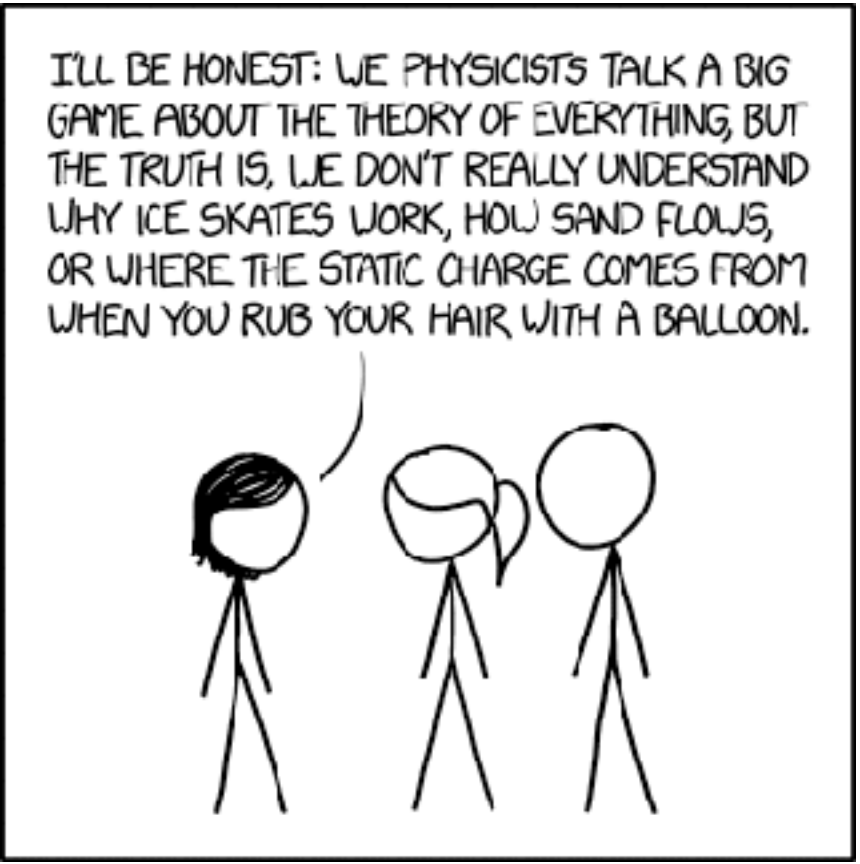
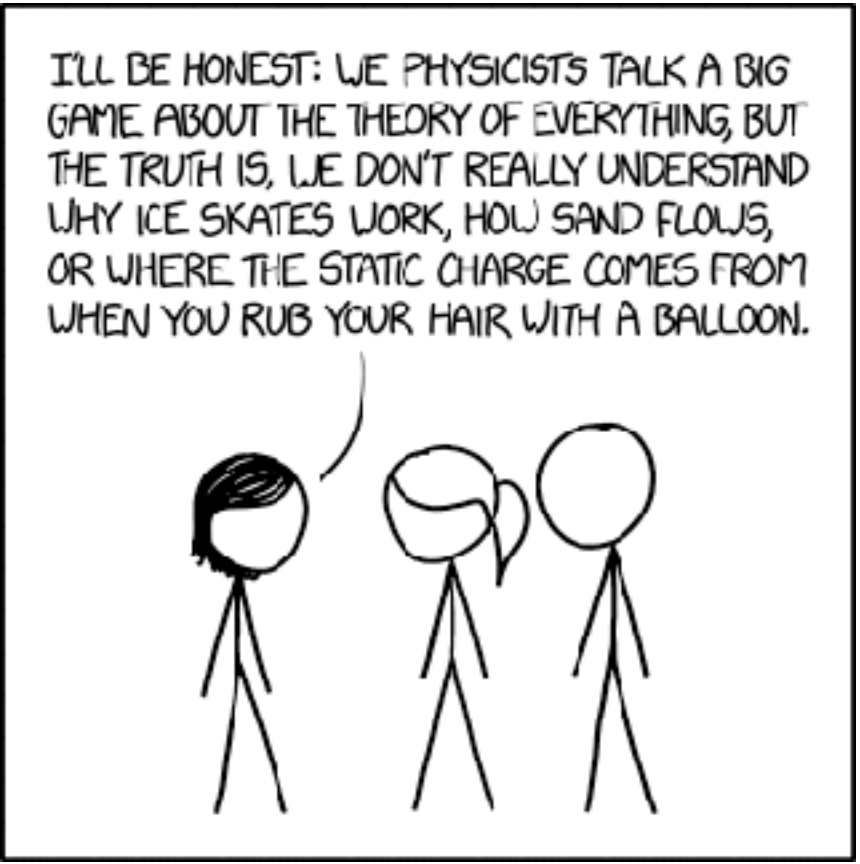
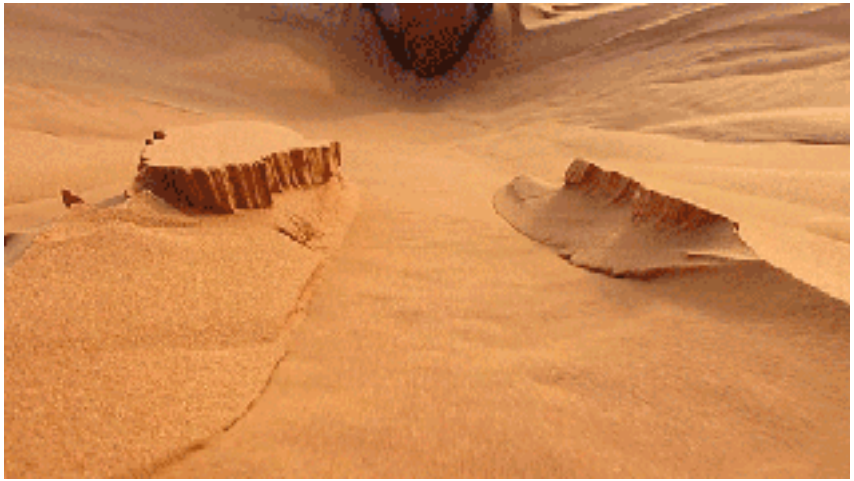


https://xkcd.com/1867/



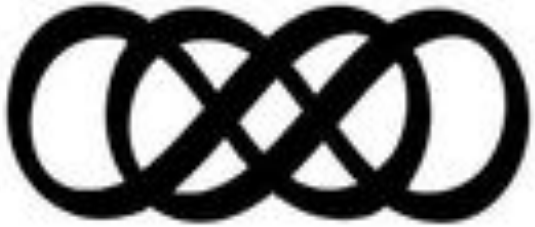
https://xkcd.com/1867/



http://giphy.com/gifs/sand-sahara-low-drifting-l6Zn1293Bi3dK

Part I:
What is Condensed Matter Physics?
Part II – at a later date:
Sand Flows (i.e. my research)

Three infinities in Physics



- Infinitely Big - cosmology
- Infinitely Small - particle physics
- **Infinitely Complex - Condensed Matter Physics.**

Source:
Marvin Cohen - Oppenheimer Lecture
https://youtu.be/PtDa9tccDaw

Essay: Fifty Years of Condensed Matter Physics, Marvin L. Cohen
https://journals.aps.org/prl/edannounce/PhysRevLett.101.250001

What do we mean by complex?

The collective behavior of many objects that cannot be easily guessed, even if we have complete knowledge of how the objects interact w/ each other

Scottie Pinwheel
https://www.youtube.com/watch?v=vDa0z0gEvI4

What if my student asks how a cell phone works?

Its okay to say…

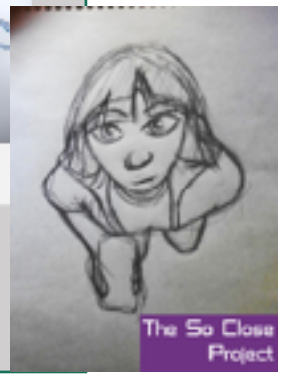
I don't know, lets find out!

What if my student asks how a cell phone works?

Web Resource (20 minute documentary and Interviews)

The So Close Project
https://youtu.be/3De1rLxvzyU?t=139

http://www.uam.es/otros/soclose/



http://www.uam.es/otros/soclose/

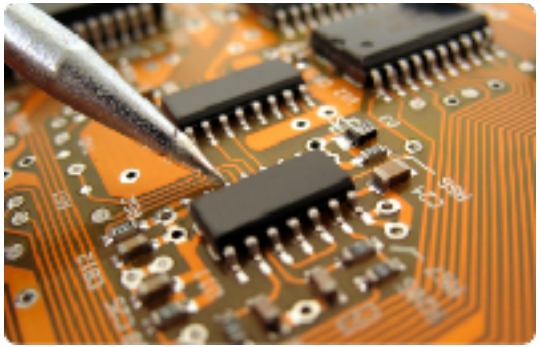
The Wonders of

Condensed Matter Physics

So Close and Such a Stranger

Liquid Crystal Displays

Transistors



Jet.com

MRI & Superconducting Magnets

http://lubricationtechnology.com/

Light Emitting Diodes

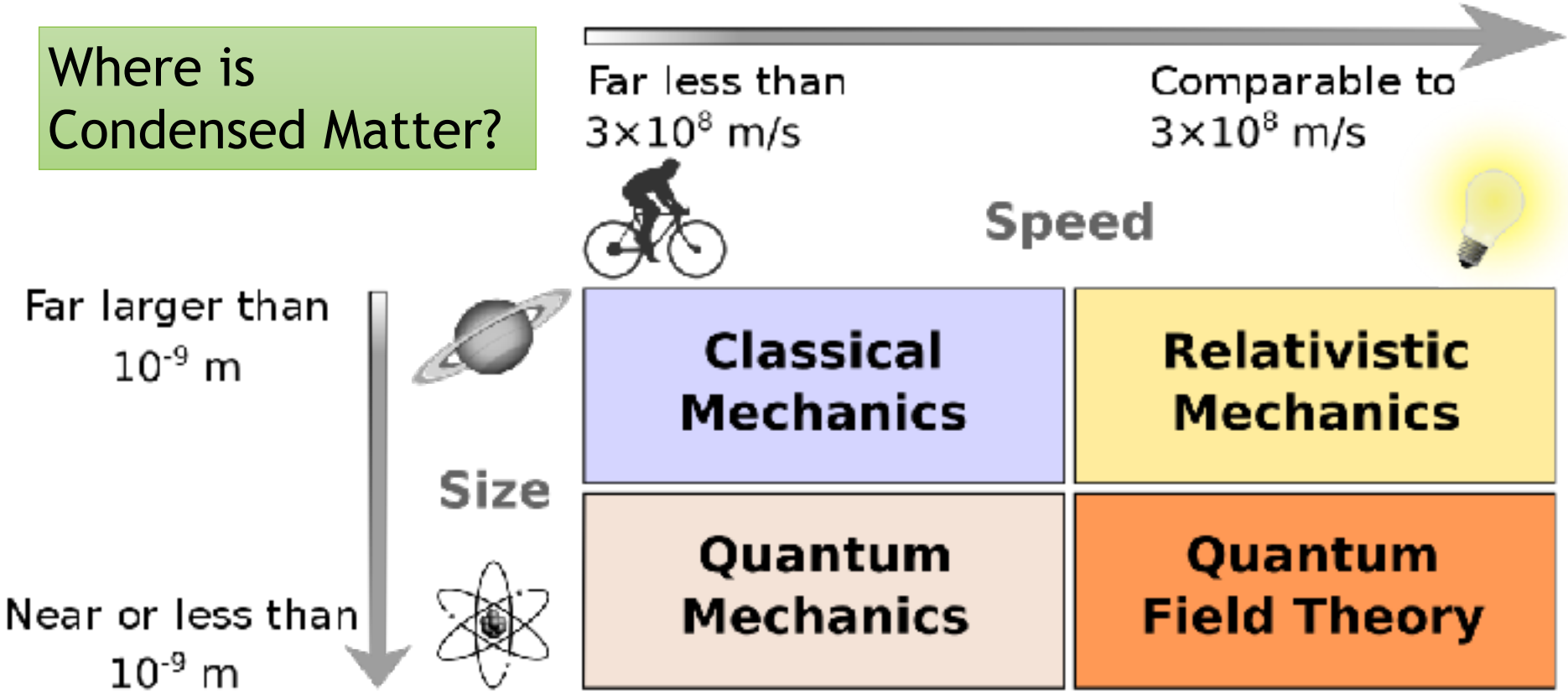
http://en.wikipedia.org/

Howstuffworks.com

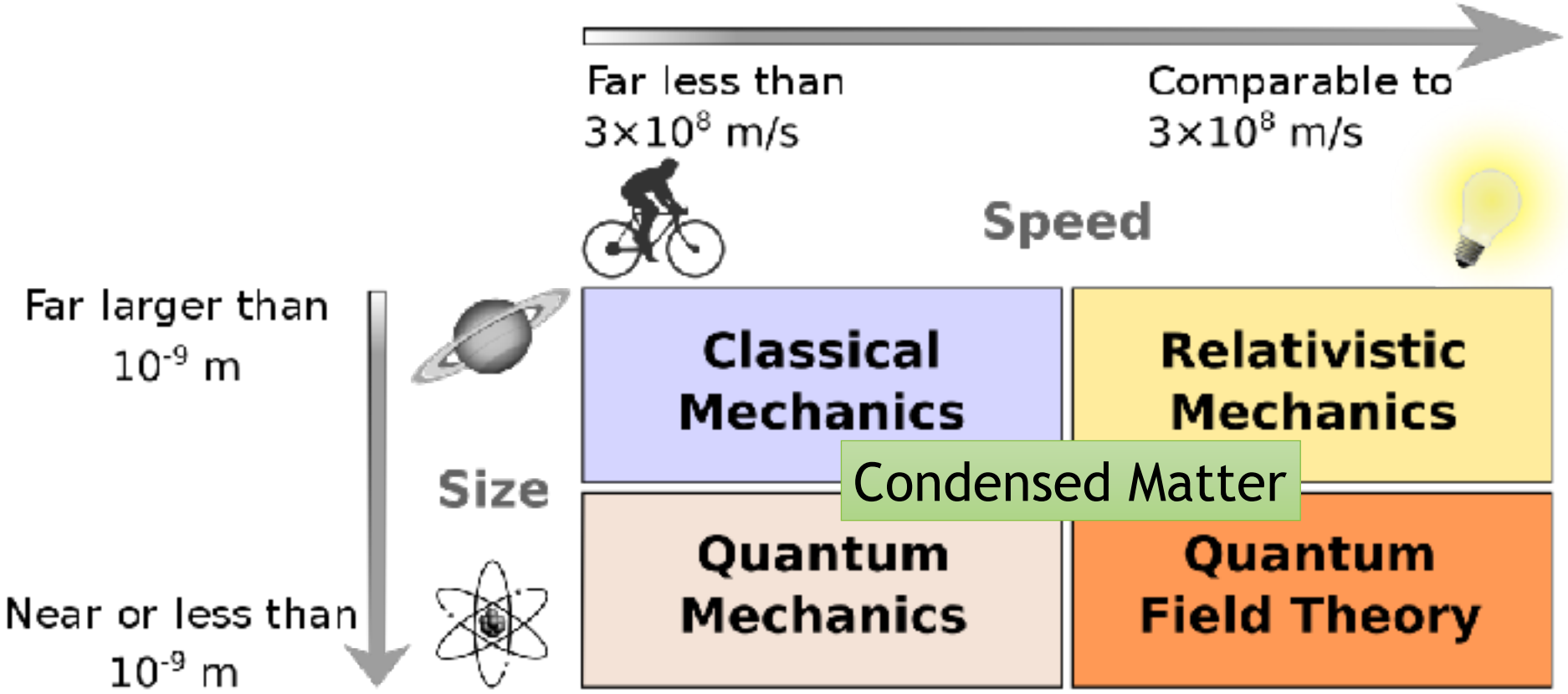
What is Condensed Matter Physics?

The study of everything larger than a few atoms and smaller than a star.

Where is Condensed Matter?



https://en.wikipedia.org/wiki/Classical_physics



https://en.wikipedia.org/wiki/Classical_physics

Thinking about Size w/ Powers of 10
(1977 and beyond)

Web Resources

http://www.eamesoffice.com/the-work/powers-of-ten/ (1977)

https://www.youtube.com/watch?v=FEuEx1jnt0M (Simpsons)

https://www.youtube.com/watch?v=jfSNxVqprvM (Apple Cosmic Eye)

Thinking about Size w/ Powers of 10
(1977 and beyond)

Web Resources

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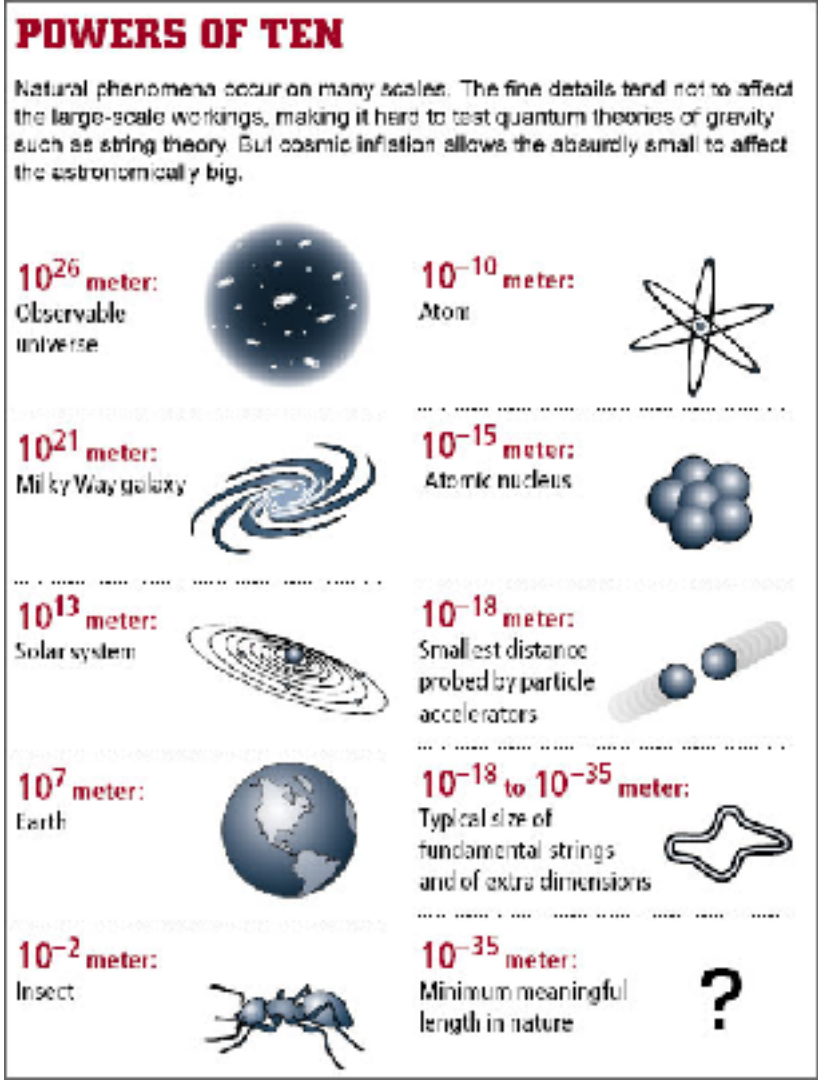
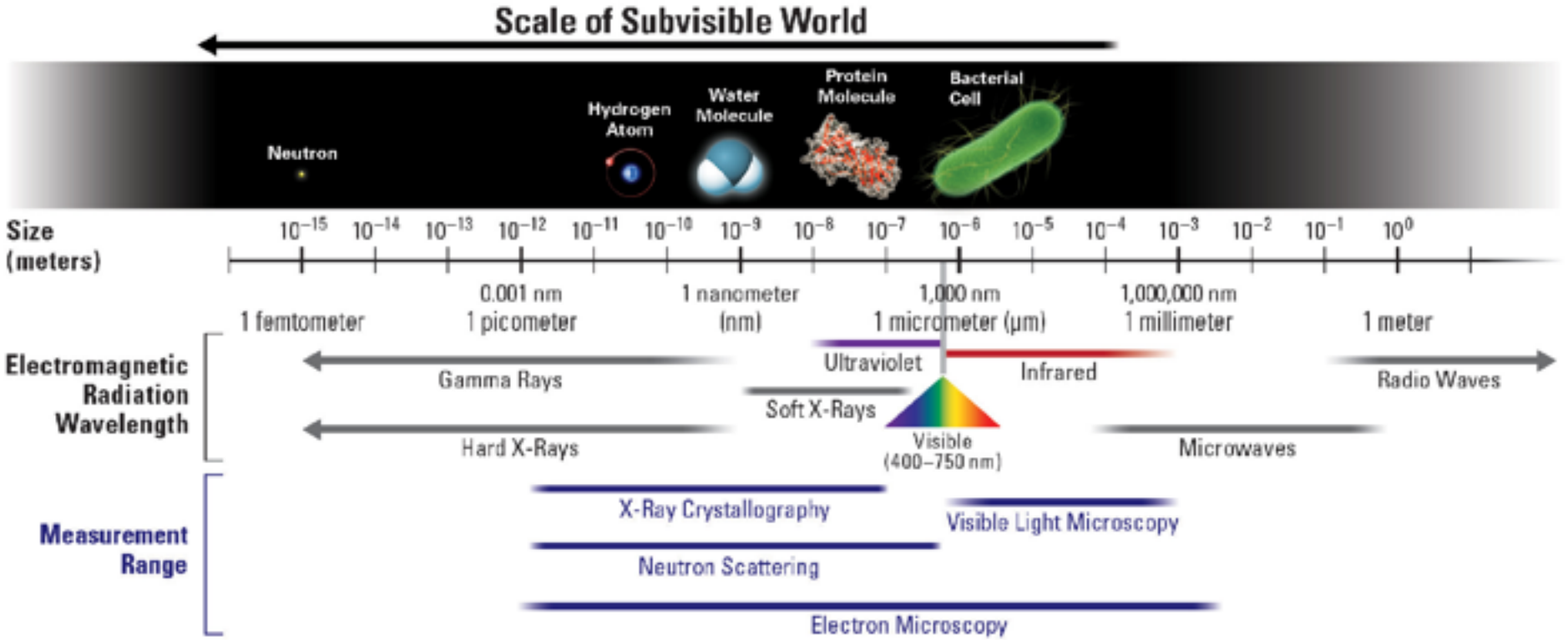
https://www.youtube.com/watch?v=jfSNxVqprvM (Apple Cosmic Eye)



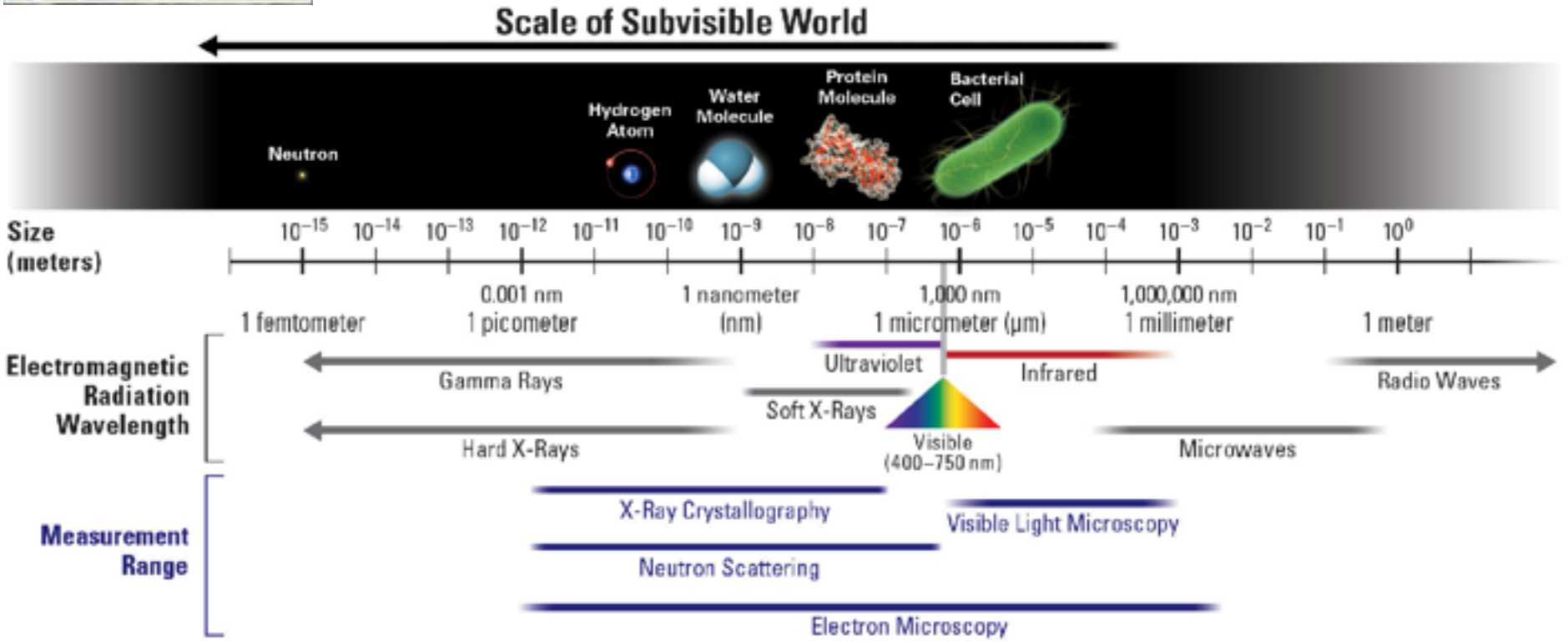
https://science.energy.gov/bes/community-resources/seeing-matter/facilities/

We know about this from scattering (imaging)



https://science.energy.gov/bes/community-resources/seeing-matter/facilities/

CERN



Lesson on Scattering/Microscopy

Similar concept to Rolling for Rutherford

Teachers collect data from their black box.

Teachers build a 3D model of their landscape.

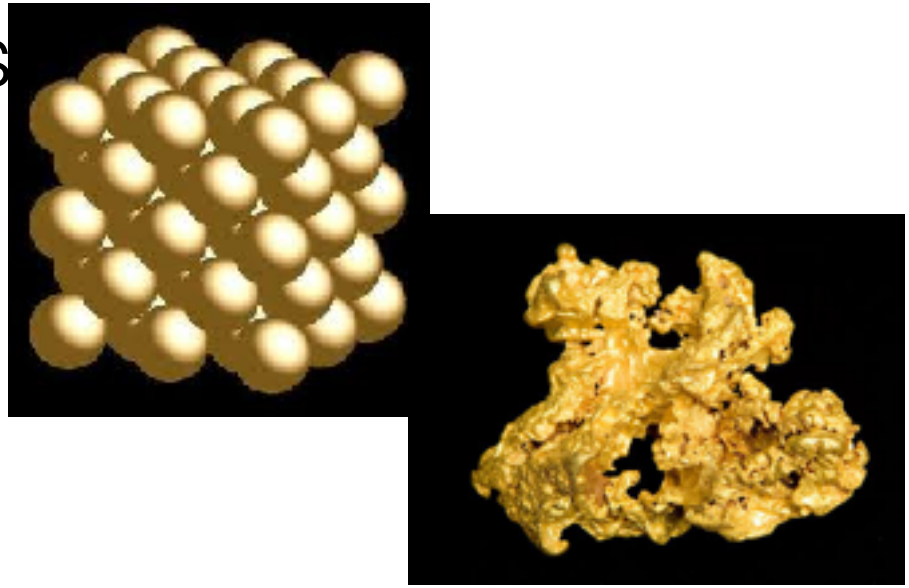
How Can We "See" What We Can Not See?
http://education.mrsec.wisc.edu/modules/MiddleSchool/SPM/index.html - and lots more!

Infinite Complexity

The collective behavior of many objects that cannot be easily guessed, even if we have complete knowledge of how the objects interact w/ each other

Collective Behaviors

- Structure
- Dynamics
- Phases
- Scattering (imaging)

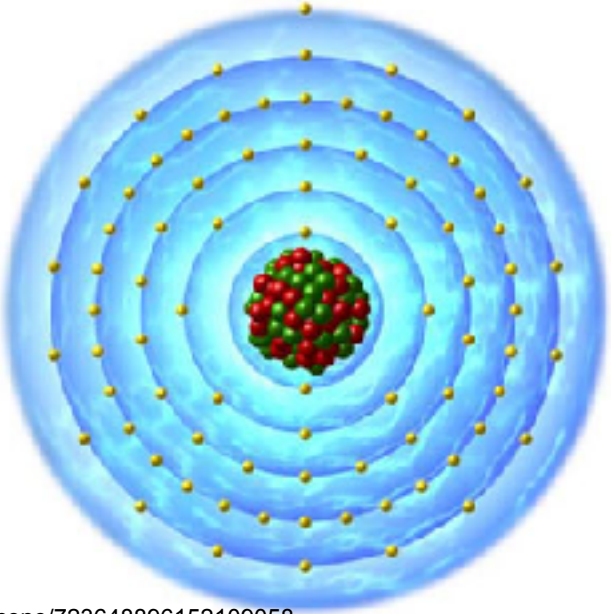


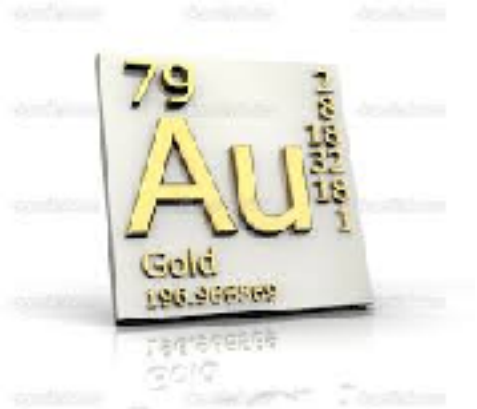
Let's set the stage by talking about

Defining Structure, Dynamics, & Phases

gold

A single atom is already a complicated object, just ask a particle physicist.



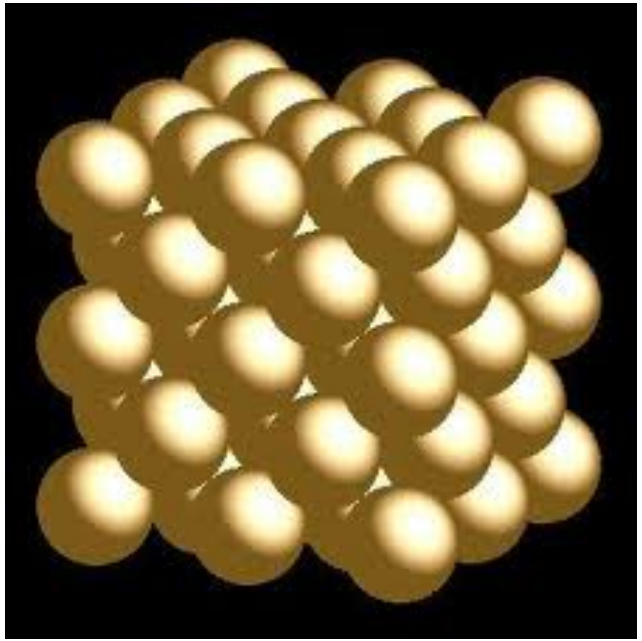


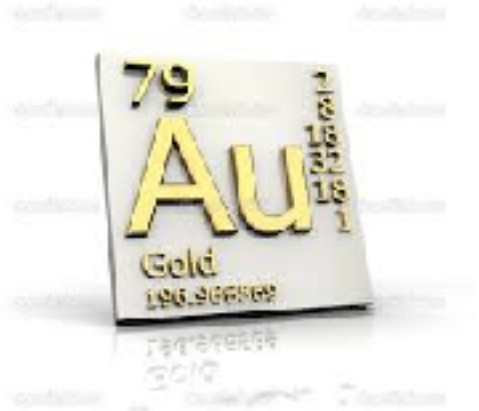
$$\text{Au: [Core] } 5d^{10}\ 6s^{1}$$

https://www.thinglink.com/scene/723648896152109058

Defining Structure

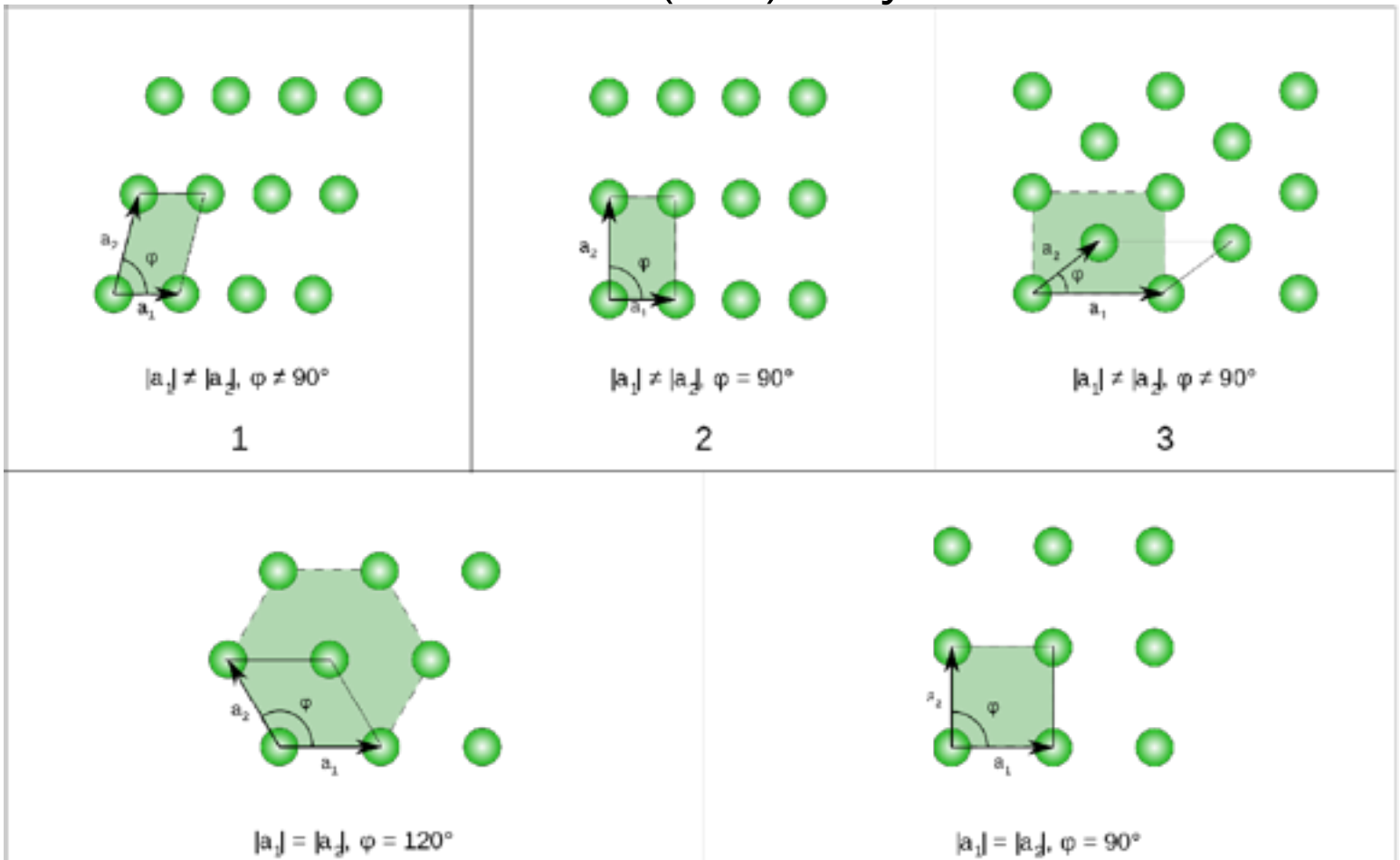
Structure: many gold atoms create a symmetric crystal





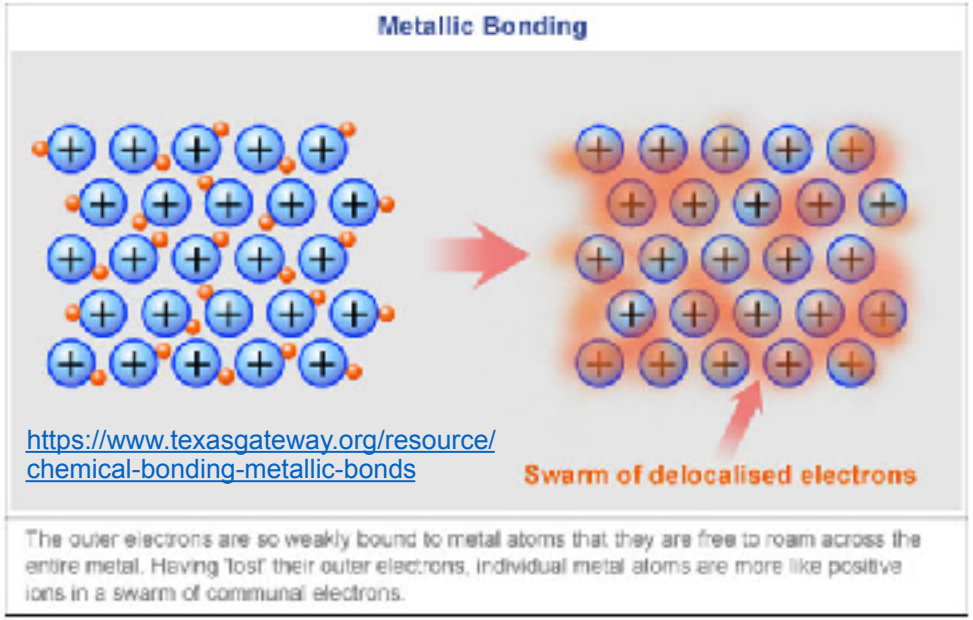
Au: [Core] $5d^{10}$ $6s^{1}$

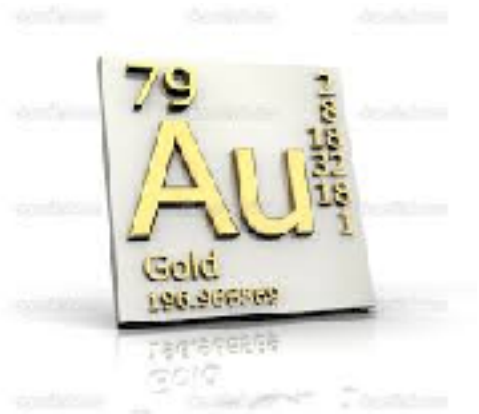
Two-Dimensional (2D) Crystal Lattices



Defining Structure & Dynamics

Crystalline gold forms metallic bonds.
Electrons flow creating a current.

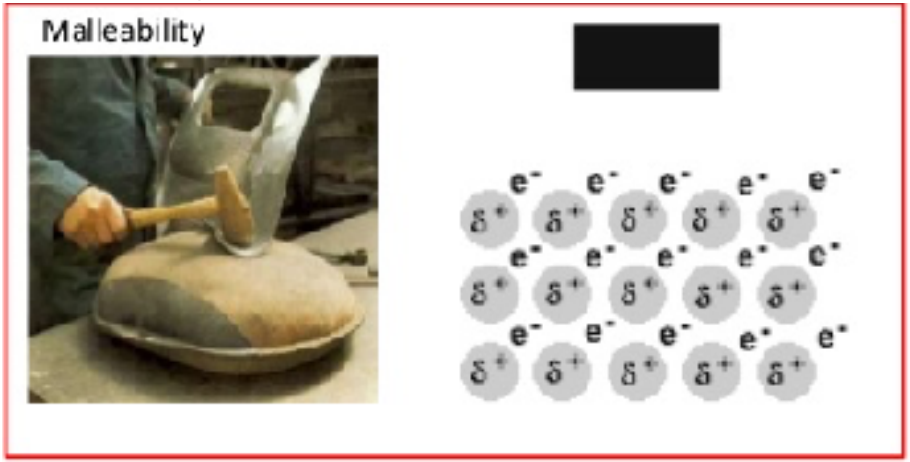


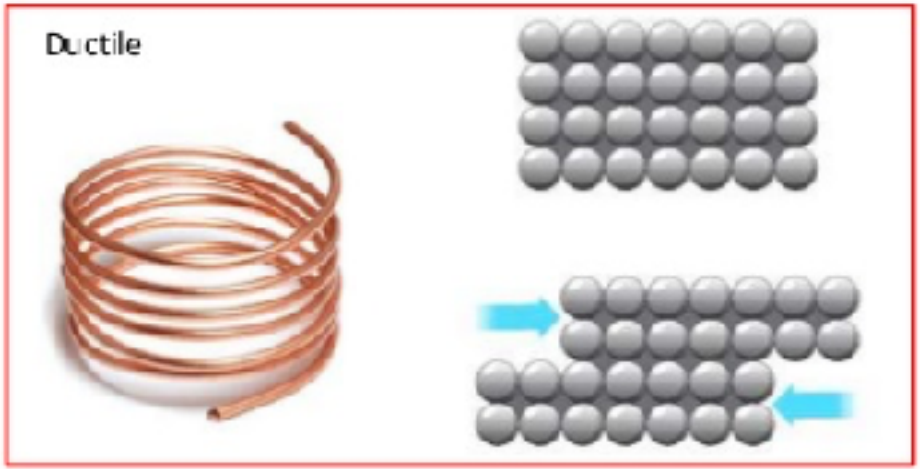


Au: [Core] $5d^{10}$ $6s^{1}$

Defining Structure, Dynamics, & Phases

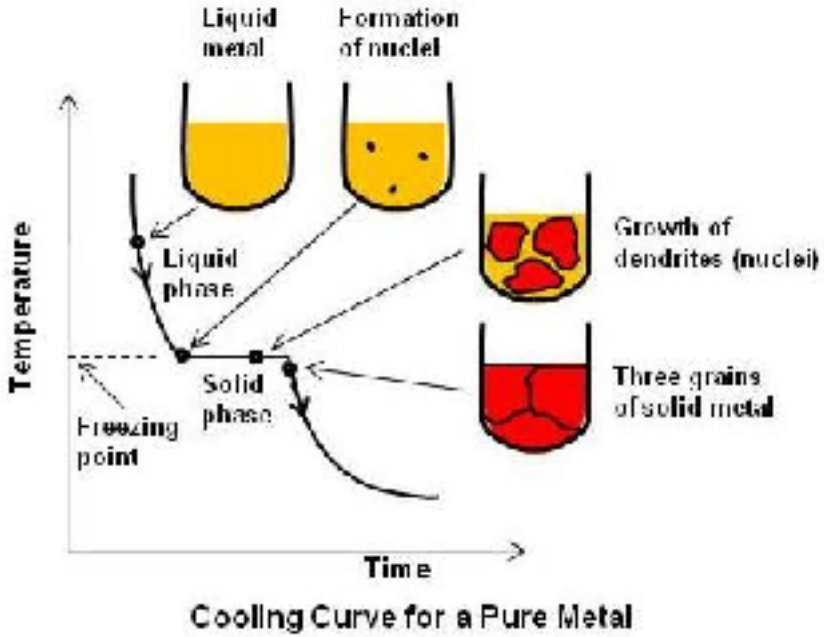
In its purest form, gold is a bright, slightly reddish yellow, dense, soft, malleable. and ductile metal.





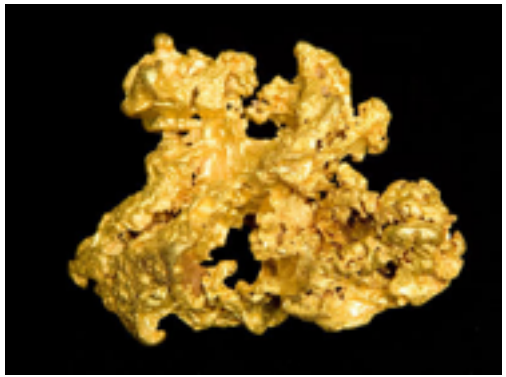
Phases

Some phases of gold: liquid to solid

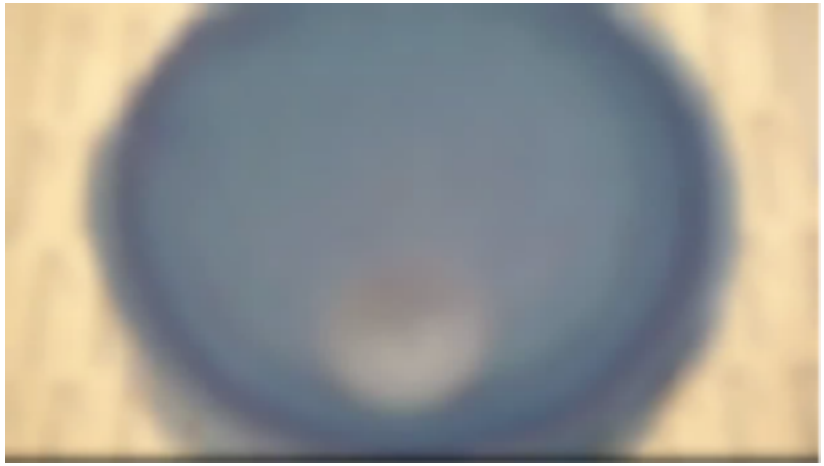


http://practicalmaintenance.net/?p=1176

http://www.dw.com/en/gold-mining-in-drc-from-the-ore-to-the-bar/



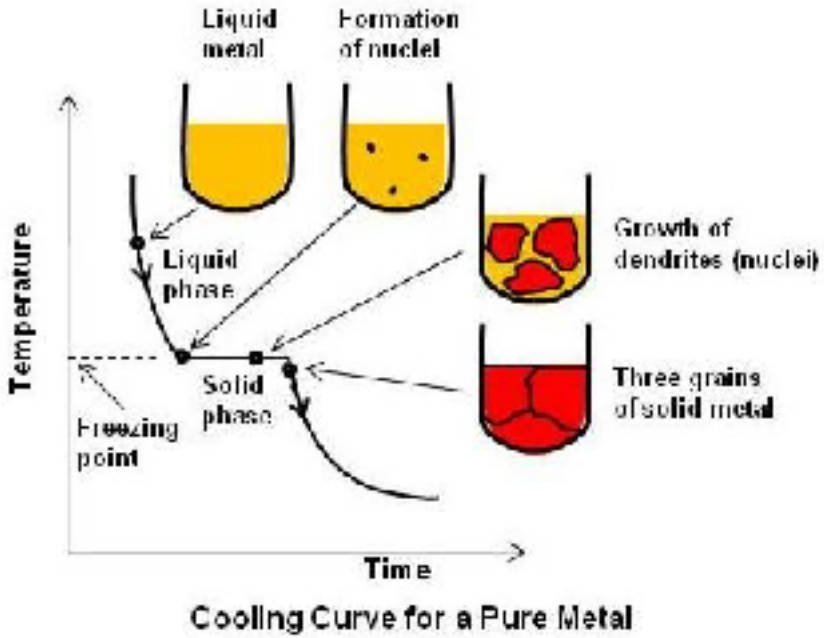
Classroom Activity:
Hand Warmer (Phase Changes)



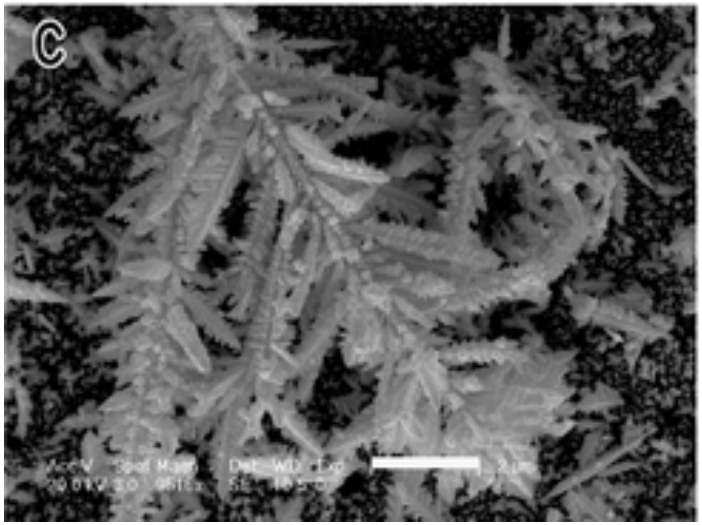
https://www.acs.org/content/dam/AACT/high-school/energy-thermodynamics/exothermic-endothermic/lesson-modelinghandwarmers.pdf

Phases

gold dendrites



Source: practicalmaintenance.net

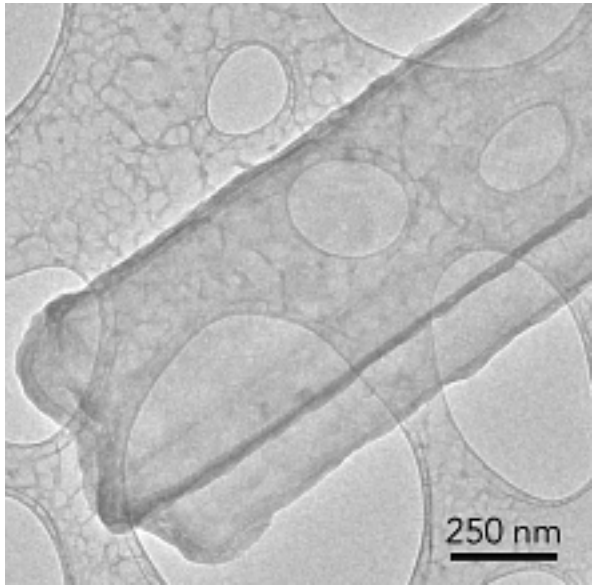


SEM images of the dendritic gold nanostructure

A new Condensed Matter result

Scientists Get First Close-ups of Finger-Like Growths that Trigger Battery Fires
Remarkable cryo-EM images of dendrites show details down to the individual atom, and will yield new insights into why high-energy batteries fail*

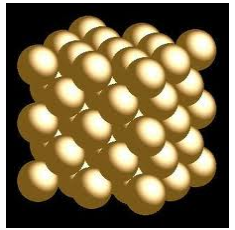
Y. Li *et al.*, *Science*, 27 October 2017 (10.1126/science.aam6014)



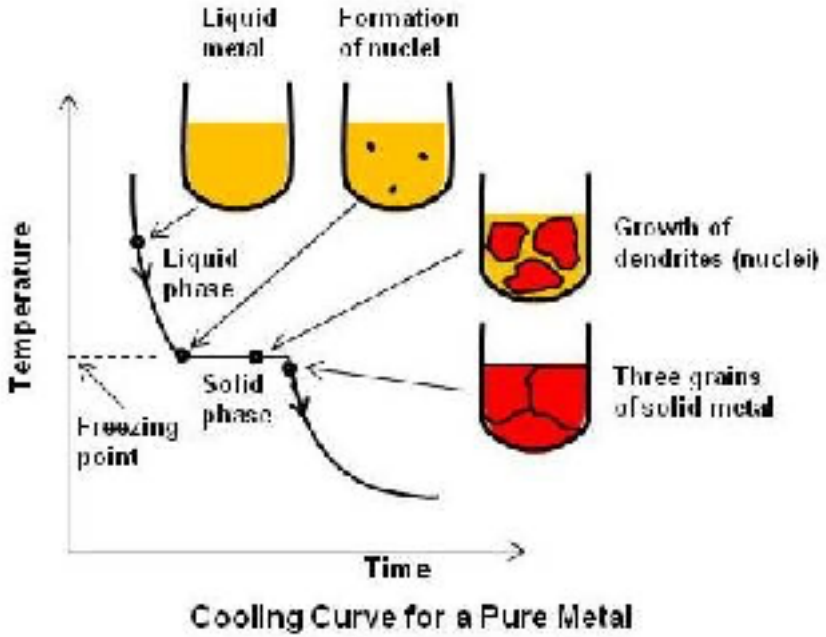
https://www6.slac.stanford.edu/news/2017-10-26-scientists-get-first-close-ups-finger-growths-trigger-battery-fires.aspx

*cryo Electron Microscopy won the 2017 Nobel Prize in Chemistry

Phases

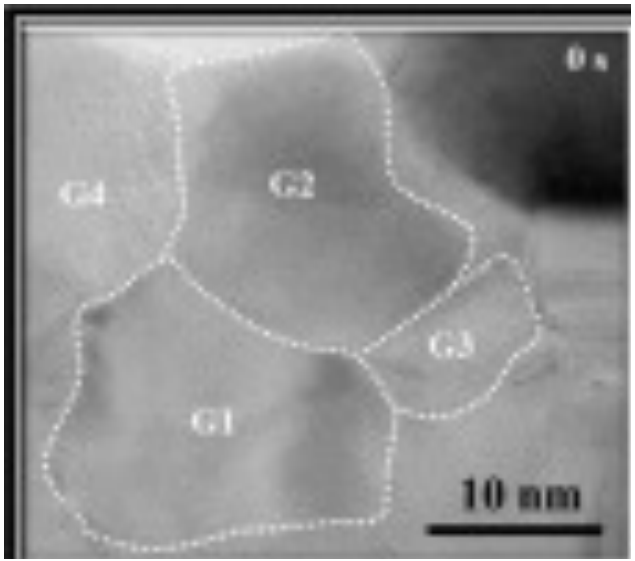


gold crystalline grains



http://practicalmaintenance.net/?p=1176

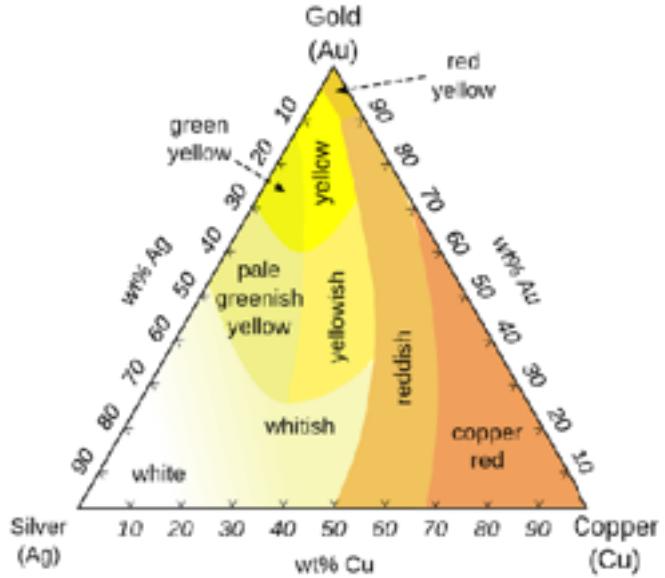
transmission electron microscope



http://www.sciencedirect.com/science/article/pii/S1359646217301173

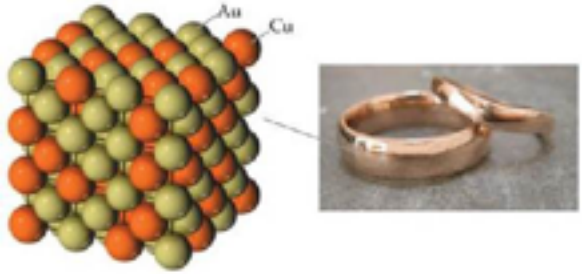
Phases

Phase diagram from gold alloys

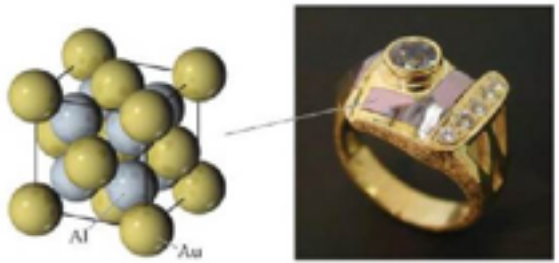


https://en.wikipedia.org/wiki/Gold

gold alloys



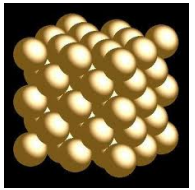
14-karat red gold, a substitutional alloy marked with a red dot in Figure 12.18



Purple gold, the intermetallic compound $AuAl_2$

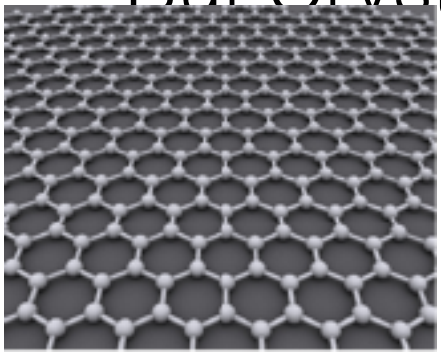
http://schoolbag.info/chemistry/central/111.html

Structure



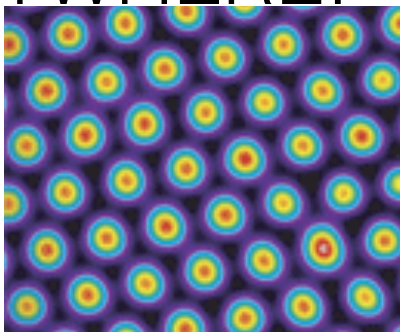
Studying solid gold is a traditional hard condensed matter topic formerly known as solid state physics.

But Crystals are EVERYWHERE!



Graphene

Superconductors



Colloids

Solar Panels

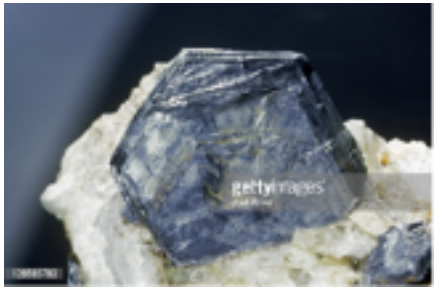
Teaching activities to explore crystals:

Stacking Stuff – tennis balls in a clear container

Figure 2 Image of a transparent box with tennis balls stacked inside in an orderly manner forming a type of crystal structure. The structure formed is hcp in this case.

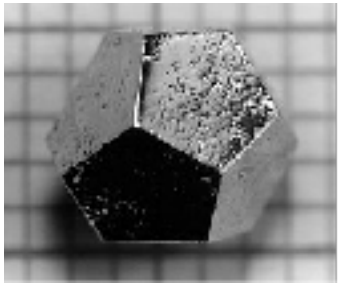
http://www.nus.edu.sg/teachingacademy/article/mastery-learning-in-the-context-of-university-education/

Crystals and Platonic Solids



Molybdenite,
molybdenum sulfide

pyrite (FeS_2)



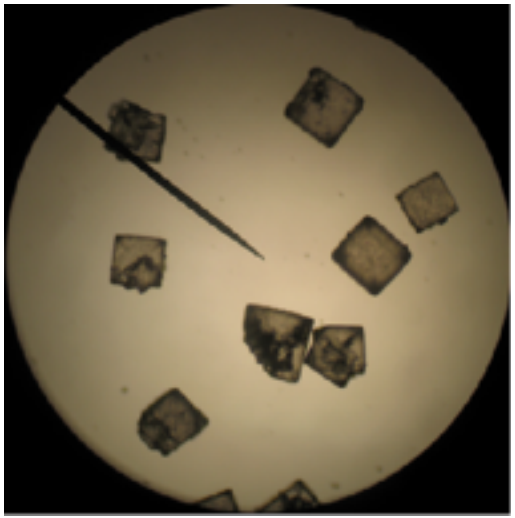
A Ho-Mg-Zn
icosahedral quasicrystal

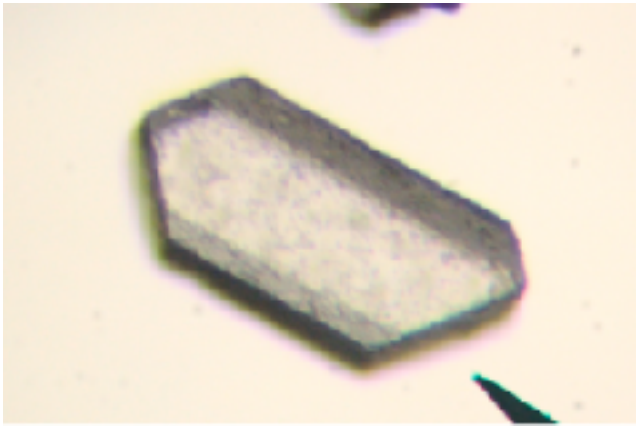
http://www.sunitanna.com, wikipedia,org,

Beryl is a ring silicate

Teaching activities to explore crystals:

Salt vs. Sugar in a microscope





http://montessorimuddle.org/2011/04/24/salt-and-sugar-under-the-microscope/

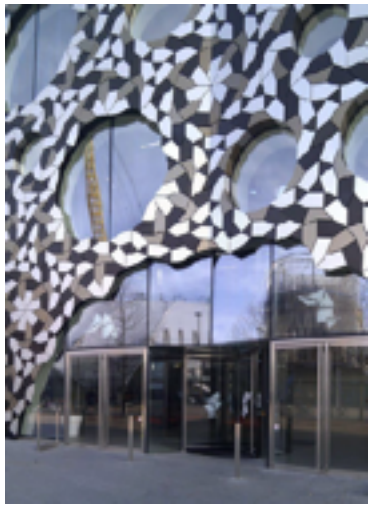
What if you don't have a microscope?

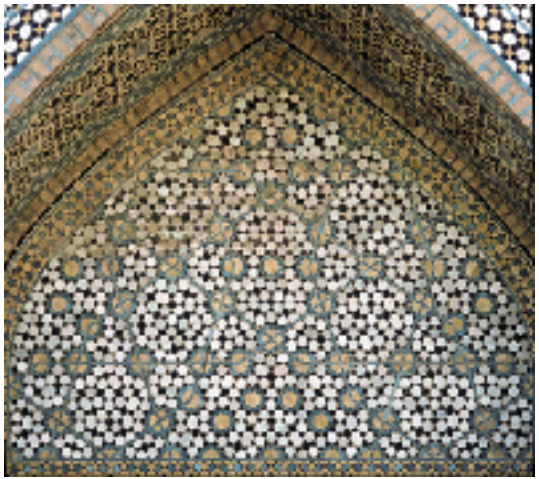
Cheap Microscope – 3mm glass bead
(w/ 3D Printed Holder): http://www.pnnl.gov/news/release.aspx?id=1071

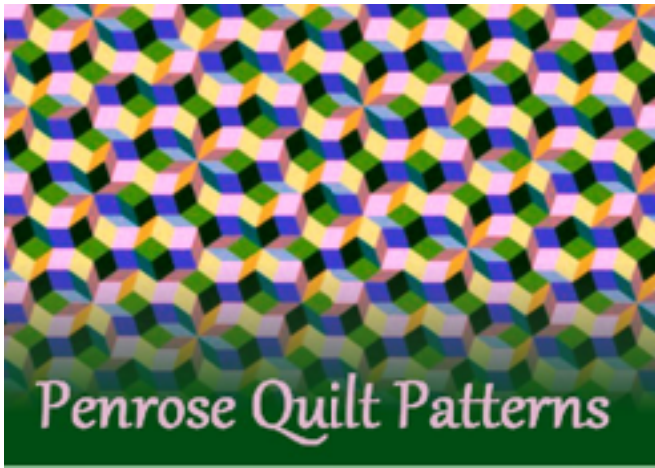
Pentrose Tiles & Quasicrystals

THE NOBEL PRIZE IN CHEMISTRY 2011
https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2011/press.html

https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2011/popular-chemistryprize2011.pdf



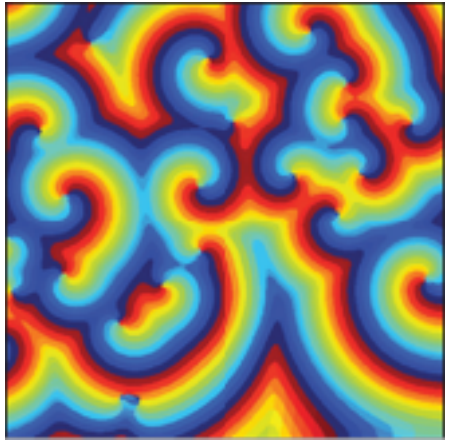




Games/Coloring
(for Outreach or Elementary School)

Nobelprize.org
The Official Web Site of the Nobel Prize

- Education Section on nobelprize.org
- Coloring Book
  http://www.physicscentral.org/explore/pictures/color-charge-bz.cfm



What's Going On Here?
A Belousov-Zhabotinsky (BZ) reaction is a complex bit of chemistry that involves atoms losing electrons, gaining them back, and losing them again.

Back to cell phones

Nobelprize.org
The Official Web Site of the Nobel Prize

The Transistor

Transistors are devices that control the movement of electrons, and consequently, electricity. They are the major component in all digital circuits, including computer microprocessors which contain millions of microscopic transistors.

→ The Transistor in a Century of Electronics

Great online resource!

Condensed matter claims 28 physics Nobel prizes – *and a few in chemistry*

Nobelprize.org
The Official Web Site of the Nobel Prize

The Transistor

Transistors are devices that control the movement of electrons, and consequently, electricity. They are the major component in all digital circuits, including computer microprocessors which contain millions of microscopic transistors.

→ The Transistor in a Century of Electronics

Inventors

William Shockley, John Bardeen and Walter Brattain were awarded the 1956 Nobel Prize in Physics for the invention of the transistor in 1947. John Bardeen is the only person awarded the Nobel Prize in Physics twice.

→ More about the Laureates

Great online resource!

Nobelprize.org
The Official Web Site of the Nobel Prize

Play and Learn!

A transistor is made of a solid piece of a semiconductor material and either used as switches, to turn electronic signals on or off – or, as amplifiers.

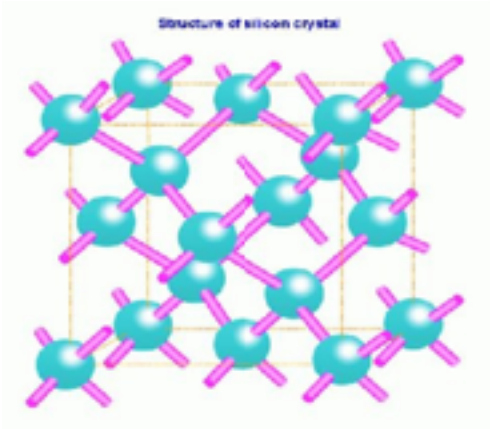
→ Play the Transistor Recycler Game or try and build a transistor replica!

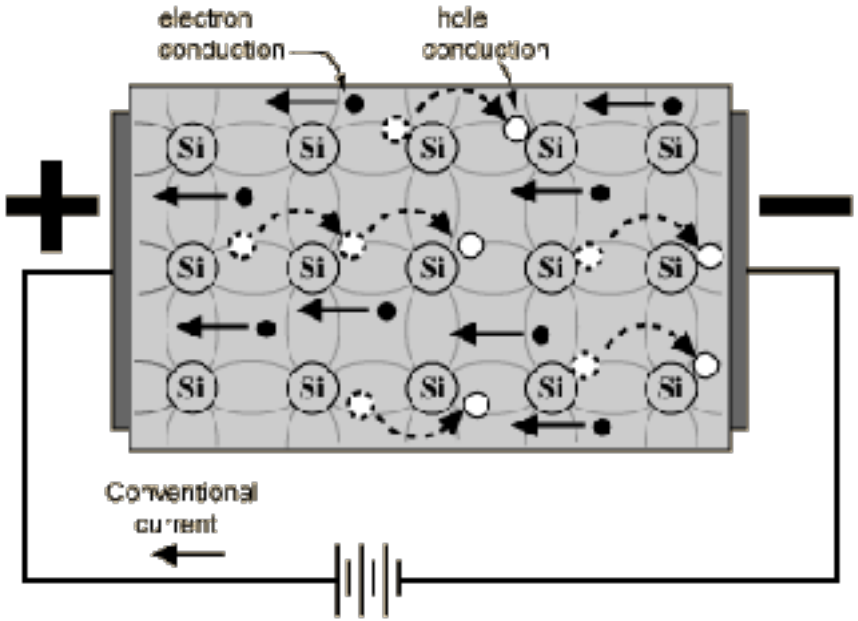
The Transistor

Transistors are devices that control the movement of electrons, and consequently, electricity. They are the major component in all digital circuits, including computer microprocessors which contain millions of microscopic transistors.

→ The Transistor in a Century of Electronics

Structure & Dynamics: Semiconductors



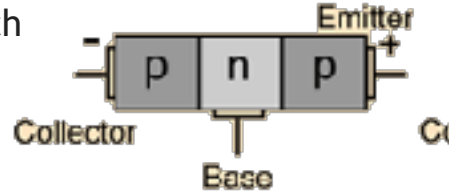


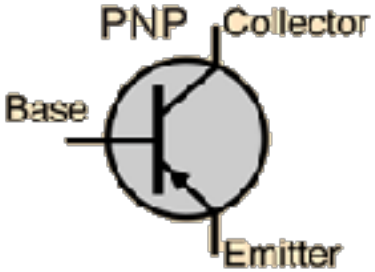
http://hyperphysics.phy-astr.gsu.edu/hbase/Solids/intrin.html

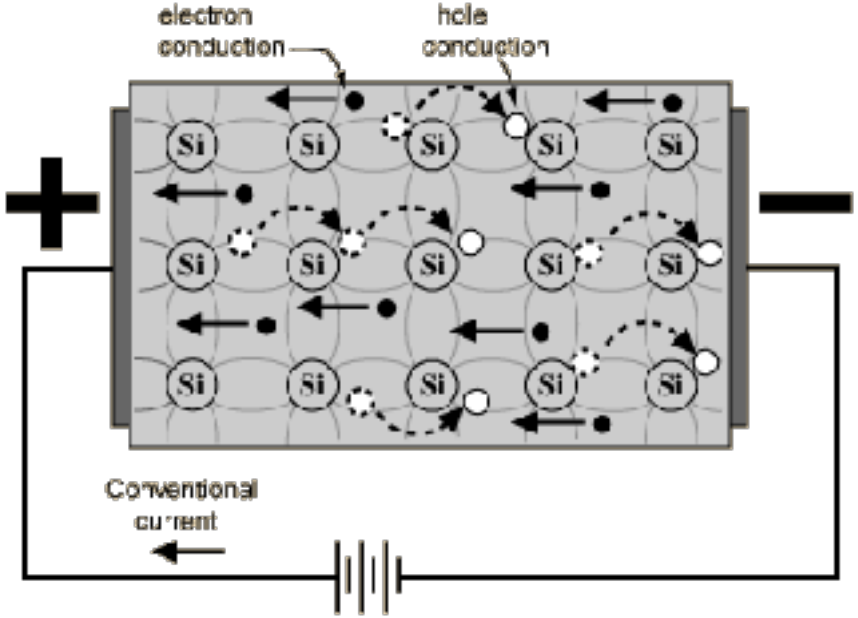
Structure & Dynamics: Semiconductors

Transistor:

3 chunks of doped semiconductors that are either electron rich or hole rich







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Structure & Dynamics: Semiconductors

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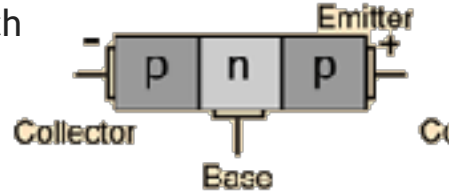
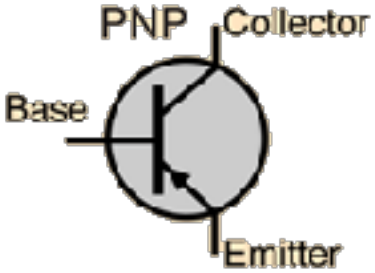




How it works

apply some input voltage, and the internal workings of the transistor provide a different output depending on the input.

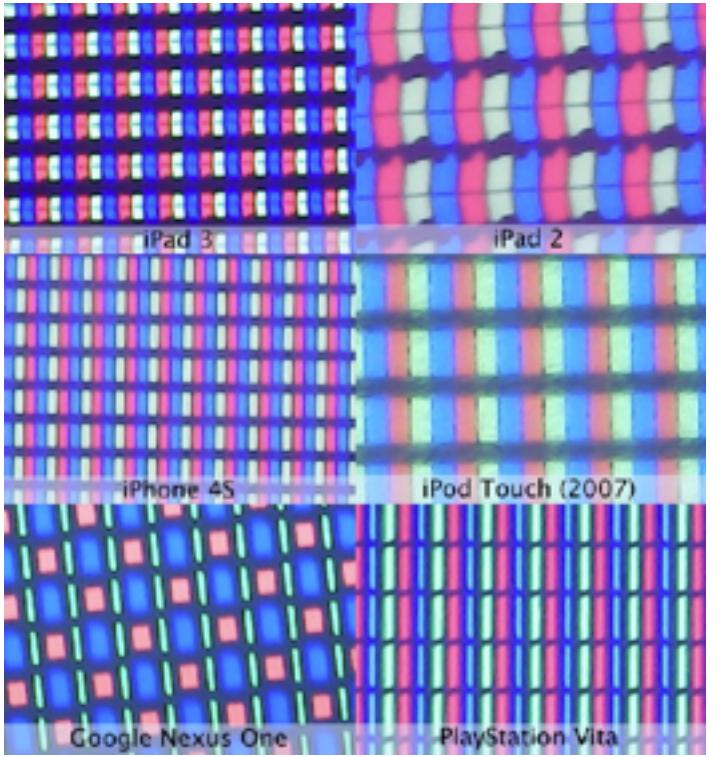
Used as:

Current Amplifier & Switch (1/0)

Microscope Activity: Have a look at your phone screen

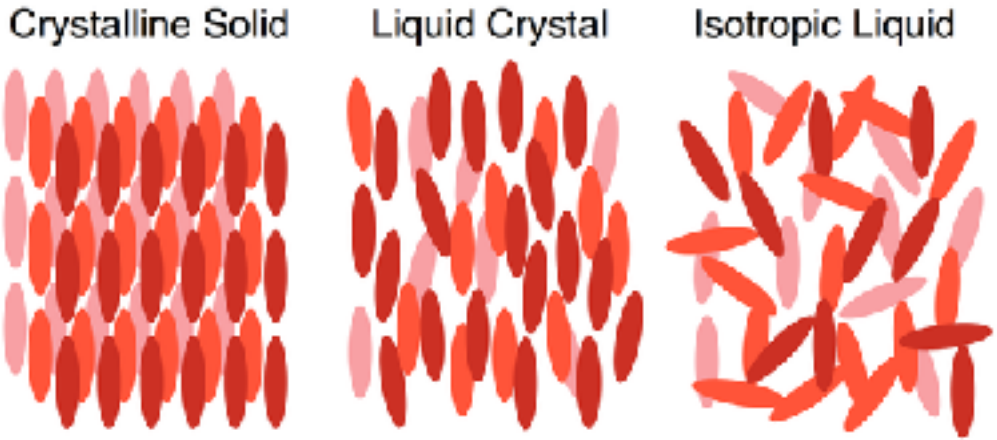
Probably an LCD display

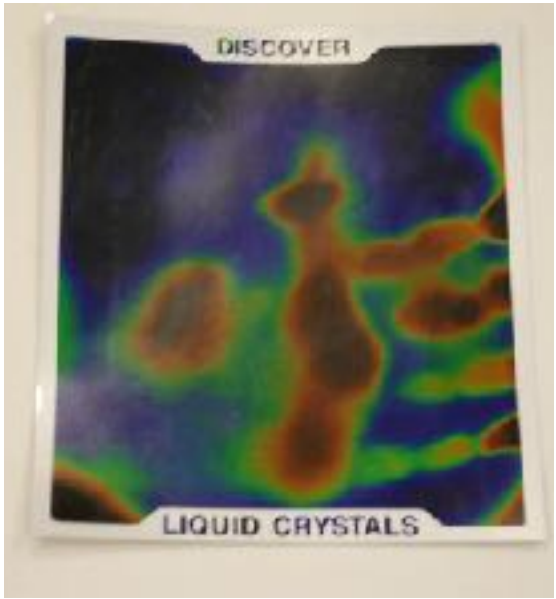
Read more about display technology
https://www.techbead.com/which-mobile-phone-display-technology-is-best/



https://www.extremetech.com/computing/122725-what-the-ipad-3s-retina-display-looks-like-under-a-microscope

Phase Changes in Liquid Crystals

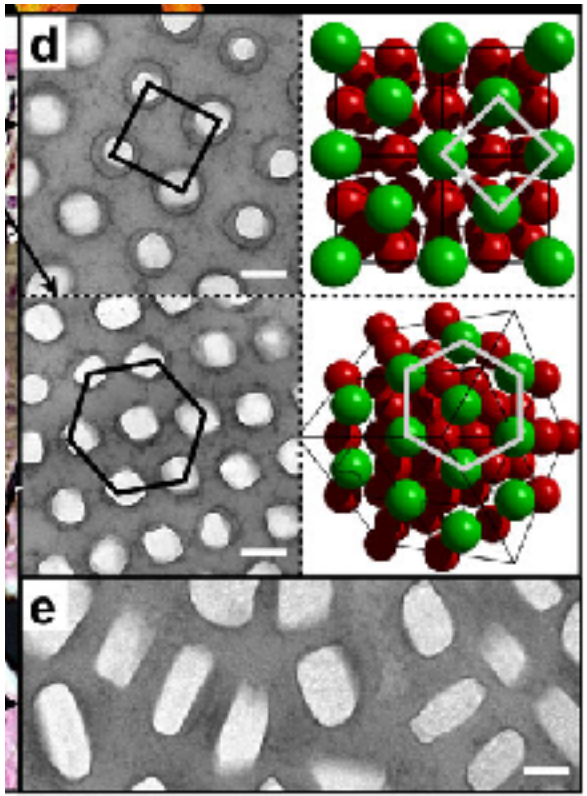


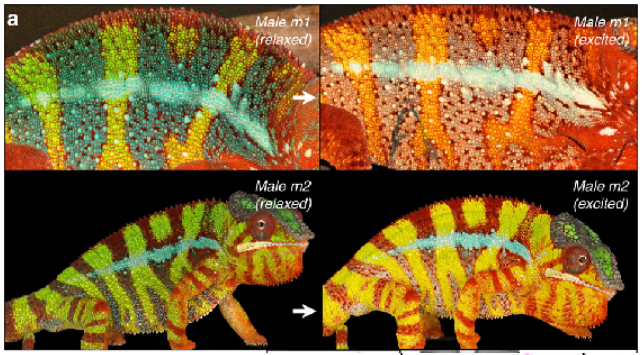


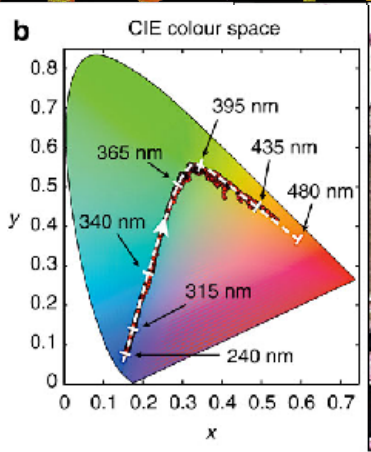
COOL DEMOS! https://www.arborsci.com/cool/liquid_crystal_demos/

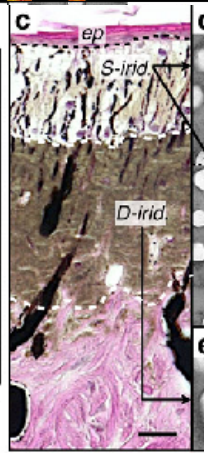
Phase Changes

Photonic crystals cause active color change in chameleons









nature.com

The study of everything larger than a few atoms and smaller

Condensed matter physics

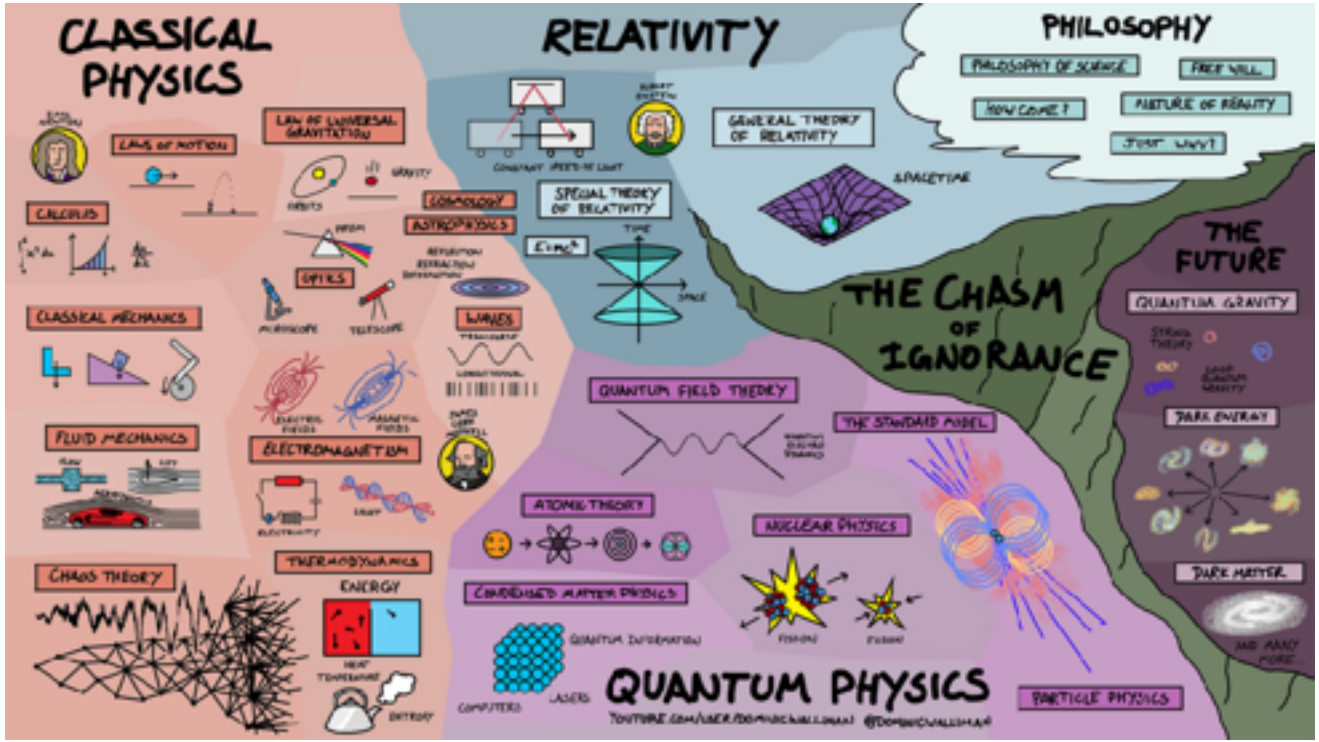
In a nutshell:

$$whole > \sum (parts)$$

More Resources

https://youtu.be/ZihywtixUYo

The Map of Physics



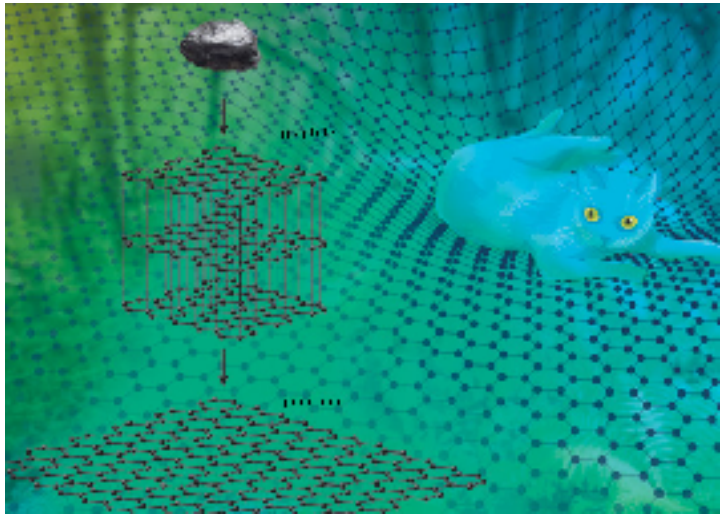
http://dominicwalliman.com

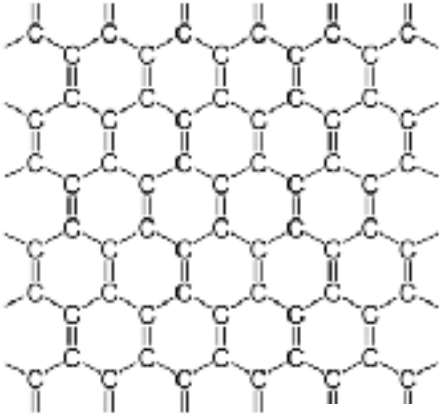
https://funsizephysics.com

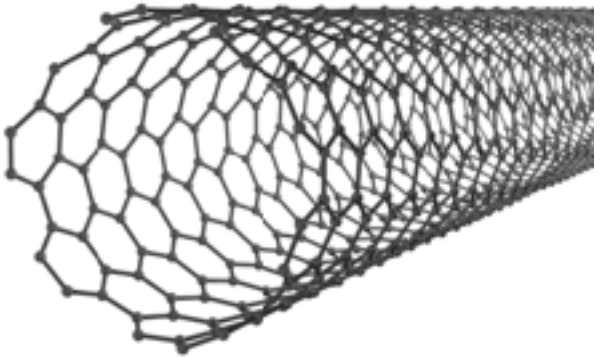
Web resource
(aimed at middle school)

Structure & Dynamics: Graphene

The Nobel Prize in Physics 2010
Andre Geim, Konstantin Novoselov



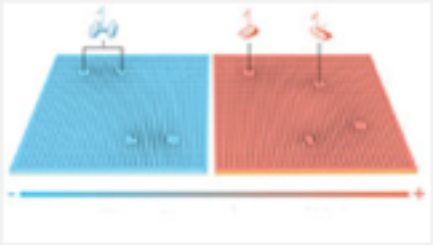




https://www.nobelprize.org/nobel_prizes/physics/laureates/2010/

https://en.wikipedia.org/wiki/Graphene

2016 Physics Prize



Phase transition. Ill: J. Jarnestad/The Royal Swedish Academy of Sciences

They Revealed the Secrets of Exotic Matter

The Nobel Prize in Physics 2016 was awarded with one half to David J. Thouless, and the other half to F. Duncan M. Haldane and J. Michael Kosterlitz.

→ More about the 2016 Physics Prize

"The basis of this year's prize is really exotic"

Professor Thors Hans Hansson, member of the Nobel Committee for Physics, explains the pioneering work of the 2016 Physica Laureates in the unknown world of matter.

→ Watch the interview

"Quantum mechanics is so much richer than we dreamed"

Read or listen to an interview with F. Duncan M. Haldane following the announcement of the 2016 Nobel Prize in Physics.

→ Interview with F. Duncan M. Haldane

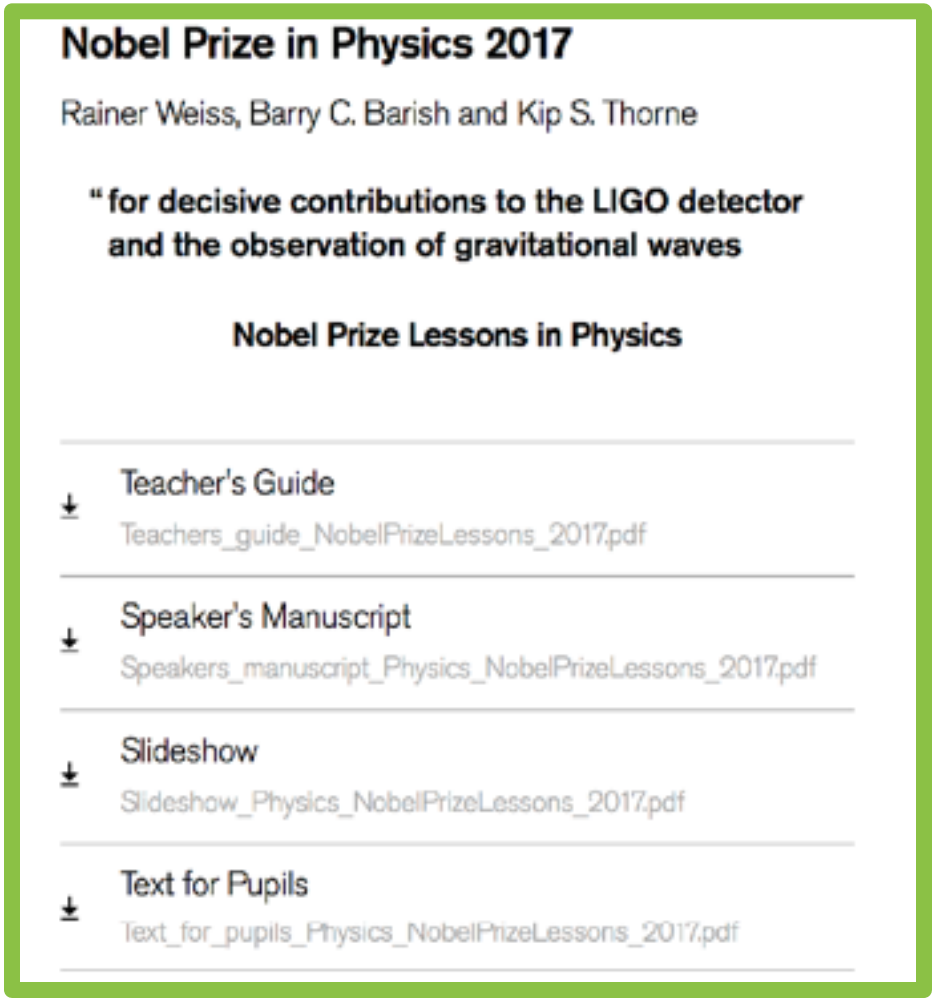
"A little bit odd getting this news in an underground carpark outside Helsinki"

J. Michael Kosterlitz in an interview following the announcement of the 2016 Nobel Prize in Physics.

→ Interview with J. Michael Kosterlitz

Nobel Prize Lessons

- http://nobelcenter.se/education/teachers-resources/



Division of Condensed Matter Physics

- Governance
- Newsletters
- Meetings
- APS Fellowship
- Prizes & Awards
- Careers
- **Outreach**
- Image Gallery
- Resources

DCMP Home | **Outreach**

https://www.aps.org/units/dcmp/outreach/

Outreach

On the History of Superconductivity

Physics for the 21st Century

Condensed Matter and Materials Research: New Developments and Opportunities

An Emergent Universe

The Future of Condensed Matter and Materials Physics

Music of the Quantum

Teacher Resources @ Molecular Expressions

Resources/Readings

- NobelPrize.org (28 Condensed Matter Physics Prizes)
- Quanta Magazine: https://www.quantamagazine.org/tag/condensed-matter-physics/
- National Magnetic Field Lab https://nationalmaglab.org/news-events
- Feynman, There's Plenty of Room at the Bottom & Tiny Machines
  - http://web.pa.msu.edu/people/yang/RFeynman_plentySpace.pdf
  - https://www.youtube.com/watch?v=4eRCygdW--c
- The Joy of Condensed Matter Physics, Inna Vishik, Assistant Professor of Physics at UC Davis, on Quora

Activities + Demos

- Oobleck (cornstarch + water = non-Newtonian fluid) https://ww2.kqed.org/quest/2009/09/08/try-these-at-home-2-sure-fire-science-demo-classics/
- Granular Experiments (jamming, sorting, Brazil Nut effect)
- Funsize Physics: https://funsizephysics.com/funsize-classroom/
- Crystal Physics Game: http://journals.sagepub.com/doi/abs/10.1177/1046878110378704
- High School Lessons (from U Wisconsin RET) http://education.mrsec.wisc.edu/modules/index.html

- More Polymer Activities (K-12): http://polymerambassadors.org/activities/
- NSF Chemistry Classroom Resources: https://nsf.gov/news/classroom/chemistry.jsp
- http://faraday.physics.uiowa.edu/outreach.html
- https://science.energy.gov/bes/community-resources/

Hands-on Activity: Exploring Acceleration with an Android

Contributed by: IMPART RET Program, College of Information Science & Technology, University of Nebraska Omaha

www.teachengineering.org

Setting up the Android acceleration "track."
copyright

Summary

Students conduct an experiment to study the acceleration of a mobile Android device. During the experiment, they run an application created with MIT's App Inventor that monitors linear acceleration in one-dimension. Students use an acceleration vs. time equation to construct an approximate velocity vs. time graph. Students will understand the relationship between the object's mass and acceleration and how that relates to the force applied to the object, which is Newton's second law of motion.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Students apply engineering concepts to mathematical and scientific problems. During the activity, students complete an experiment that requires a specific process and analysis of the results. Engineers perform this same type of experimentation and data collection in their fields every day. For example, engineers gather acceleration data during car safety crash tests, and acceleration data is a useful measure of racing vehicle performance during competition. Software engineers create applications and software, as well as work on programs to collect and analyze data. Engineers from other disciplines, such as civil, electrical and aerospace, continually measure, record and analyze data as part of the design process

Quick Look

Grade Level:	11 (9-12)
Time Required:	70 minutes
Expendable Cost/Grp:	US $0.00 This activity requires the use of some non-expendable (reusable) items such as computers and Android smartphones or tablets; see the Materials List for details.
Group Size:	3
Activity Dependency:	Android Acceleration
Subject Areas:	Computer Science Data Analysis and Probability Physics

Print this activity