Theoretical Physics Theory of Condensed Matter

Gareth Conduit

Physics at Work 2007

What is it?

- Examples
- Rôle of observations
- Mathematics
- Predictions

2 Applications in TCM

- Quantum mechanics
- TCM
- Superconductivity

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Can you name any physicists?

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Galileo's experiment



• Can you spot the pattern?

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Galileo's experiment



• Physics is about pattern recognition

- Experiments give quantitative clues
- Theory must explain observations
- Must make new predictions
- Unify understanding of different phenomenal

Time = 0 seconds Time = 1 second	Time/s	Distance/m
Time = 2 seconds	1	1
	2	4
Time = 3 seconds	3	9
	4	16
	5	25

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- What is the formula here?
- Distance dropped = time

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The unreasonable effectiveness of Mathematics

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Time/s	Distance/m	• What is the formula here?
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5	25	• 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
- t² 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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Figure: Path of a projectile

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

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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



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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

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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

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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)

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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