What is Physics?

Understanding the nature and properties of matter and energy in the universe and their *interactions and relationships*: includes mechanics, heat, radiation,

1. Fundamental properties

Determine what are the most *fundamental* quantities in the universe that can be **precisely measured.** (e.g., position, velocity, energy, time, mass, electric & magnetic fields….).

Homework Exercise: Suggest some other possible quantities and justify why fundamental (one page maximum)

2. **Laws (relationships)**

Find relationships between those fundamental quantities (e.g., Hooke's law, thermodynamics, conservation of energy, special relativity). These relationships or patterns and correlations are expressed using words, equations, graphs, charts, diagrams, pictures, videos.

3. **How**

Design, conduct and analyze experiments: The Art of Physics.

3. Why are laws useful

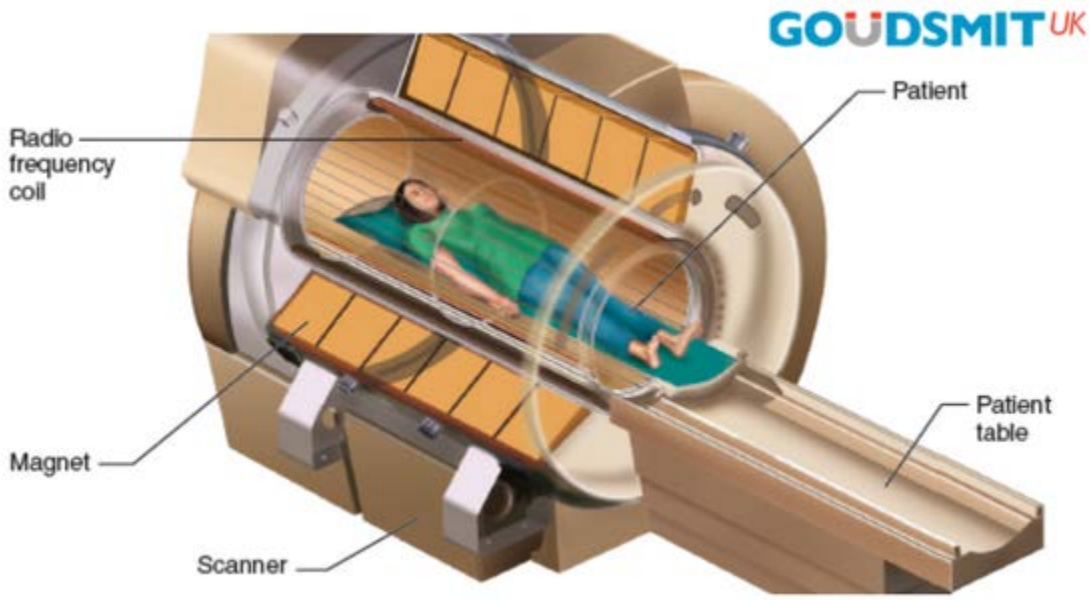
For a new system make predictions
Design buildings safely (Hooke's law)
Place satellites in orbit (Newton's laws)
MRI (quantum mechanics)
Transistors (cell phones and all that) (quantum mechanics)

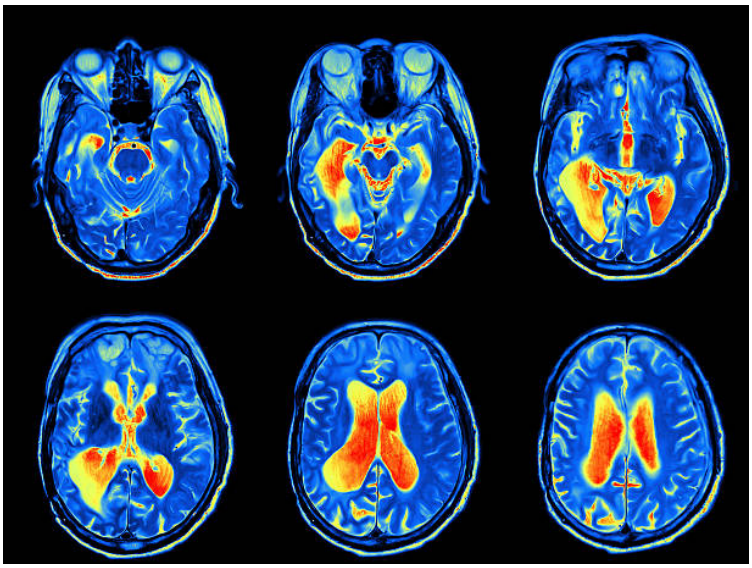
Willliam Gilbert demonstrates magnet to Elizabeth I, 1858 (Painting by E. Board).

MRI

Need superconducting magnet (quantum mechanics)

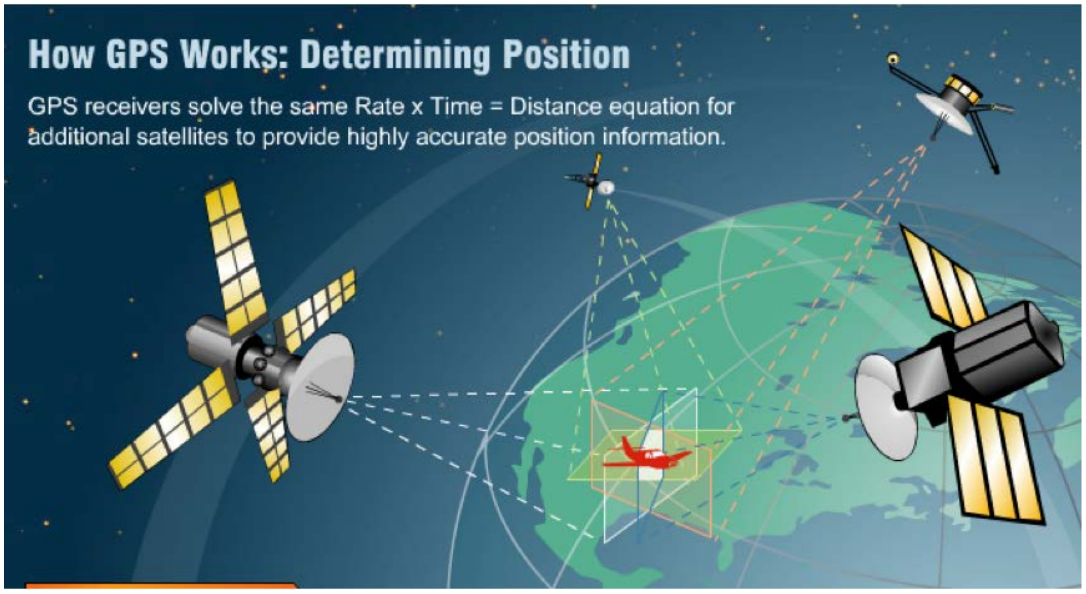
Need radio waves to tickle nuclei (quantum mechanics)





GPS and General relativity

Works by receiving signals from separate satellites in orbit (at about 20,000 km. Signals tell when sent and time to be received hence have distance to satellite Need three for triangulation (actually use 4 to correct for atmospheric and other errors). Need clocks to be accurate to 20 nanoseconds for accuracy of ~ 10 m.

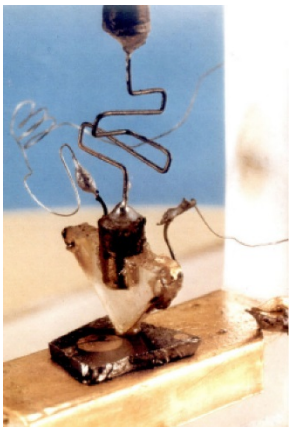


BUT according to **general relativity** clocks in orbit run faster (in weaker gravitational field) by about 45 microseconds per day.

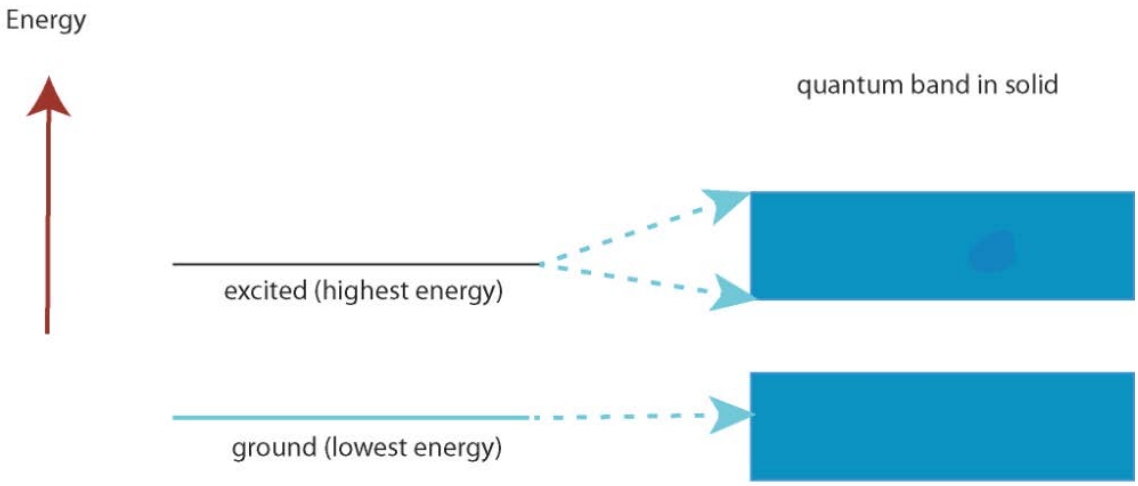
ALSO clocks on satellites move with high speed and by **special relativity** those clocks run slower --- about 7 microseconds per day.

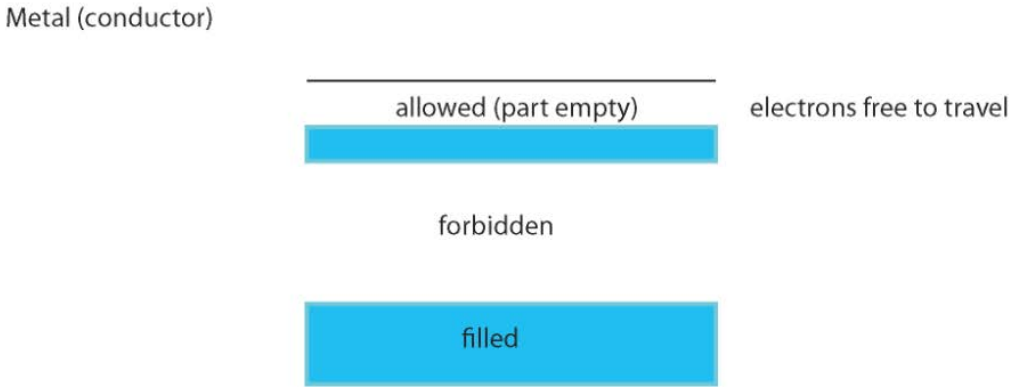
Net error: 38 microseconds or about 11 km /day

Transistors and Quantum Theory



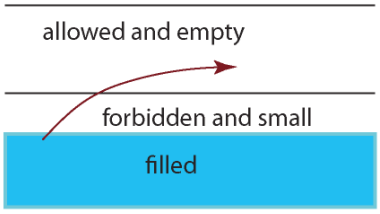
Transistor behavior depends critically on the fact that the electrons travel as waves (quantum theory) and not like particle projectiles. Because of this their energy states are bands and not discrete levels. There is a low energy band and a high energy band (or bands). Depending on available electron density the bands are filled or partially filled





Insulator (S, P...)

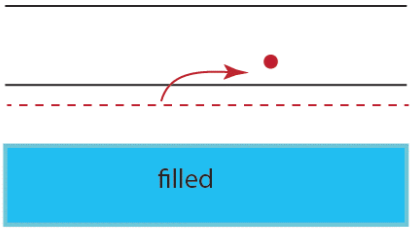
Semiconductor (Si, Ge...)



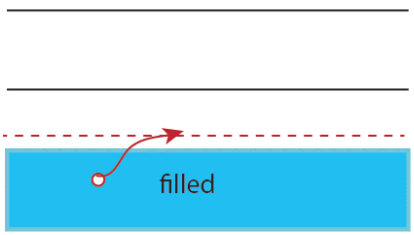
electron can be excited to MT band needs energy (thermal energy)

Clever idea (Who?)

n-type semiconductor
add impurrity e.g. In in Ge donates an electron
(conductors -ve charged)

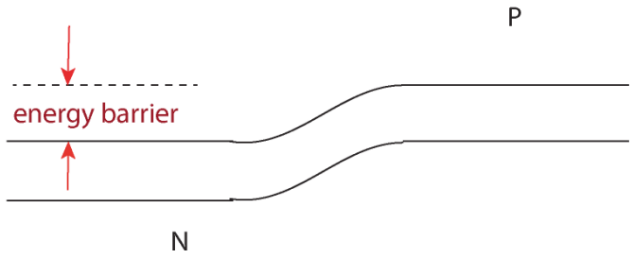


p-type semiconductor
add impurrity e.g. Ga takes an electron
(leaves behind a "hole" -- can move
conductors +ve charged)

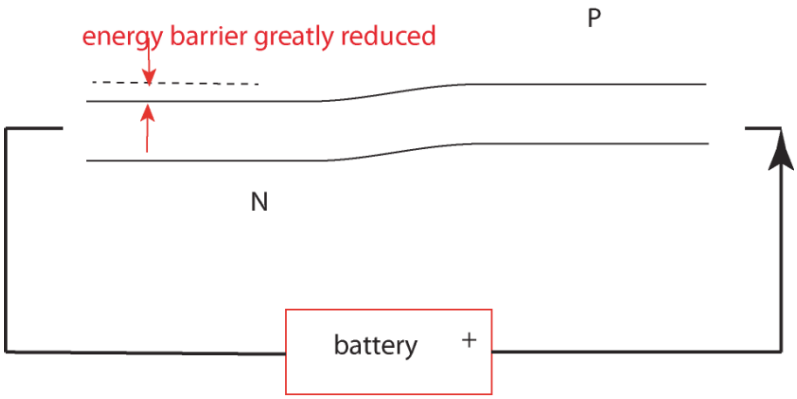


Put N-type and P-type together (diode)

conductors cannot flow



Apply external voltage (current flows)



Inventor: Ferdinand Braun (Wurzburg University, 1876)

Galena cristal (cats whisker)

Patented: Jagadis Bose (1901)

Used extensively for microwave detection in WW II

Transisior developed much later (1947)