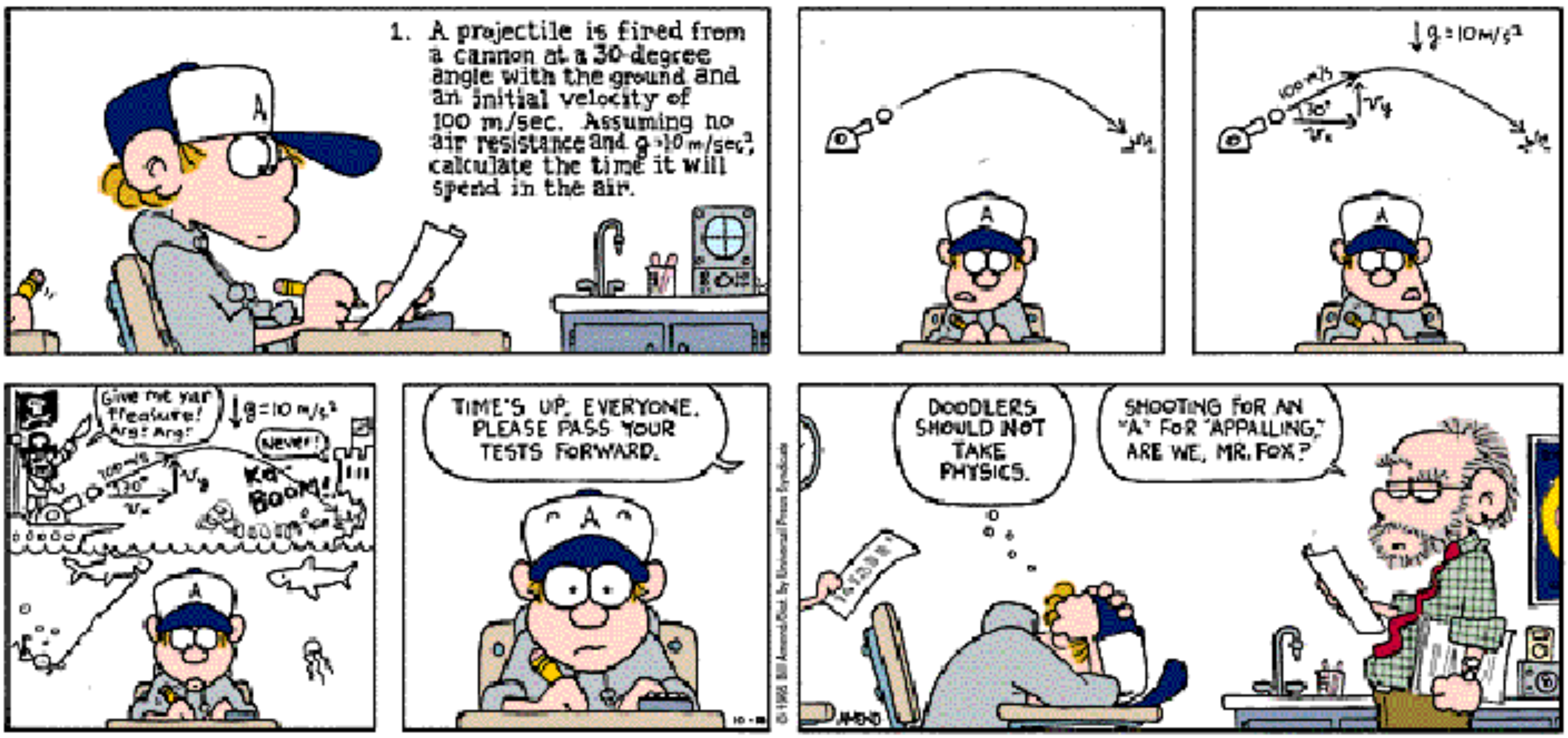
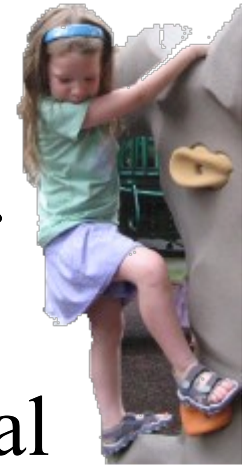
- **<u>Theme Music:</u> Duke Ellington**
  Take the A Train
- **<u>Cartoon:</u> Bill Amend *FoxTrot***



Foothold ideas:
Charge – A hidden property of matter



- Matter is made up of two kinds of electrical matter (positive and negative) that usually cancel very precisely.
- Like charges repel, unlike charges attract.
- Bringing an unbalanced charge up to neutral matter polarizes it, so both kinds of charge attract neutral matter
- The total amount of charge (pos – neg) is constant.

Foothold ideas: Conductors and Insulators

- Insulators
  - In some matter, the charges they contain are bound and cannot move around freely.
  - Excess charge put onto this kind of matter tends to just sit there (like spreading peanut butter).
- Conductors
  - In some matter, charges in it can move around throughout the object.
  - Excess charge put onto this kind of matter redistributes itself or flows off (if there is a conducting path to ground).

Foothold idea: Coulomb's Law

- All objects attract each other with a force whose magnitude is given by

$$\vec{F}_{q\to Q} = -\vec{F}_{Q\to q} = \frac{k_C qQ}{r_{qQ}^2}\hat{r}_{q\to Q}$$

- k_C is put in to make the units come out right.

$$k_C = 9\times 10^9\ \text{N-m}^2/\text{C}^2$$

Foothold ideas: Properties of solids

- Density $\rho = \frac{M}{V}$

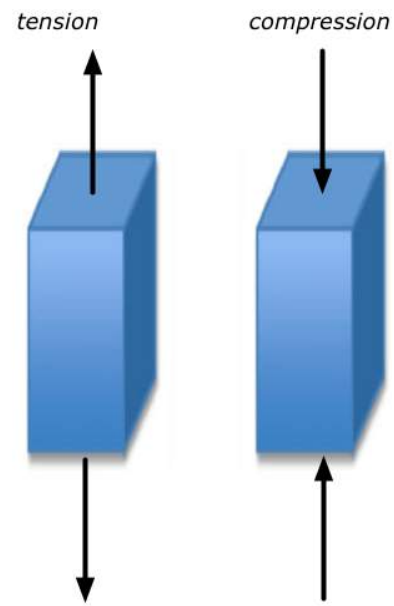
- Stretch and squeeze:

$$F = k\Delta L$$

$$\sigma = F/A \quad \text{(stress)} \qquad \varepsilon = \Delta L / L_0 \quad \text{(strain)}$$

$$E = \sigma/\varepsilon \quad \text{(Young's modulus)}$$

$$k = E\frac{A}{L_0}$$



- Breaking stress

Foothold ideas: Pressure

- A constrained fluid has an internal pressure –like an internal force at every point in all directions. (Pressure has no direction.)
- At a boundary or wall, the pressure creates a force perpendicular to the wall. $\vec{F} = p\vec{A}$
- The pressure in a fluid increases with depth. (Why?)

$$p = p_0 + \rho g d$$

- When immersed in a fluid, an object feels an (upward) BF equal to the weight of the displaced fluid. (Archimedes' Principle)

Foothold ideas: Buoyancy

- ***Archimedes' principle***: When an object is immersed in a fluid (in gravity), the result of the fluid's pressure variation with depth is an upward force on the object equal to the weight of the water that would have been there if the object were not.
- As a result, an object whose density is less than that of the fluid will float, one whose density is greater than that of the fluid will sink.
- An object less dense than the fluid will float with a fraction of its volume under the fluid equal to the ratio of its density to the fluid's density.

Foothold ideas: Surface tension

- Due to the intermolecular interactions holding a liquid together, the surface of a liquid experiences a tension.
- The pull across any line in the surface of the liquid is proportional to the length of the line.

$$F_{\text{surface tension}} = \gamma L$$

Foothold ideas: Incompressible Flow

- Flow = volume / sec crossing an area.

$$Q = Av$$

- Flow in a pipe: volume in = volume out

$$A_1 v_1 = A_2 v_2$$

- Resistance to flow –
  - Drag is proportional to *v* and *L*.

$$\Delta P = ZQ$$

$$Z = 8\pi\mu \frac{L}{A^2}$$

Foothold ideas: Momentum

- Define <u>momentum</u>: $\vec{p} = m\vec{v}$
- Impulse-momentum theorem:

$$\vec{a} = \vec{F}^{net} / m$$

$$\frac{d\vec{v}}{dt} = \frac{\vec{F}^{net}}{m}$$

$$m\Delta\vec{v} = \vec{F}^{net}\Delta t$$

$$\vec{\mathscr{J}}^{\,net} = \vec{F}^{net}\Delta t$$

$$\Delta\vec{p} = \vec{\mathscr{J}}^{\,net}$$

- Because of N3, when two objects interact, they change each others momenta in equal and opposite ways.

Foothold ideas: Kinetic Energy and Work

- Newton's laws tell us how velocity changes. The Work-Energy theorem tells us how speed (independent of direction) changes.
- Kinetic energy = $\frac{1}{2}mv^2$
- Work done by a force = $F_x \Delta x$ or $F_{\parallel} \Delta r$ (part of force || to displacement)
- Work-energy theorem: $\Delta(\frac{1}{2}mv^2) = F_{\parallel}^{net}\,\Delta r$

Foothold ideas: Potential Energy

- For some forces work only depends on the change in position. Then the work done can be written

$$\vec{F} \cdot \Delta\vec{r} = -\Delta U$$

  U is called a *potential energy*.

- For gravity, $U_{gravity} = mgh$

  For a spring, $U_{spring} = ½\ kx^2$

  For electric force, $U_{electric} = k_C Q_1 Q_2 / r_{12}$

Foothold ideas: Conservation laws

- Momentum
  - The momentum of a system of objects is conserved IF the external forces acting on them cancel.

$$\Delta\left(\sum_{n=1}^{N}\vec{p}_n^{\,initial}\right)=0$$

$$\sum_{n=1}^{N}\vec{p}_n^{\,initial}=\sum_{n=1}^{N}\vec{p}_n^{\,final}$$

- Mechanical energy
  - The mechanical energy of a system of objects is conserved IF resistive forces can be ignored.

$$\Delta\left(KE+PE\right)=0$$

$$KE_{initial}+PE_{initial}=KE_{final}+PE_{final}$$