3 Simple Physics Experiments

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Overview of the Talk

School Physics

- Optics
- Fluids
- Mechanics
- Electrodynamics*
- Thermodynamics*
- Modern Physics*

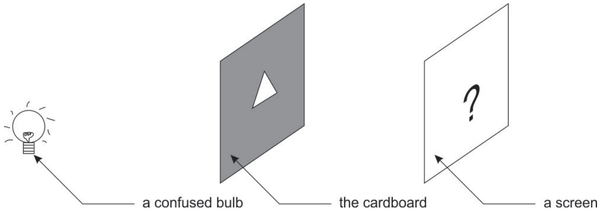
1. Optics

The Wicked Shadow

first demonstrated to us by Prof. Arvind

The Setup

There's a bright light source. There's a cardboard with a triangular hole. The cardboard blocks light from the light source to cast a shadow on a screen.

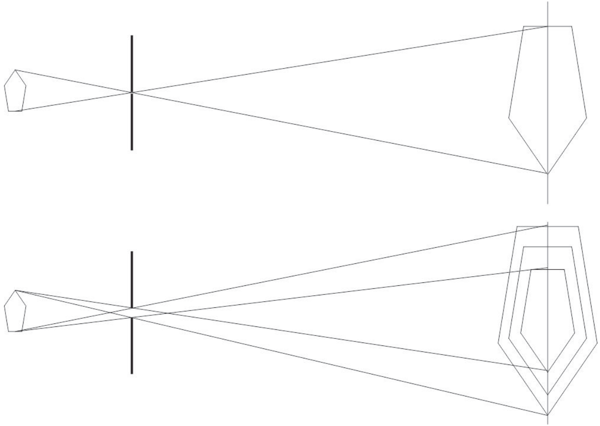


The Demonstration

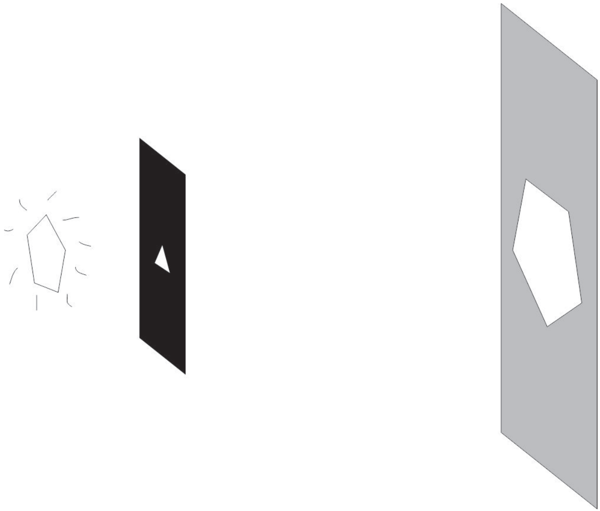
The Explanation

Pinhole Camera

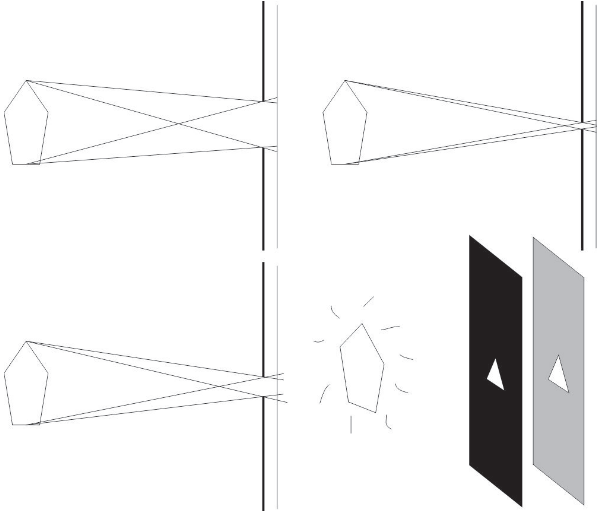
The Explanation



The Explanation



The Explanation



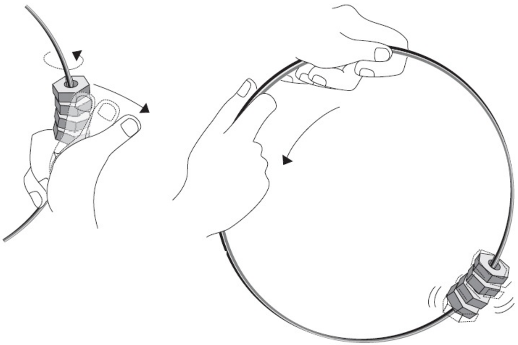
2. Mechanics

The Nut Spinner

first demonstrated to us by Dr. Ravi Mehrotra
conceived by Dr. Arvind Gupta

The Setup

Imagine a steel loop with a 1 foot diameter. There are some (say 4) nuts passing through the loop. You spin the nuts and rotate the ring as shown in the figure.



The Demonstration

Simple Questions

1. What is the direction of torque being applied (by us)?
2. What is the direction of the angular momentum of the nut?
3. Can we neglect friction?
4. How is the energy being transferred?

The Explanation

Think about it.

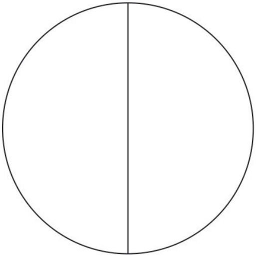
3. Fluids

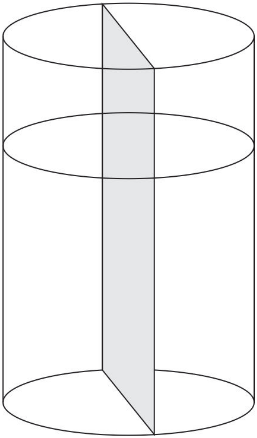
The Mystery Worker

we were first asked by Dr. Mukun Thattai

The Setup

Consider a cylindrical jar containing water as shown in the figure. A rectangular membrane is placed in the cylinder along the diameter of its circular cross-section, such that the water is divided into two equal parts.



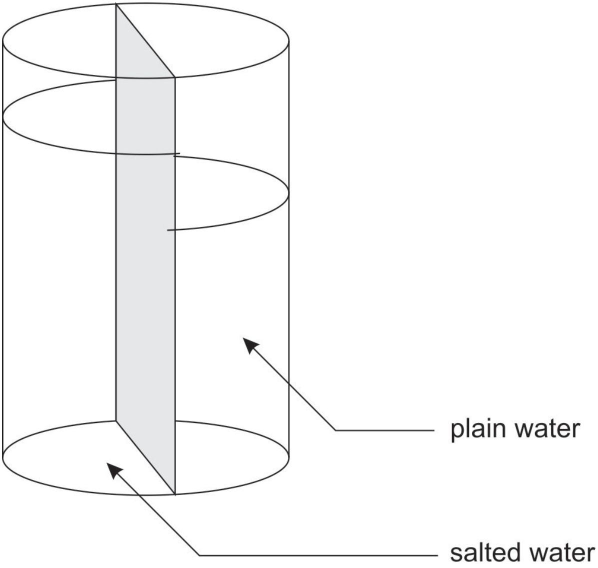


Simple Questions

1. What happens if salt is added to a partition?
2. Is there any work done?
3. If yes, who's doing the work?

The Demonstration

The Explanation



The Explanation

Let there be n_0 moles of solvent and n_1 moles of solute in the solution.
Free energy of the solution

$$A = U - TS \tag{1}$$

Where the internal energy $U = U(T, P, n_0, n_1)$. Using taylor series we have

$$U(T, P, n_0, n_1) = U(T, P, n_0, 0) + n_1 \frac{\partial U}{\partial n_1} + \ldots \tag{2}$$

Assuming homogeneity

$$U(T, P, n_0, n_1) = n_0 u_0(T, P) + n_1 u_1(T, P) \tag{3}$$

$$V(T, P, n_0, n_1) = n_0 v_0(T, P) + n_1 v_1(T, P) \tag{4}$$

where u_0 and v_0 are internal energy and volume per unit mol respectively.

The Explanation

Considering entropy

$$ds = \frac{dQ}{T} = \frac{1}{T}(dV + PdV) = n_0 \left[\frac{du_0 + Pdv_0}{T} + \frac{n_1}{n_0} \frac{du_1 + Pdv_1}{T} \right] \quad (5)$$

Since $\frac{n_1}{n_0}$ is arbitrary

$$ds_0 = \frac{du_0 + PdV_0}{T} \quad (6)$$

and

$$ds_1 = \frac{du_1 + PdV_1}{T} \quad (7)$$

must be separately exact.
Thus, we have entropy

$$S(T, P, n_0, n_1) = n_0 s_0(T, P) + n_1 s_1(T, P) + \lambda(n_0, n_1) \quad (8)$$

The Explanation

Considering T high and P low solution evaporates and we can consider them as two ideal gas

It will be seen that osmotic pressure arises from term $\lambda(n_0, n_1)$

Entropy of 1 mole of ideal gas T,P

$$S(T,P) = c_p \log T - R \log P + K \tag{9}$$

Therefore

$$S_{\text{ideal}}(T,P,n_0,n_1) \tag{10}$$
$$= (n_0 c_{p_0} + n_1 c_{p_1}) \log T \tag{11}$$
$$-n_0 R \log p_0 - n_1 R \log p_1 + \tag{12}$$
$$n_0 K_0 + n_1 K_1 \tag{13}$$

where p_0 and p_1 are partial pressures of two gasses

$$P = p_0 + p_1 \tag{14}$$

$$p_0/n_0 = p_1/n_1 \tag{15}$$

The Explanation

$$p_0 = \frac{n_0 P}{n_0 + n_1} = P(\text{approx}) \tag{16}$$

$$p_1 = \frac{n_1 P}{n_0 + n_1} = n_1 P / n_0(\text{approx}) \tag{17}$$

On substitution and comparison of coefficients we get

$$\lambda(n_0, n_1) = -n_1 R \log \frac{n_1}{n_0} + n_0 k_0 + n_1 k_1 \tag{18}$$

The first term gives rise to the osmotic pressure (entropy of mixing)

$$A(T, P, n_0, n_1) = n_0 a_0(T, P) + n_1 a_1(T, P) + n_1 RT \log \frac{n_1}{n_0} \tag{19}$$

The End