Part I: Newton’s Laws
Chapter 6: Dynamics I: Motion Along a Line

6.3 Mass, Weight, Gravity
What is mass? (What is that \( m \) in N2L that appears with the \( \vec{a} \)?)

- Mass is an intrinsic property of the object.
- It is not in relation to anything else.
- It is not related to where, when, or what’s going on.
- **Mass is the amount of matter.** Vague! What does this mean?

How many nucleons (protons + neutrons) in 1 kg?

- Atomic mass unit (\( \frac{1}{12} \) the mass of an atom of carbon-12): \( 1\text{u} = 1.66\times10^{-27} \text{kg} \).
- \( (1 \text{kg})/(1.66\times10^{-27} \text{kg}) = 6.02\times10^26 \).
- Working with kilograms is easier to manage than working with nucleon counts! Both characterize the amount of matter that makes up the object.
What does the term **weight** mean?

- I am sorry to say.....
  There is no agreement.
  So sad, so very very sad.

- Some say $|\vec{F}_G|$ !!!
  Some say $|\vec{F}_{Spring}|$ !!!

- Often the same.
  Often different.

- **Knight:**
  Points out both.
  Chooses $|\vec{F}_{Spring}|$.

- **Cut the cable!**
  He feels *weightless*.
Newton’s law of gravity.

Gravity is **weak**.
You can jump.....
even though the agent is the..... **ENTIRE PLANET EARTH !!!**

Everything attracts everything.

Spheres behave *AS IF* they were points at their centers.

\[ F_G = \frac{Gm_1m_2}{r^2} \]

where \( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \) is a constant of **THE UNIVERSE**.
Life near the earth’s surface.

- We don’t look like spheres, but with \( r = R_E \), we ARE points!

\[
F_G = \frac{G M_{\text{Earth}} m}{(R_{\text{earth}} + h)^2}
\]

- \( F_G = \frac{G M_{\text{Earth}} m}{R_{\text{earth}}^2} \times \frac{1}{(1 + h/R_{\text{earth}})^2} \)

- \( R_{\text{earth}} = 6.37E6 \text{ m} = 6,370,000 \text{ m}, \quad h_{\text{Everest}} = 8.85E3 \text{ m} = 8,850 \text{ m} \).

\[
\frac{1}{(1 + h/R_{\text{earth}})^2} = 0.997 \quad \text{less than 1\% reduction in } F_G.
\]
For you to do:

- Compare the two equations above. Symbolically, what is $g$?
- Do dimensional analysis on your result to make sure you get m/s$^2$.
- Use the value of $g$ to estimate$^1$ the mass of the earth.

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$^1$The earth isn’t perfectly spherical. Also, our reference frame is a non-inertial reference frame due to the earth’s rotation. Small effects, but noticeable.