Theoretical Physics

Theory of Condensed Matter

Gareth Conduit

Physics at Work 2007

Outline

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Can you name any physicists?

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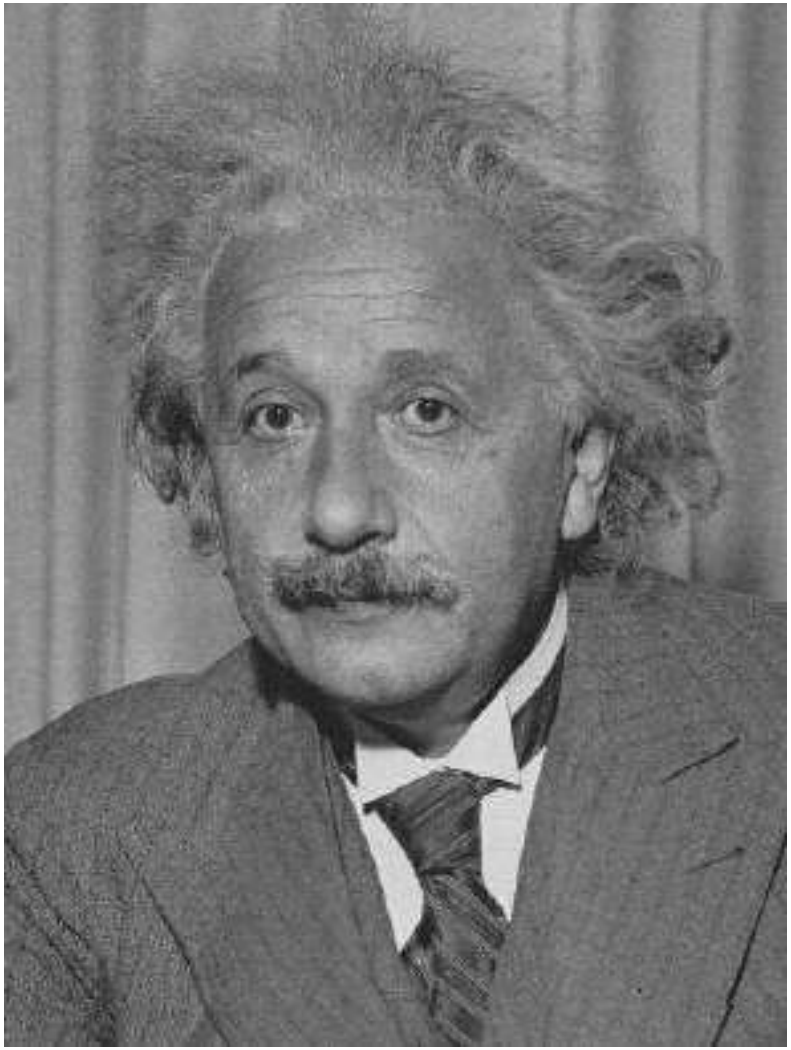

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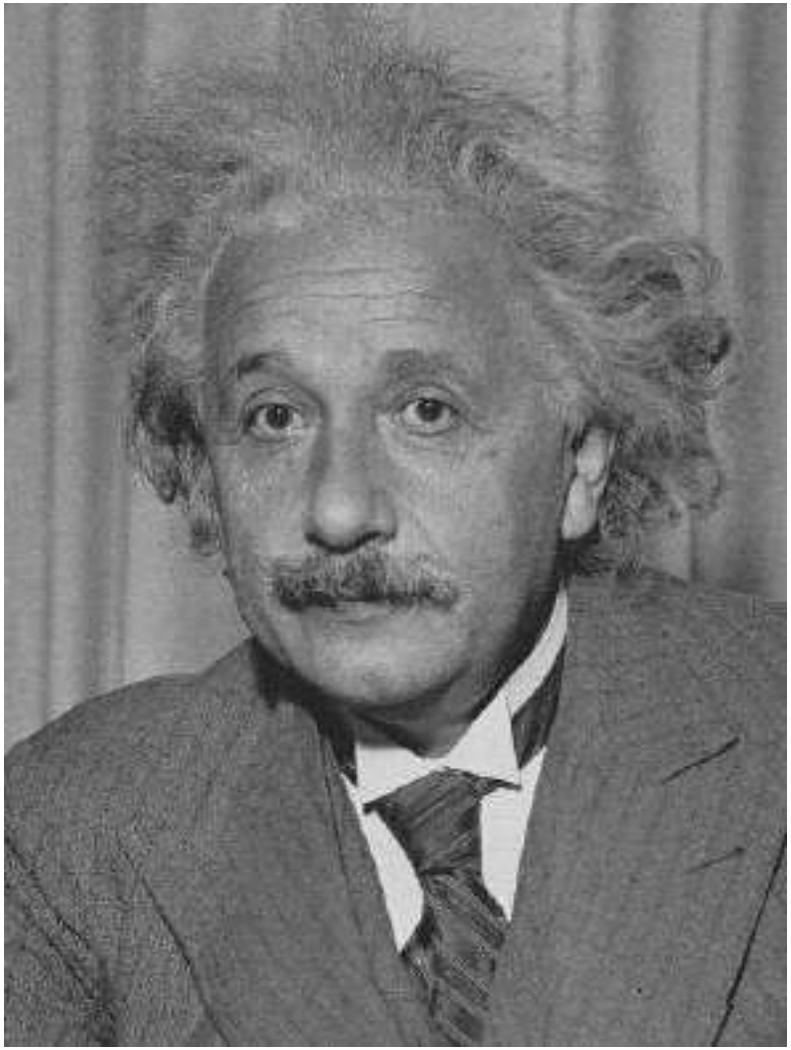

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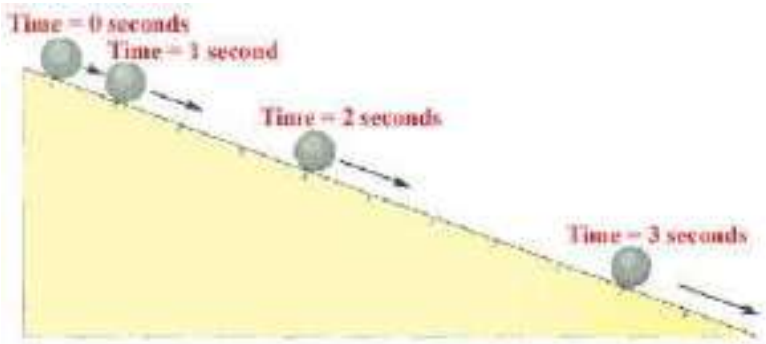
Galileo's experiment



Time/s	Distance/m
1	1
2	4
3	9
4	
5	

- Can you spot the pattern?

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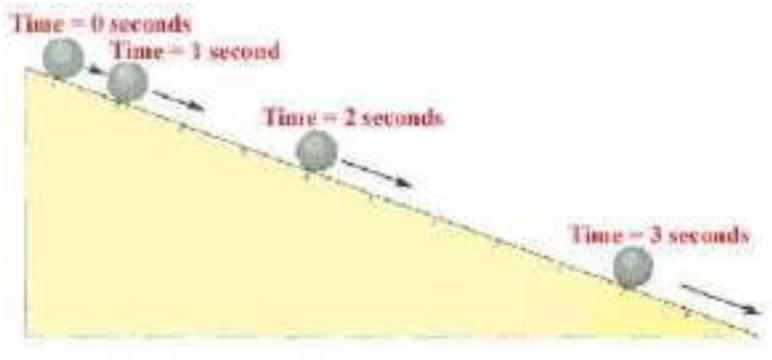

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- Physics is about pattern recognition
  - Experiments give quantitative clues
  - Theory must explain observations
  - Must make new predictions
  - Unify understanding of different phenomena

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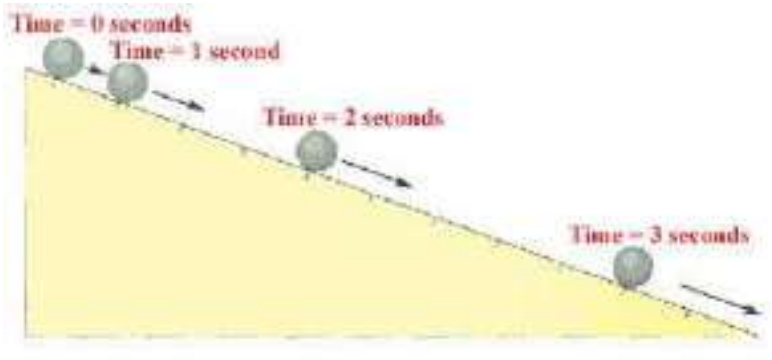

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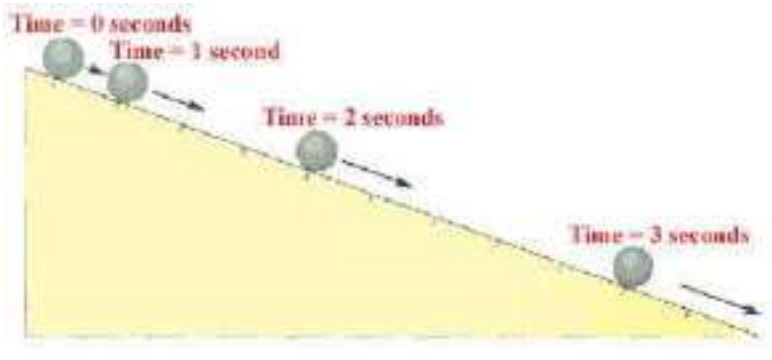

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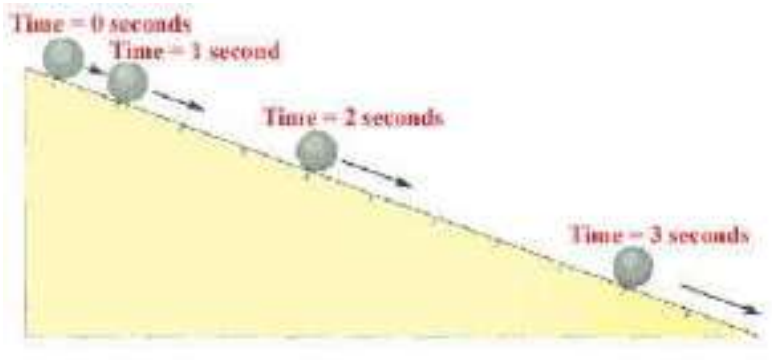

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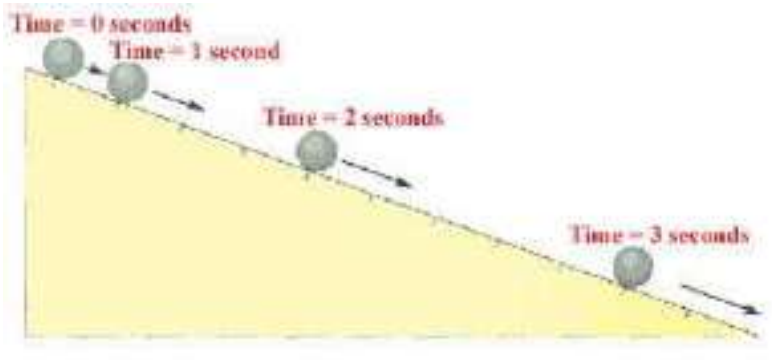

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The unreasonable effectiveness of Mathematics

- Mathematics is the natural language of Nature
- Compact and simple expressions of complicated objects
- In-built logic system — manipulations have well-defined rules

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- Distance dropped = time squared
- Or $d = t^2$

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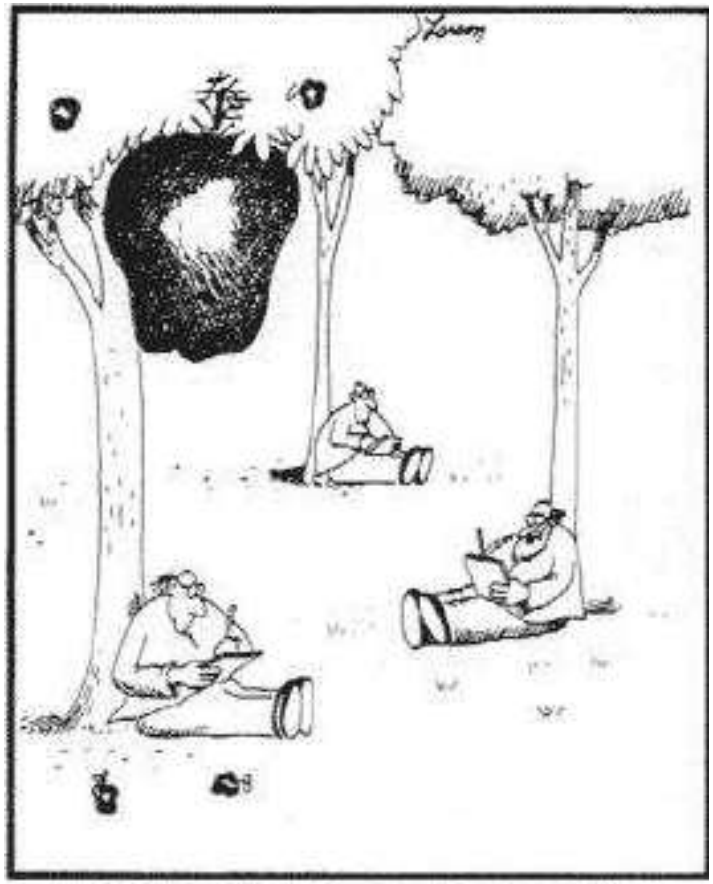

"Nothing yet . . . How about you, Newton?"

- Can we use this for other falling bodies and projectiles? — Yes
- t^2 distance dropped means constant acceleration, g, due to gravity
- In free space, only force is gravity, which acts vertically.
- Horizontal motion is motion at constant speed

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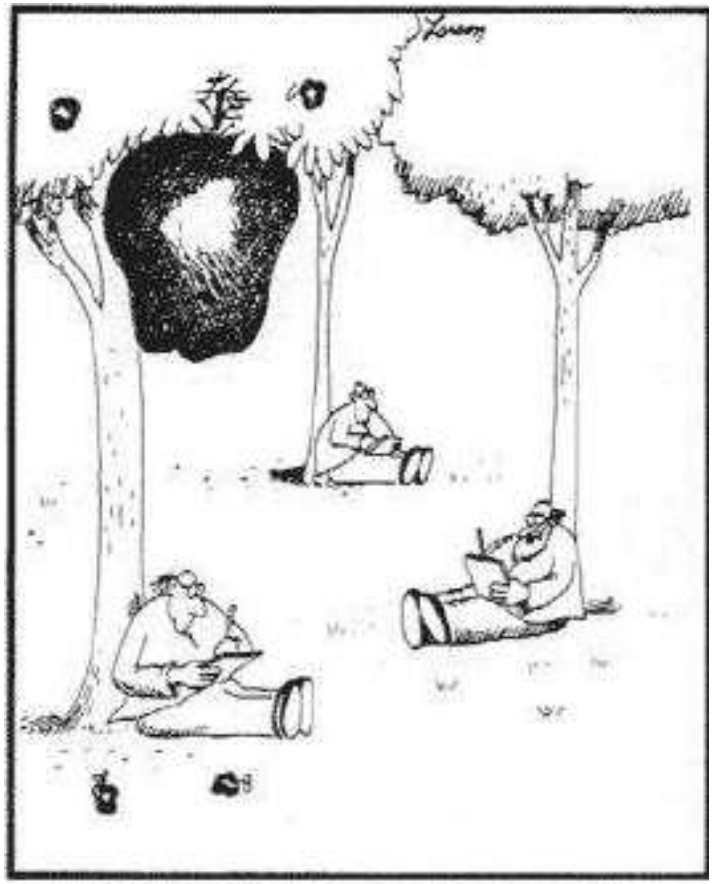

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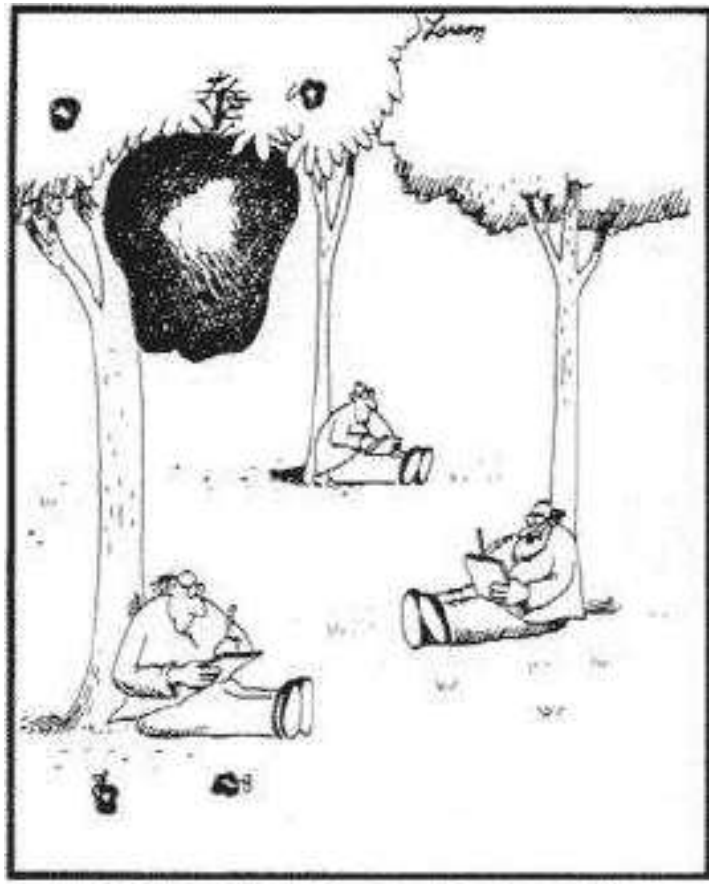

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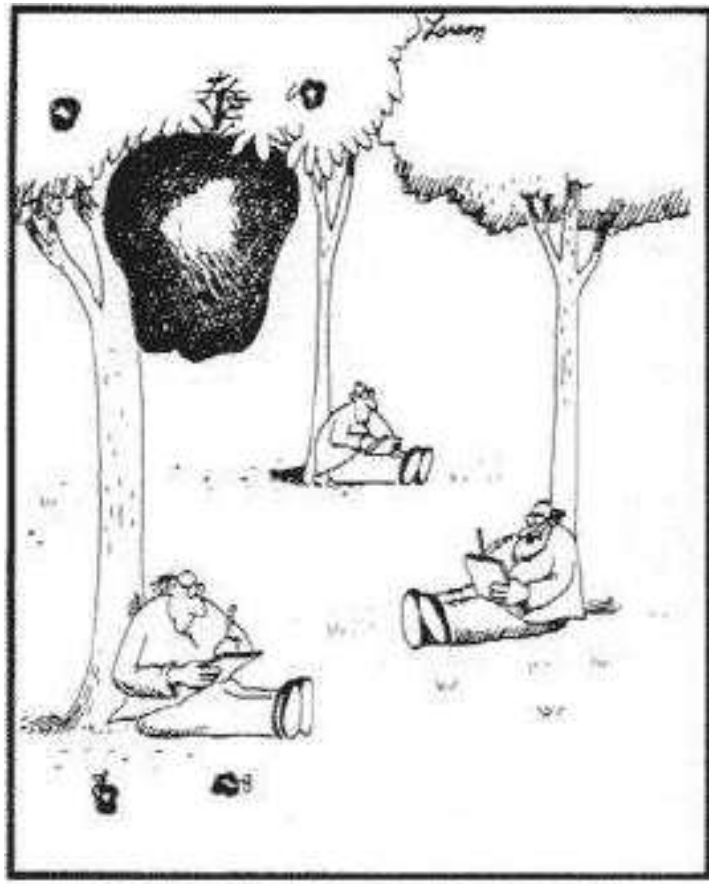

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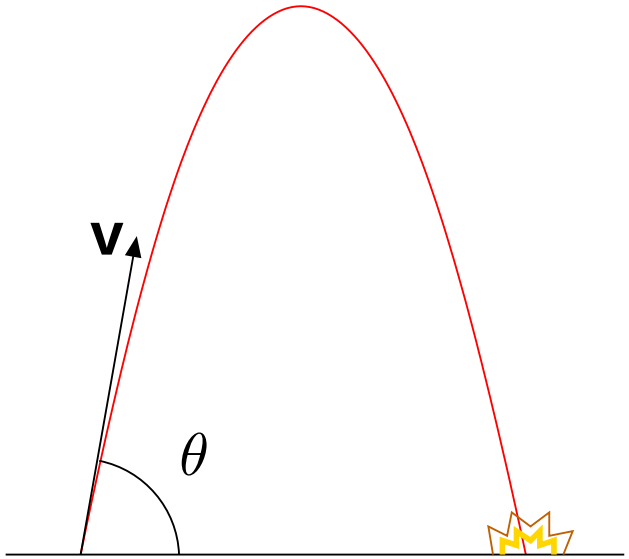

Figure: Path of a projectile

- Vertical motion:
- $y = v \sin\theta\, t - \frac{1}{2} g t^2$
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- $x = v \cos\theta\, t$
- Equation for trajectory is a quadratic

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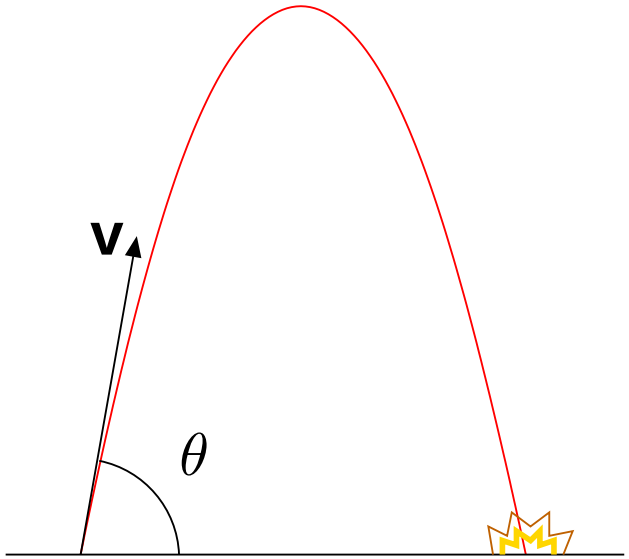

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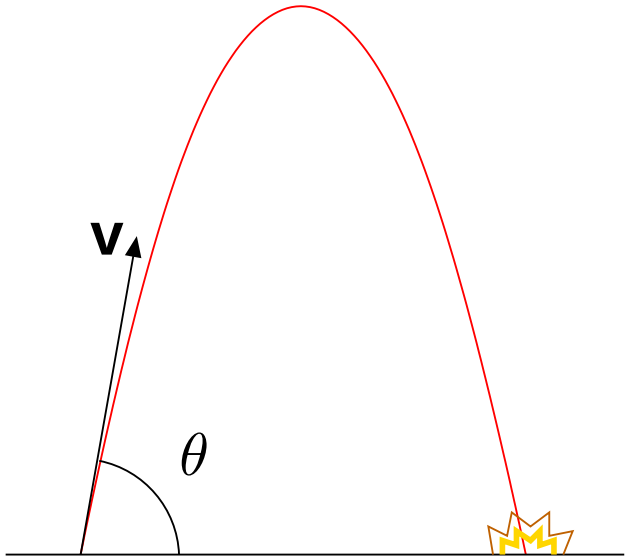

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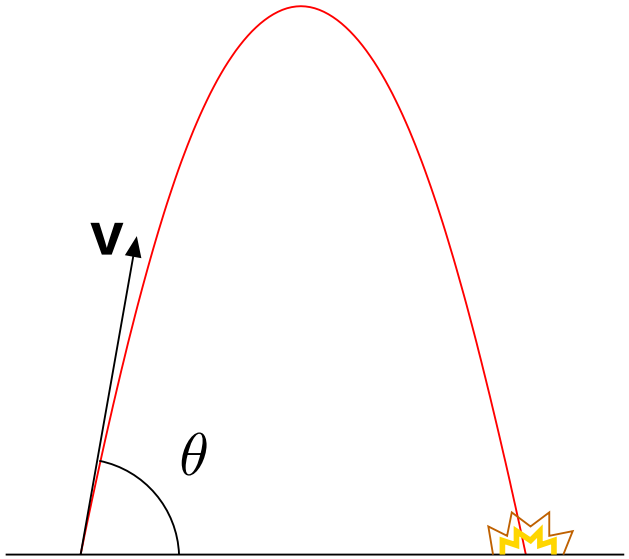

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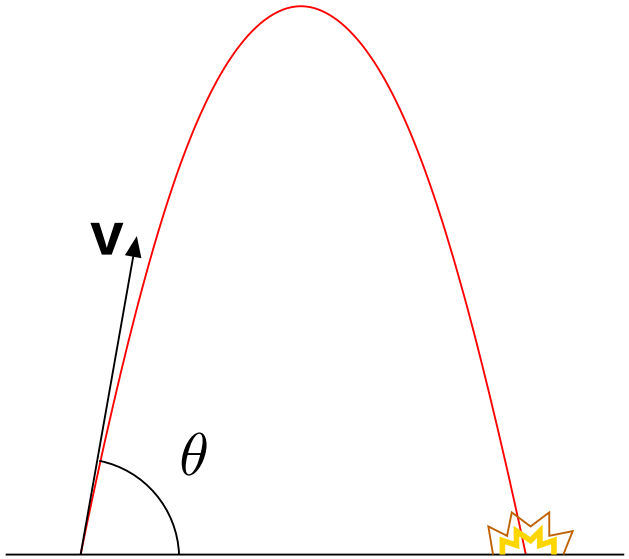

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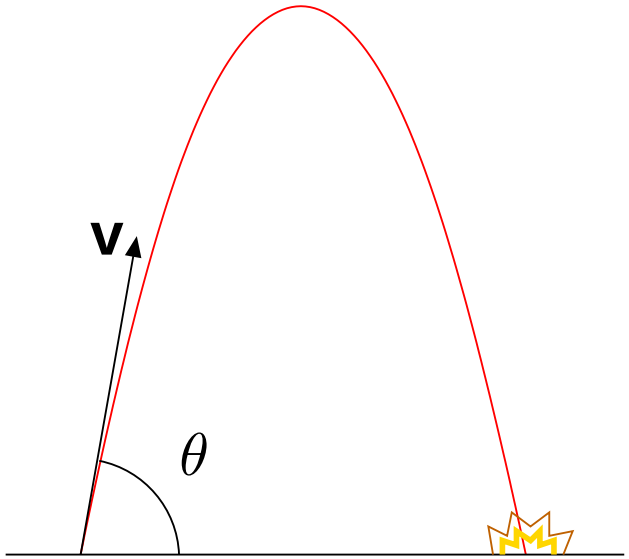

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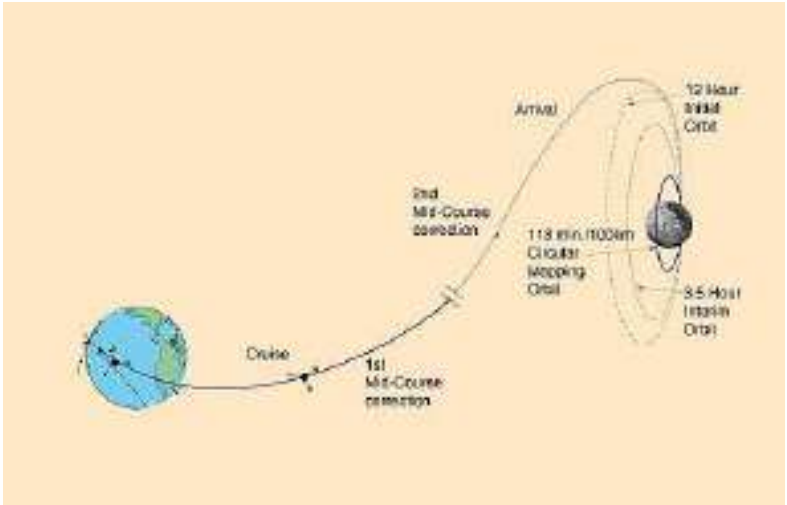
Getting to the Moon

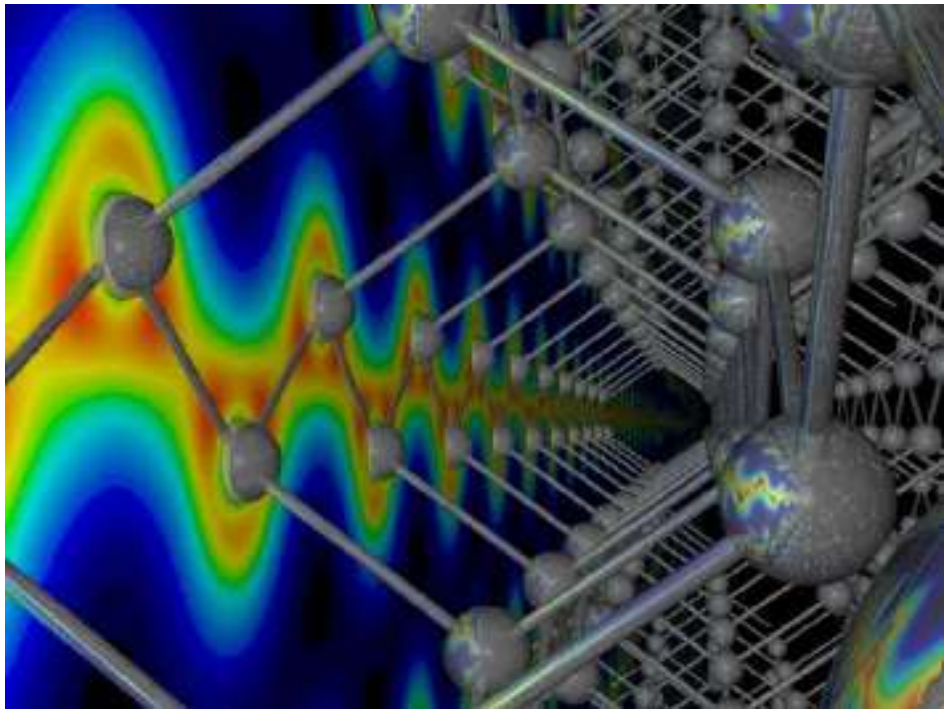
- Same ideas are enough to allow us to send a rocket to the Moon
- Can calculate precise trajectory for a rocket
- We can use theory when experiments are either difficult, expensive or dangerous (or all three!)
- For example to calculate the optimal amount of fuel needed for the Moon-landings



Outline

Quantum mechanics

- Matter consists of many interacting particles
- Quantum mechanics describes the world on an atomic scale
- It can predict the properties of matter
- This includes gases, liquids, solutions, metals, crystals, polymers....

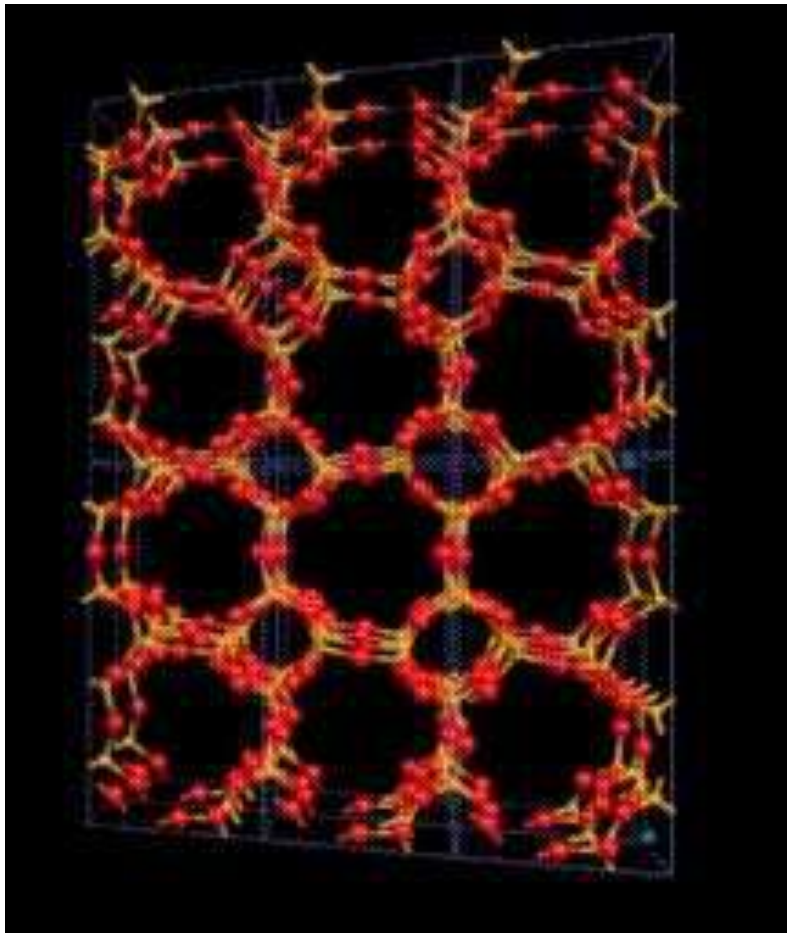


“Inside” diamond

Outline

Theory of Condensed Matter

- Carbon-based semiconductors — flat panel displays
- Aggregated carbon nanorods (ACNR) - a material harder than diamond
- Drug design
- Room temperature superconductors
- Solid state data storage



A zeolite catalyst

Outline

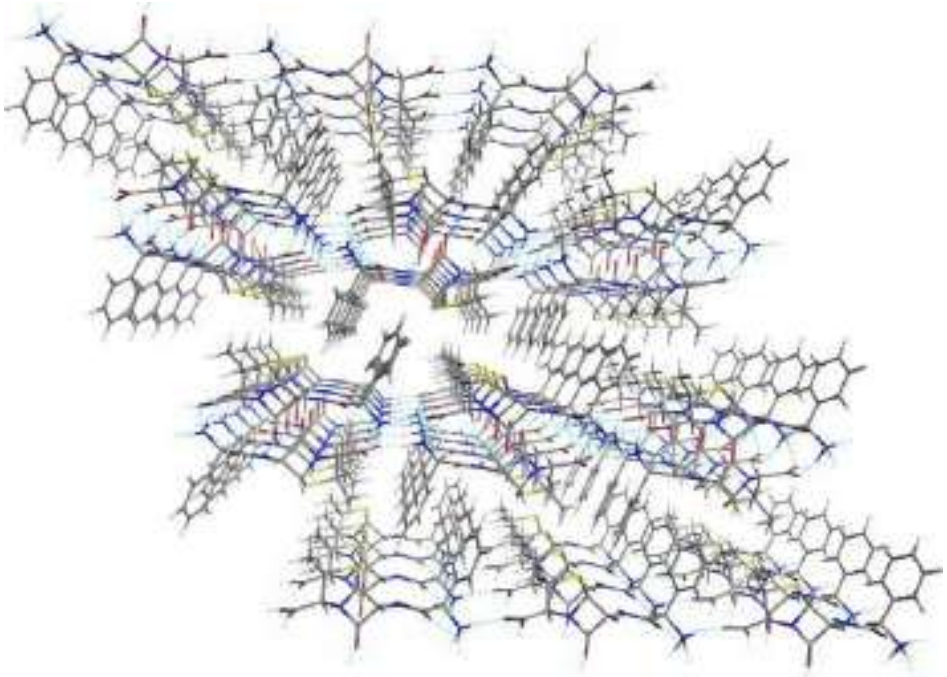
Superconductivity

- Some materials lose all electrical resistance at very low temperatures
- Superconductors possess other interesting and counter-intuitive properties
- Superconductivity is purely quantum mechanical effect
- Yet to understand fully high temperature superconductors

Levitating magnet (and sumo wrestler)

Conclusions

- Theoretical science is an important companion to experiments
- Theorists work on a wide range of problems in both universities and industry
- A great many important theoretical problems remain unsolved!



Crystal structure of penicillin