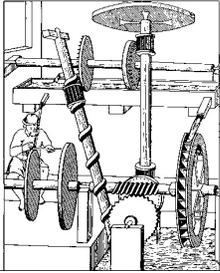


1905 Physics Introduction: How Things Work and all that



Peter
Watson

What is Science?

- The scientific approach to the examination of phenomena is a defence against the pure emotion of fear... This made for a kind of harmony and confidence. The sun came up about as often as it went down, in the long run... Tom Stoppard, Rosenkrantz and Guildenstern are Dead
- By and large, it works



Culture/Philosophy of Science:

- Science differs from most other areas of academic endeavour in that
- Primary Sources are not important (no one reads Newton)
- Knowledge is cumulative
- "If I have seen further than other men, it is because I have stood on the Shoulders of Giants." Isaac Newton

- General principles exist, from which many consequences follow
- **Essentia non sunt multiplicanda praeter necessitatem** (Entities are not to be multiplied beyond necessity) *William of Occam*
- Or **KISS**
- **Hypotheses non fingo** *Isaac Newton*
- (although he was lying!)
- practitioners totally ignore the critics (e.g. the philosophers, the sociologists, the social constructivists)

What is Physics?

- We'll take physics as the example science
- Physics is about the way the universe works: i.e. what are the laws of nature.
- How do we deduce laws from Nature?
- Guess them, and see what the consequences are
- How do we guess?
- **Look for patterns in Nature**

e.g. Everything Stops Moving

1. Is it true that everything stops?
2. Why does it appear that all motion stops?
3. Are there any examples of systems where things don't stop moving?

- There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact. (Mark Twain)
- We can think of this as a game, but what is a game? (Wittgenstein)

But usually knowledge is incomplete

- The number of rational hypotheses that can explain any given phenomenon is infinite (Zen and the Art of Motorcycle Maintenance, Pirsig)
- Given two theories, how do we choose between them?
- Find an experiment to distinguish them or
- Choose the simpler (???????) which is known as Occam's Razor
- (unfortunately "simpler" is a loaded term)

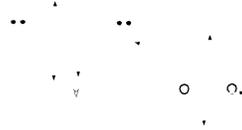
E.g Motion: Aristotle...

- Motion can be divided up into "Natural" and "Unnatural"
- e.g. it is natural for a stone to fall, and a force must be supplied to stop it
- It is natural for a cart to stop moving, and so a force must be supplied to keep it moving, so the motion is "unnatural"



Motion: Galileo/Newton

- All forms of motion are the same
- e.g. A stone has a gravitational force that acts on it and causes it to fall. To stop it falling, an equal upward force must be applied
- A cart has a frictional force which slows it down: to overcome this force, a force in the direction of motion must be applied.



Motion: Galileo/Newton

- SIMPLER??
- Aristotle didn't need to introduce these extra forces. However, Galileo/Newton theory makes more predictions



Critical Test:

- Aristotle: Heavy objects fall faster than light
- Galileo/Newton: All things should fall at same speed (in absence of air resistance)
- The experiment Galileo didn't do!
- **First get your facts, then you can distort them at your leisure** (Mark Twain)

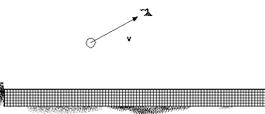


- Note how dangerous it is to do one step in this process: theory without experiment is bad.
- **It is contrary to reason to say that there is a vacuum or a space in which there is absolutely nothing.** Descartes
- Particularly dangerous is developing theories based on assumptions which are SO obvious that you don't write them down: e.g.
- **Time is the same whether you are moving or not**
- **The world is 3-dimensional**
- **The simplest objects in the universe can't have a "handedness"**

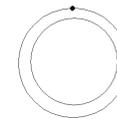
Models

- This is a theme we keep returning to: Life is Difficult (usually too difficult!)
- Ball will have air resistance, gravity will vary, sun and moon will attract ball, ball won't be a perfect sphere.....

So replace it:
Note that the world has become an infinite flat plain, we have ignored air resistance, the child is irrelevant.....

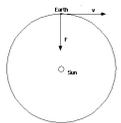


- Note that, although you have to be careful in choosing the model, you don't have to have the same model in two different calculations.
- e.g. for a satellite in orbit, we need to consider the earth as a perfect sphere, 6500 km in radius



e.g for the earth in orbit around the sun, we need to consider the earth as a point with some mass

Note that these models for the earth are not only different, they are not even consistent!
The earth cannot be an infinite flat plane, a sphere and a point at the same time!



What is an electron?

- “What is” questions usually require a description ..
- What is a pomegranate?



What is an electron?

- “What is” questions usually require a description ..
- What colour is an electron?
- What shape is an electron?
- Is it soft or hard?
- How big is it?

- What colour is an electron?
- Colour comes from reflected light: an electron is too small (actually, it reflects light of all colours, so)
- What shape is an electron?
- To decide what shape something is, we need to "see" it
- Is soft or hard?
- What can we "poke" it with?
- How big is it?
- Depends on how you measure size; best assumption is that it's a point.

- "What is an electron?" is not a good question
- "How does an electron behave?" is, but
- You're not going to like the answer (Marvin, in the Hitchhiker's Guide to the Galaxy)
- It behaves like a solution of the Dirac Equation

$$i\hbar \left[\gamma_0 \frac{\partial}{\partial t} - \gamma_1 \frac{\partial}{\partial x} - \gamma_2 \frac{\partial}{\partial y} - \gamma_3 \frac{\partial}{\partial z} - \gamma_4 \frac{\partial}{\partial x} - \dots \right] \psi(\mathbf{r}, t) = 0, \gamma_5 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \text{etc}$$

But for a model of an electron

- a spinning ball of negative charge
- Note: this is not reality, but a convenient crutch for thinking!!!!
- ..Any picture of the atom that our imagination is able to invent is for that reason defective. An understanding of the atomic world in that primary sensuous fashion ..is impossible. Heisenberg

