mass of
on earth it weighs
on the moon it weighs

Force: Newton's Laws of Motion

Dimensional analysis: fundamental units

$$\vec{F} = m\vec{a} = [\text{mass} \cdot L \cdot T^{-2}]$$
$$= kg \cdot m \cdot s^{-2} \quad SI$$
$$= \text{Newton}$$
$$= N$$

Mass = amount of material in a body

Weight = Force due to gravity action on a body

1 liter of water has a mass of 1 kg

on earth it weighs $\vec{F} = m\vec{g} = 1kg \cdot 9.81\ m/s^2 = 9.81N$

on the moon it weighs $F = m\vec{g}_m = 1kg \cdot 1.64\ m/s^2 = 1.64N$

What does a Newton feel like?

V = 14 mph
dt = 0.5s
16 lb ball

We want f=mA in SI units

http://www.youtube.com/watch?v=LOINRpWGrlw

What does a Newton feel like?

Units of Force

The **newton** (N) is the basic unit of force in the International System. A newton is the force required to impart an acceleration of one meter per second per second to a body of one kilogram mass. In the cgs system, the basic unit of force is the **dyne**, which is the force required to impart an acceleration of one centimeter per second per second to a body whose mass is one gram. A force of one newton is equivalent to the force of 10^5 dynes.

What Does a Newton Feel Like?

Randy Richardson (University of Arizona) helped us with this one. Let's say we go to the bowling alley in our purple and yellow shirts with flyaway collars. As amateurs we pick up a bowling ball (it weighs 16 lb), dry our fingers, go into our rhythm, extend arm and ball all the way backward during the approach (for an instant the ball is at rest!), then launch the ball forward, and then release. Randy estimates the time (t) that transpires from the ball at rest to release is approximately 0.5 s.

In calling around to the alleys, Randy learned that the velocity of the ball at release for amateurs is on the order of 13 to 15 miles per hour (mph). He then calculated acceleration (a) by dividing velocity (V) by time (t) (converting to metric in the process):

$$V = 14 \text{ mph} = \frac{14 \text{ mi}}{\text{hr}} \times \frac{\text{km}}{0.62 \text{ mi}} \times \frac{\text{hr}}{3600 \text{ s}} \times \frac{10^3 \text{ m}}{\text{km}} = 6.27 \frac{\text{m}}{\text{s}}$$

$$\frac{V}{t} = \frac{6.27 \text{ m/s}}{0.5 \text{ s}} = 12.54 \text{ m/s}^2$$

To calculate force (F), in newtons, Randy multiplied mass (m) times acceleration (a), again converting to metric, and determined that the constant force needed to accelerate the ball to the point of release is about 90 N:

$$F = \text{ma}$$

$$m = 16 \text{ lb} \times 16 \frac{\text{oz}}{\text{lb}} \times \frac{28.35 \text{ g}}{\text{oz}} \times \frac{\text{kg}}{10^3 \text{ g}} = 7.26 \text{ kg}$$

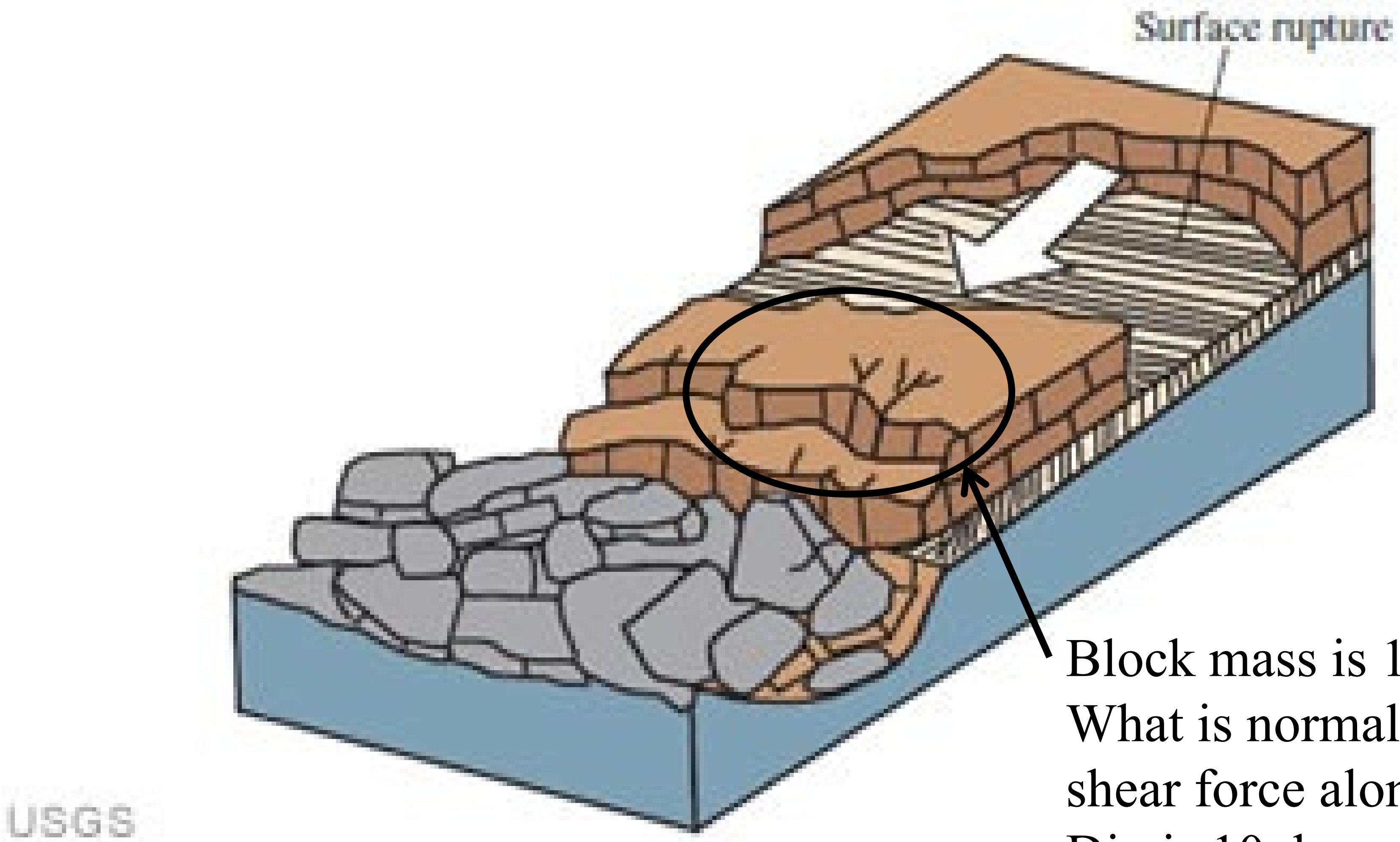
$$F = ma = 7.26 \text{ kg} \times 12.54 \text{ m/s}^2$$

or $$F = 91.1 \text{ kg} \times \text{m/s}^2$$

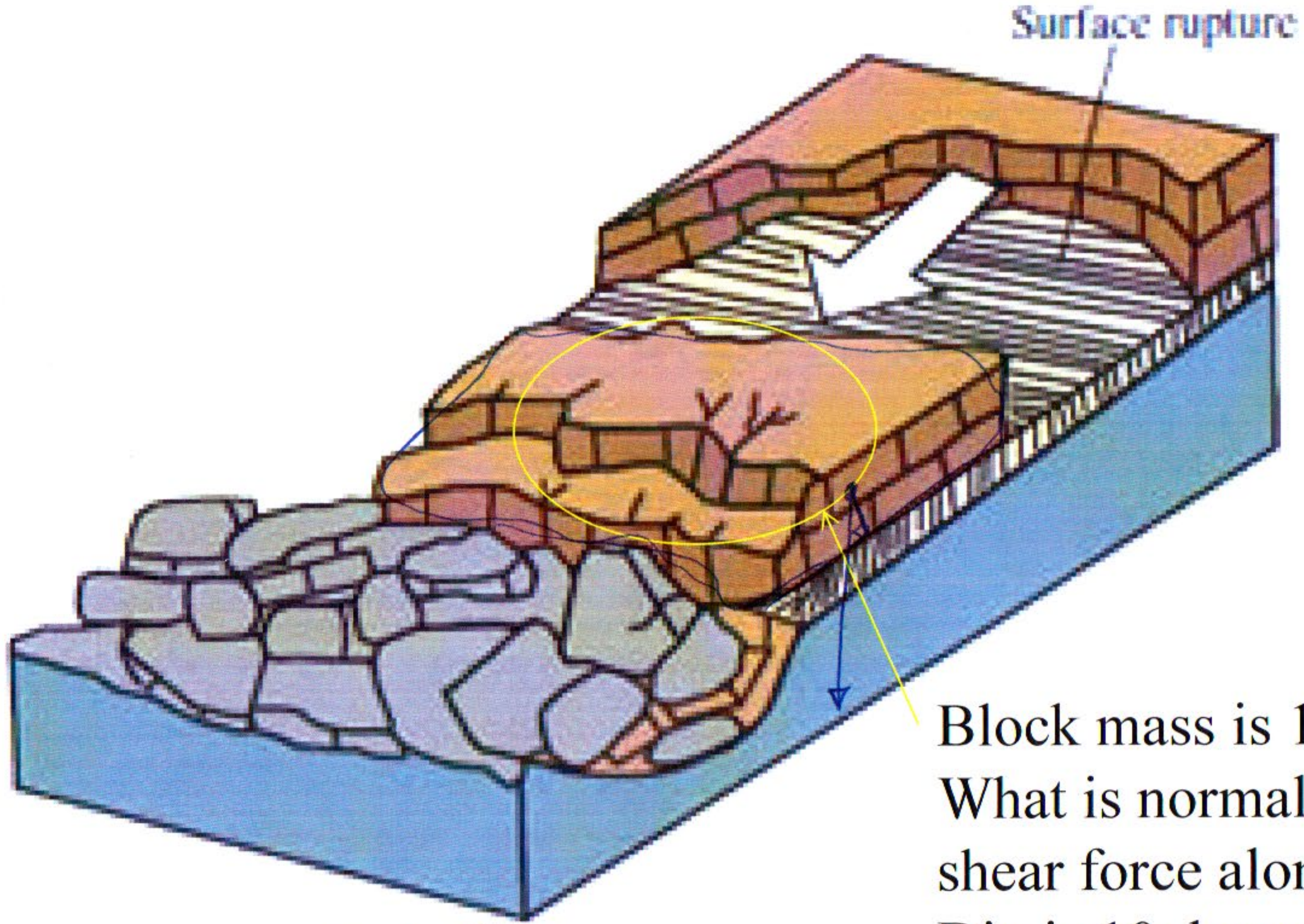
or $$F = 91.1 \text{ N}$$

Randy indicates that the biggest uncertainty in the calculation is t, and that next time at the alleys we should all use a stopwatch to time the movement from the back of the swing to release.

-Davis and Reynolds (vo. 2), p. 101

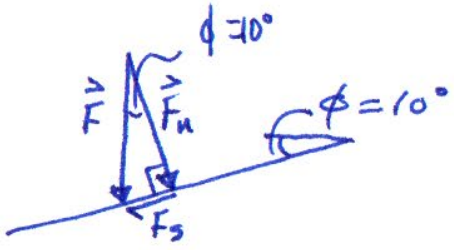


Block mass is 10000 kg
What is normal and
shear force along base?
Dip is 10 degrees.



Block mass is 10000 kg
What is normal and shear force along base?
Dip is 10 degrees.

$$\vec{F} = m\vec{a} = m\vec{g} = 10000\,\text{kg} \cdot 9.81\,\text{m/s}^2$$
$$= 10^5\,\text{kg} \cdot 9.81\,\text{m/s}^2 = 9.81 \times 10^5\,\text{N}$$

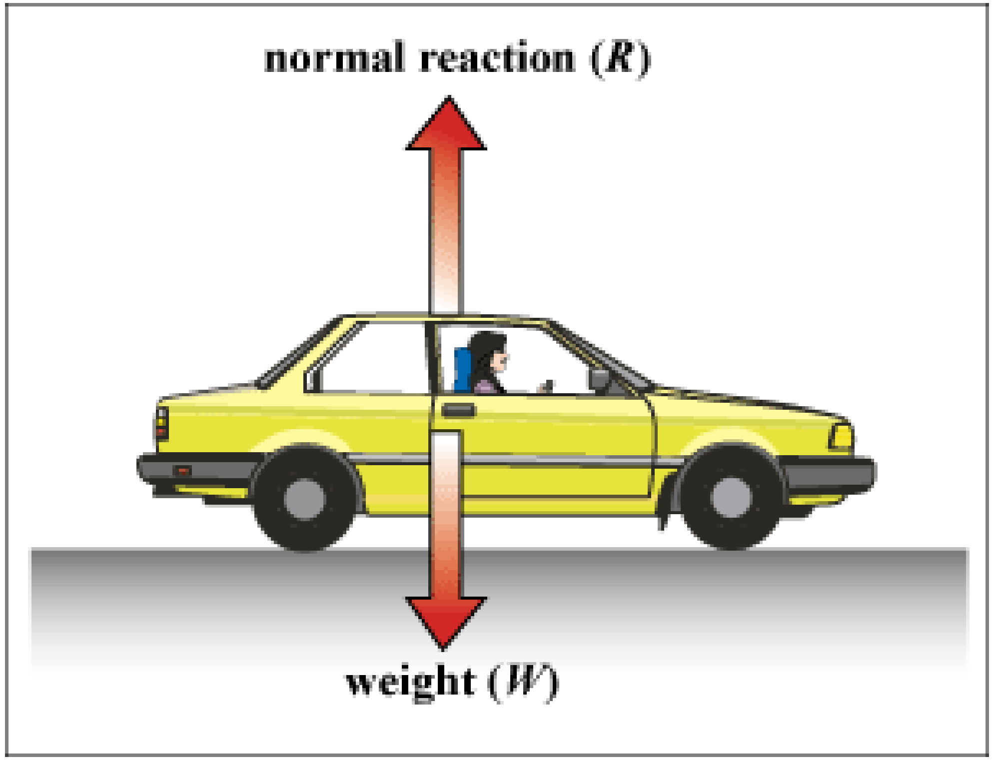


$$\cos\phi = \frac{F_n}{F} \Rightarrow F_n = F\cos\phi = 9.81\times10^5\,\text{N} \cdot \cos 10^\circ = 9.66\times10^5\,\text{N}$$

$$\sin\phi = \frac{F_s}{F} \Rightarrow F_s = F\sin\phi = 9.81\times10^5\,\text{N} \cdot \sin 10^\circ = 1.7\times10^5\,\text{N}$$

Force: Newton's Laws of Motion

- Law III: To every action there is always opposed an equal reaction, or the mutual actions of two bodies on each other are always equal in magnitude and opposite in direction



http://www.hk-phy.org/contextual/

Force: Newton's Laws of Motion

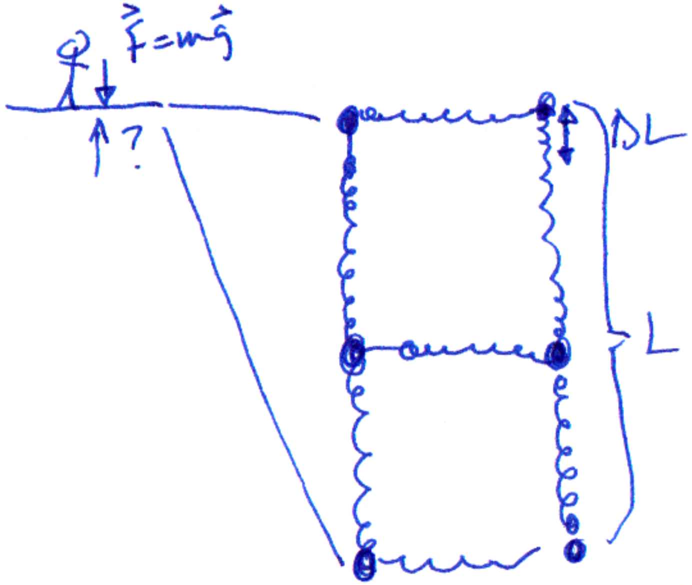
- Law III: To every action there is always opposed an equal reaction, or the mutual actions of two bodies on each other are always equal in magnitude and opposite in direction

Equilibrium

Force: Newton's Laws of Motion

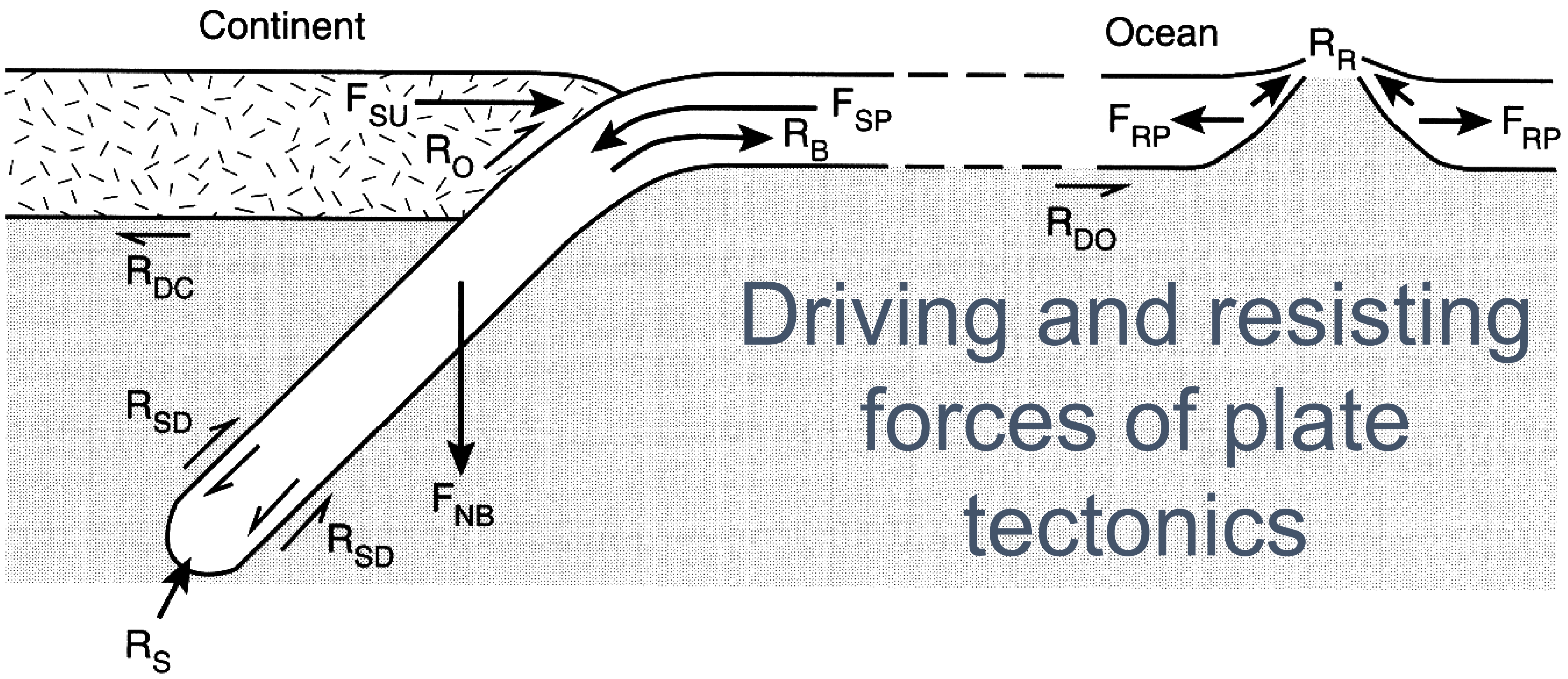
Equilibrium $\sum \vec{F} = 0$

Why don't we fall through floor? What resists?



resisting force: occurs at molecular level from interatomic forces that act like springs

Driving and resisting forces of plate tectonics



F_{RP} – Ridge push
F_{NB} – Negative buoyancy
F_{SP} – Slab pull
F_{SU} – Trench suction

R_R – Ridge resistance
R_B – Bending resistance
R_S – Slab resistance
R_O – Overriding plate resistance
R_{DO} – Mantle drag under ocean
R_{DC} – Mantle drag under continent
R_{SD} – Slab-drag resistance