Force and Linear Motion
Work and Energy

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Introduction:

Applied Physics			
Course Code:	PHY-102	Semester:	1st and 2nd
Credit Hours:	2+1	Prerequisite Codes:	
Instructor:	Dr. M. Imran Malik	Class:	BEE-12ABC
Lecture Days:	Tuesday, & Firday	E-mail:	imran.malik@seecs.edu.pk
Knowledge Group:	Applied Physics	Updates on LMS:	Before every lecture

Books:

Text Book:	1. Physics for Scientists and Engineers with Modern Physics 10th Edition ISBN-13: 978-1337553278, ISBN-10: 1337553271 Authors: Raymond A Serway; John W Jewett; Vahé Peroomian 2. Fundamentals of Physics By Halliday, Resnick & Walker (7th Edition)
Reference Books:	1.University Physics with Modern Physics 15th Edition ISBN-13: 978-0135159552, ISBN-10: 0135159555 Authors: Hugh D Young, Carnegie Mellon University http://gen.lib.rus.ec Library Genesis

Major Topics to be Covered:

1. Newton's laws, Work and Energy
2. Friction, Rotation, Moment of Inertia
3. Oscillations and Waves
4. Charge, Coulomb's law and Electric field
5. Gauss' law
6. Electric potential
7. Electric current and Magnetic field
8. Ampere's law
9. Faraday's law

Course description and Objectives

Course Description:

The course comprises the topics of Physics, which are directly related to Engineering and Technology. These include Motion, Friction, Moment of inertia, Oscillations, waves and propagation, Electric Charge & Coulomb's Law, Electric Field, Electric Potential, Capacitors & Dielectric, Current & Resistance, Magnetic fields, Ampere's Law and Faraday's law.

Course Objectives:

The course aims to give students both a theoretical and a practical foundation for engineering courses, like; Engineering Mechanics, Electromagnetic Field Theory, Systems and Signals, Control Systems, Transmission Lines and Antennas & Microwave Devices. The course gives the students a sound knowledge of Physics with its applications to problems of practical nature. After studying this course the students will be able to apply Physics as a strong tool to understand and develop the problems which they come across in Engineering/Technology.

Physics Laboratory (SNS)

Lab Experiments:	
Lab 01:	Introduction to Lab
Lab 02:	Understanding Errors
Lab 03:	Mini-launcher (Exp. 1,2,3)
Lab04:	Mini-launcher (Exp. 4,6)
Lab 05:	PAScar with Mass (Exp. 1,2,3)
Lab 06:	PAScar with Mass (Exp. 4,6)
Lab 07:	Compound Pendulum
Lab 08:	Heat Engine/Gas Laws (Exp.1,2,3)
Lab 09:	Ripple Tank
Lab 10:	Faraday's Law
Lab 11:	DC Electronics
Lab 12:	DC Electronics

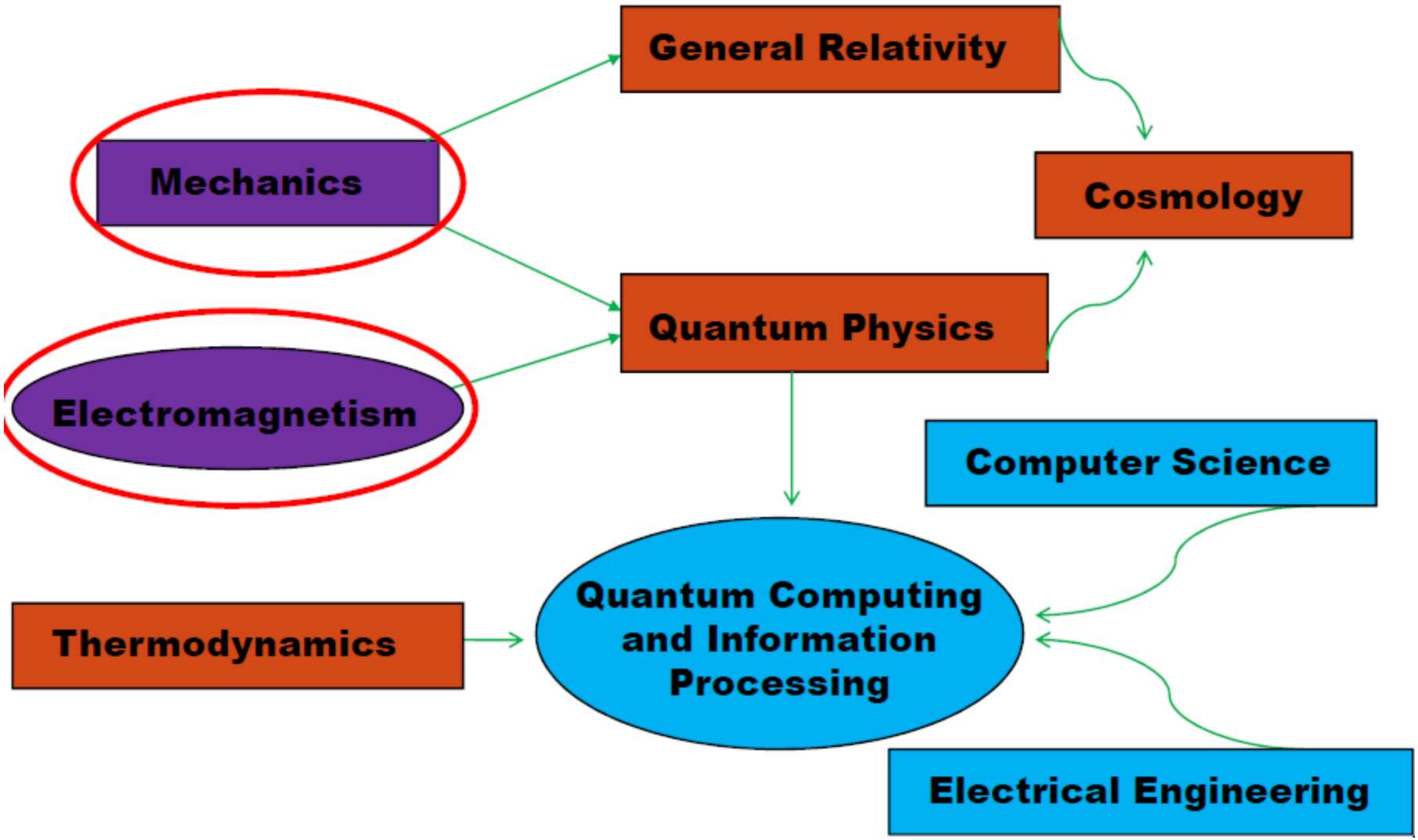
Grading

Assignments: (Home and Class Group Assignments)
Midterm
Labs
End Semester Exam
Total : 100 %

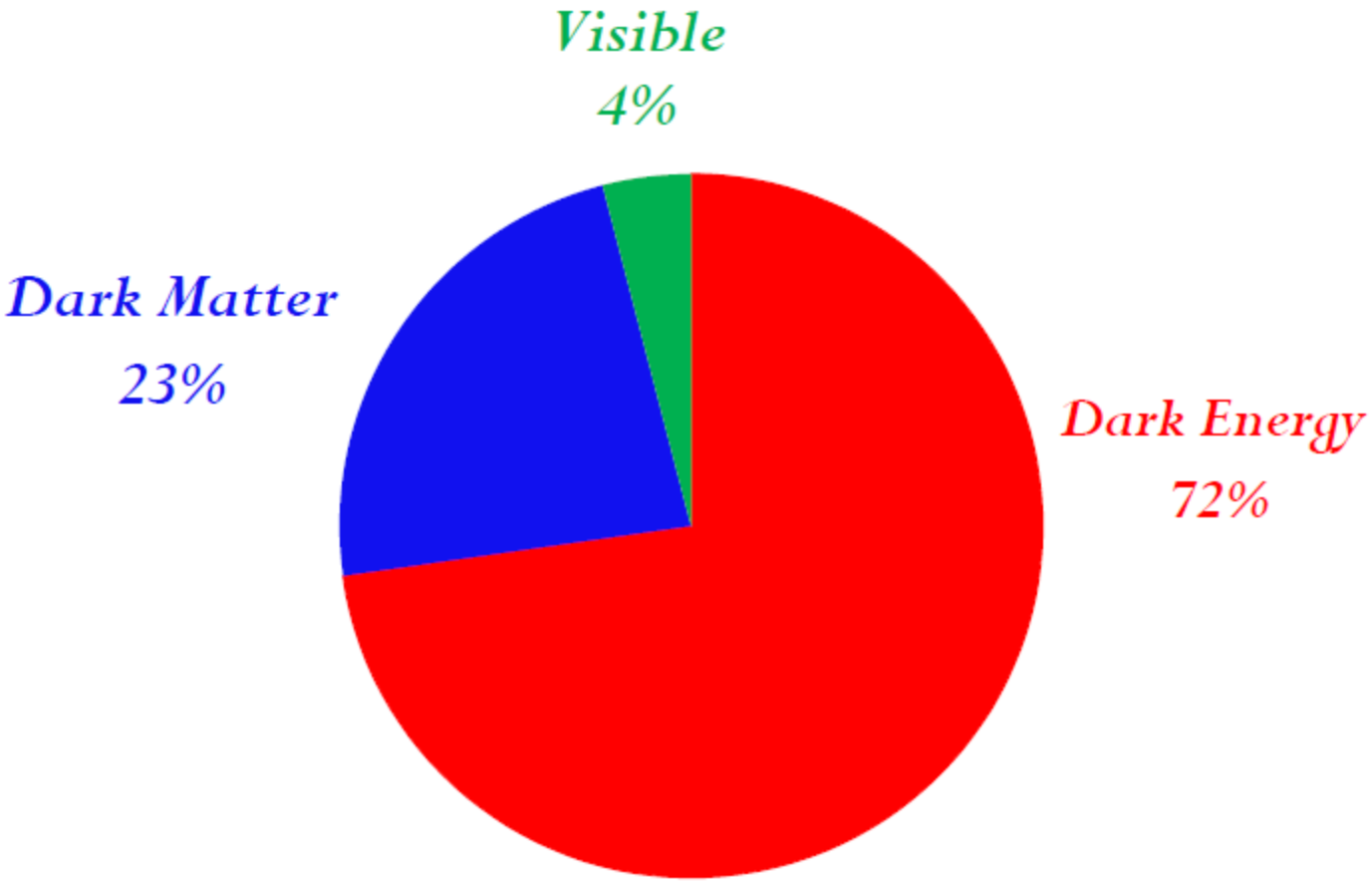
Grading Policy

Grading Policy:	
Quiz Policy:	The quizzes will be unannounced and normally last for ten to fifteen minutes. The question framed is to test the concepts involved in last few lectures. Number of quizzes that will be used for evaluation is at the instructor's discretion.
Assignment Policy:	In order to develop comprehensive understanding of the subject, assignments will be given. Late assignments will not be accepted/graded. The students are advised to do the assignment themselves.
Lab Conduct:	The labs will be conducted for three hours every week. A lab handout will be given in advance for study and analysis The lab handouts will also be placed on LMS. The students are to submit their results by giving a lab report at the end of lab for evaluation. One lab report per group will be required. However, students will also be evaluated by oral viva during the lab.
Plagiarism:	SEECS maintains a zero tolerance policy towards plagiarism. While collaboration in this course is highly encouraged, you must ensure that you do not claim other people's work/ ideas as your own. Plagiarism occurs when the words, ideas, assertions, theories, figures, images, programming codes of others are presented as your own work. You must cite and acknowledge all sources of information in your assignments. Failing to comply with the SEECS plagiarism policy will lead to strict penalties including zero marks in assignments and referral to the academic coordination office for disciplinary action.

Realms of Physics



Physics: Matter and Energy

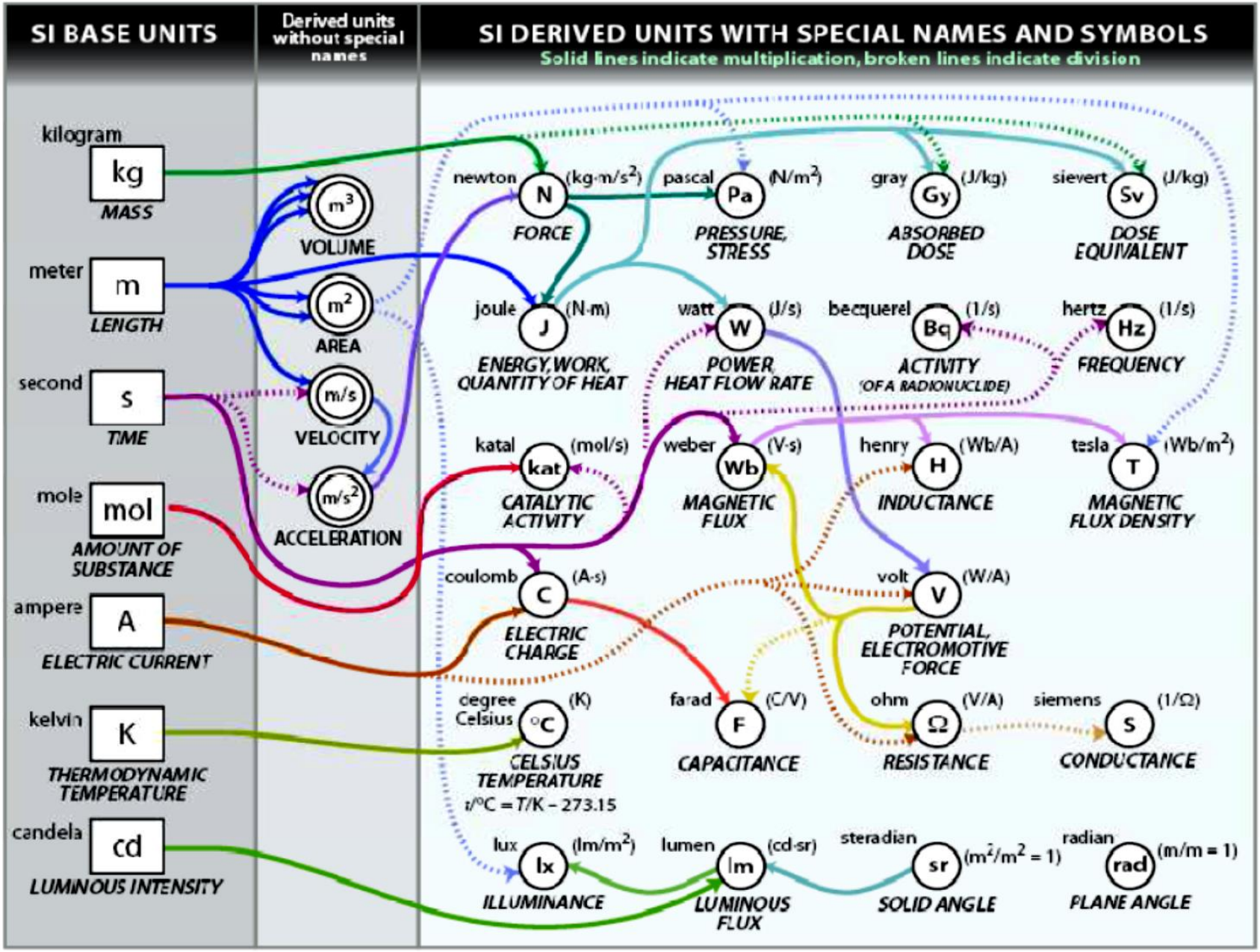


Physics in 1900

- The close of the 19th century was a period of transition in physics, moving from "old physics" to "new physics".
- Old Physics
  - *Classical mechanics (Newton)*
  - *The theory of electromagnetism (Maxwell)*
- New Physics
  - *The theory of relativity (Einstein)*
  - *Quantum physics (Planck, Einstein)*

Physics and Measurement

Quantity	Unit	Abbr.
• Length	meter	m
• Mass	kilogram	kg
• Time	second	s
• Electric current	ampere	A
• Thermodynamic temp.	Kelvin	K
• Amount of a substance	mole	mol
• Luminous Intensity	Candela	cd


SI BASE UNITS
Derived units without special names
SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS
Solid lines indicate multiplication, broken lines indicate division
kilogram
kg
MASS
meter
m
LENGTH
second
s
TIME
mole
mol
AMOUNT OF SUBSTANCE
ampere
A
ELECTRIC CURRENT
kelvin
K
THERMODYNAMIC TEMPERATURE
candela
cd
LUMINOUS INTENSITY
m3
VOLUME
m2
AREA
m/s
VELOCITY
m/s2
ACCELERATION
newton N (kg·m/s2)
FORCE
pascal Pa (N/m2)
PRESSURE, STRESS
gray Gy (J/kg)
ABSORBED DOSE
sievert Sv (J/kg)
DOSE EQUIVALENT
joule J (N·m)
ENERGY, WORK, QUANTITY OF HEAT
watt W (J/s)
POWER, HEAT FLOW RATE
becquerel Bq (1/s)
ACTIVITY (OF A RADIONUCLIDE)
hertz Hz (1/s)
FREQUENCY
katal kat (mol/s)
CATALYTIC ACTIVITY
weber Wb (V·s)
MAGNETIC FLUX
henry H (Wb/A)
INDUCTANCE
tesla T (Wb/m2)
MAGNETIC FLUX DENSITY
coulomb C (A·s)
ELECTRIC CHARGE
volt V (W/A)
POTENTIAL, ELECTROMOTIVE FORCE
degree Celsius °C (K)
CELSIUS TEMPERATURE
t/°C = T/K − 273.15
farad F (C/V)
CAPACITANCE
ohm Ω (V/A)
RESISTANCE
siemens S (1/Ω)
CONDUCTANCE
lux lx (lm/m2)
ILLUMINANCE
lumen lm (cd·sr)
LUMINOUS FLUX
steradian sr (m2/m2 = 1)
SOLID ANGLE
radian rad (m/m = 1)
PLANE ANGLE

Force and Linear Motion
Work and Energy

A force is… a push or a pull.

Friction, Drag and Gravity etc. are forces…

Newton's 1st law of motion

Every body continues in its state of rest or of uniform speed in a straight line as long as no net force acts on it.

Newton's 2nd law of motion

The acceleration of an object is directly proportional to the net force acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the net force acting on the object.

$$a = \frac{F}{m}$$

$$F = ma$$

Newton's 3rd law of motion

- Newton's second law of motion describes quantitatively how forces affect motion.
- Observations suggest that a force applied to any object is always applied by *another object*.

Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

Forces or Energy

- Physical problems can be solved either by:

FORCES

$$\frac{d^2x}{dt^2} = a = F/m$$

OR

ENERGY

$$\Delta K + \Delta U + \Delta E_{\text{int}} = W_{ext}$$

Formulism of Forces

Dynamics

$$\frac{d^2x}{dt^2} = F/m \Rightarrow x(t)$$

$$v = \frac{dx}{dt} \qquad p = mv = m\frac{dx}{dt} \qquad P.E = mgx(t)$$

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{dx}{dt}\right)^2 \qquad \vec{\tau} = \vec{x}(t) \times \vec{F}$$

Statics

$$\sum \vec{F} = 0 \qquad \sum \vec{\tau} = 0$$

Physical Quantities: Constant or Variable

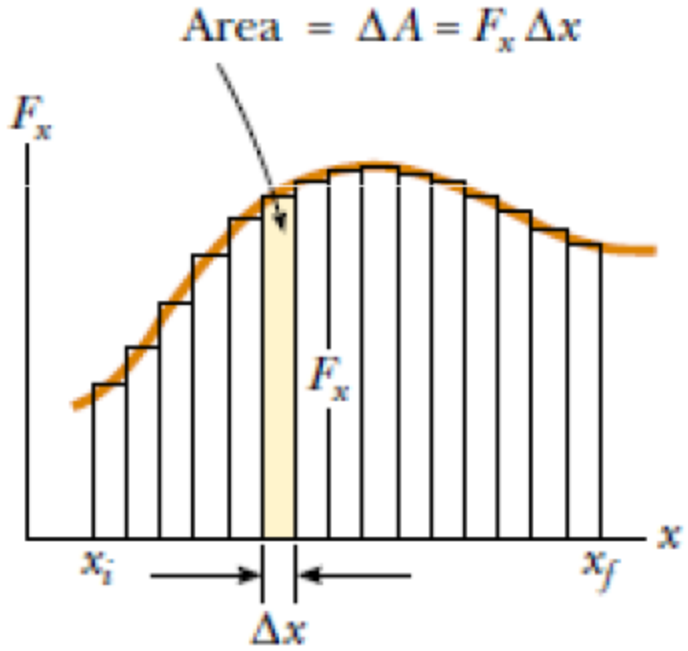
Work done by constant force

$$W = \vec{F} \bullet \vec{s}$$

Work done by variable force

$$W_{if} = \int_i^f \vec{F} \bullet d\vec{s}$$

$$W = \int_{x_i}^{x_f} F_x dx$$



This technique is most general and valid for all other physical quantities.

Conservative Forces, Work done and potential energy

- The work done by a conservative force on a particle moving between any two points is independent of the path taken by the particle.
- The work done by a conservative force on a particle moving through any closed path is zero.
- Potential energy can be defined only for conservative forces.
- Work done in moving an object from some initial position i to certain final position f stores as potential energy in the system.
- Potential energy is related to work done as

$$\Delta U = U_f - U_i = -W$$

Electromagnetic and gravitational forces are conservative.

Potential Energy

- Associated with conservative forces.
- Reference is necessary.
- Gravitational potential energy can be:

$$U = mgh$$ **Reference: Surface of earth**

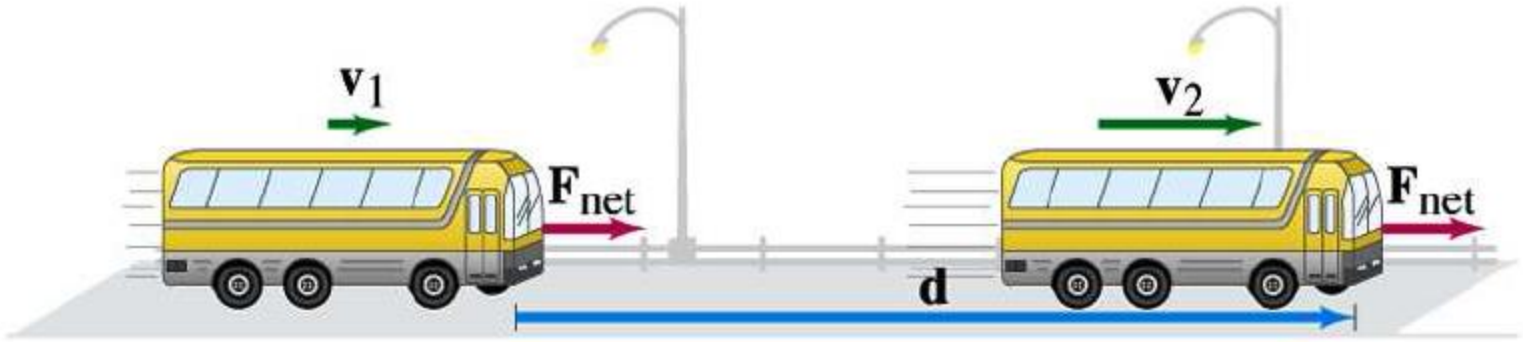
$$U = mg(R+h)$$ **Reference: Center of earth**

$$U = \frac{GMm}{r}$$ **Reference: infinity**

***Where can be reference if P.E is defined as:** ?

$$U = -\vec{P} \bullet \vec{E}$$

Work-Energy Theorem



$$W = F.d = (ma)d$$

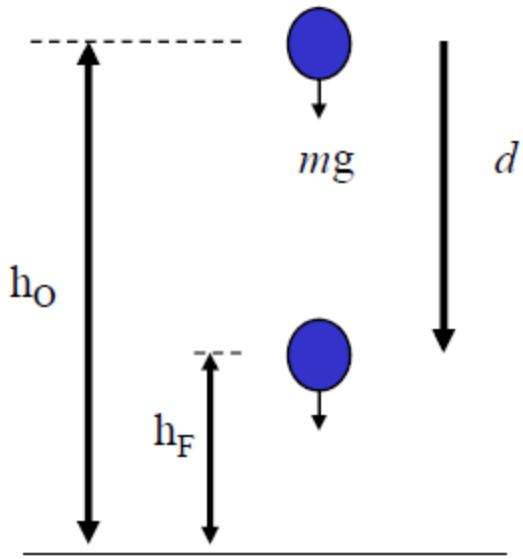
$$= m\frac{(v_2^2 - v_1^2)}{2d}d = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

$$= K_2 - K_1 = \Delta K$$

Here $\Delta U = 0$, So $W = \Delta K = \Delta E$

Work-Energy Theorem

$$
\begin{aligned}
W &= F.d \\
&= mg(h_0 - h_F) \\
&= mgh_0 - mgh_F \\
&= U_0 - U_F \\
&= -\Delta U
\end{aligned}
$$



Falling object

Both W=- ΔU and W=ΔK can be used.

W= ΔK=- ΔU

Work-Energy Theorem

In general, when both kinetic and potential energies are being changed during motion, for example, when mass m is moving in circular orbits and changes its orbit also with time:

$$\Delta E = W_{ext}$$

$$\Delta K + \Delta U + \Delta E_{\text{int}} = W_{ext}$$

When a net external force does work W on an object, the energy of the object changes from its initial value E_O to a final value E_F, the difference in the two being equal to the work.

What is Energy and energy transfer?

- “The ability to do work”
- Causes changes
- Two forms

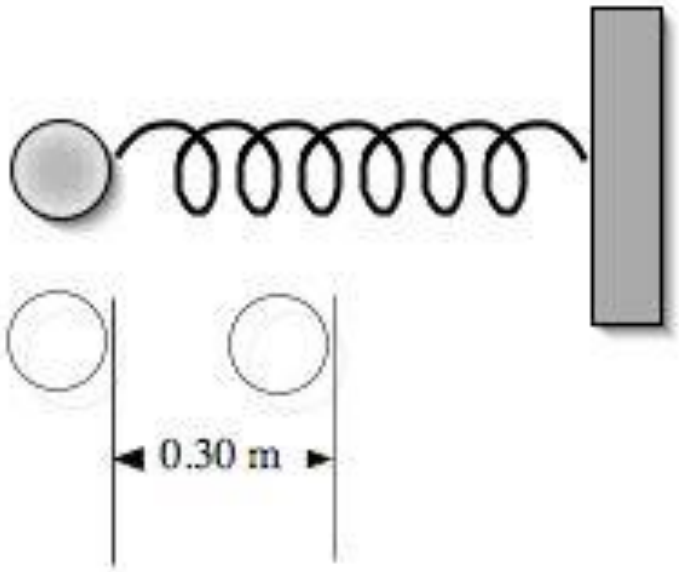
Potential

Kinetic

Stored Mechanical Energy

Energy stored in an object by the application of force

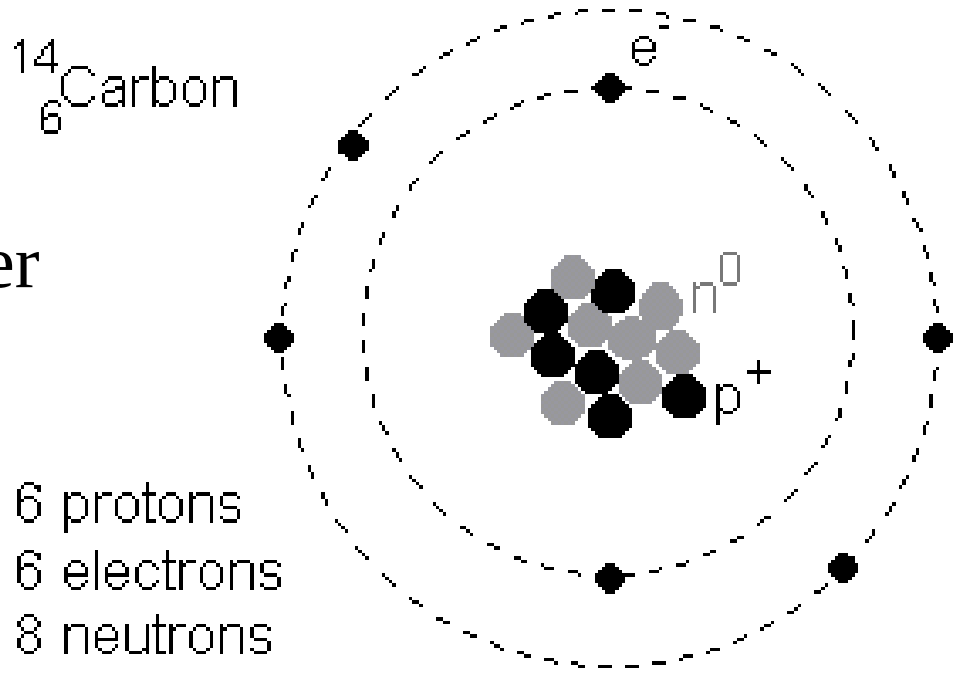
Must push or pull on an object



Nuclear Energy

Energy stored in the nucleus of the atom

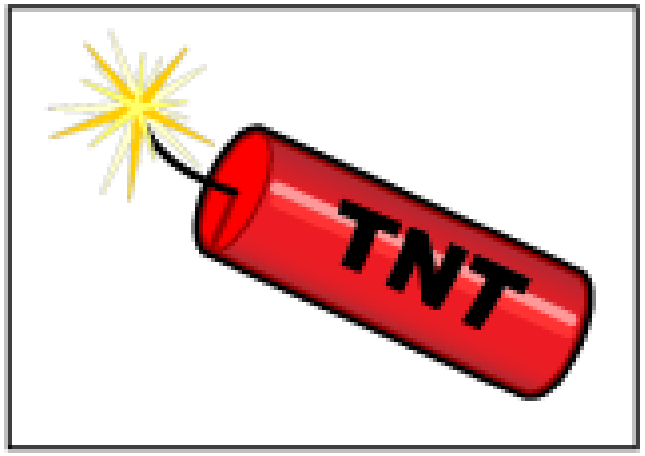
Holds the nucleus together



Chemical Energy

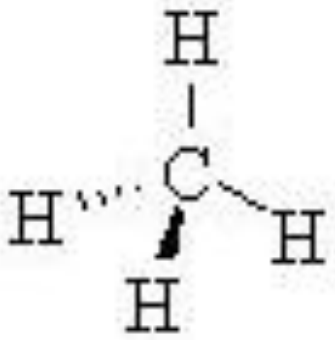
Energy stored in the bonds between atoms

Holds molecules together



CH_4

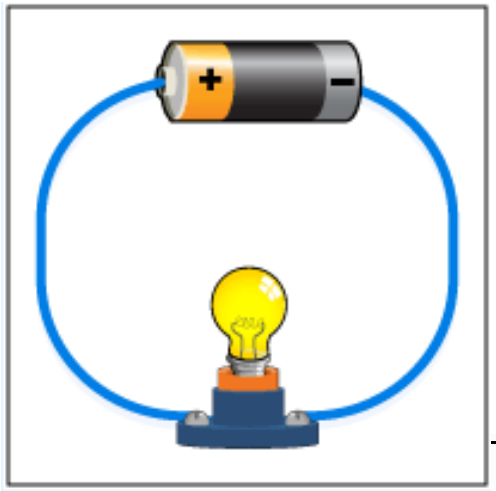
Molecular Formula



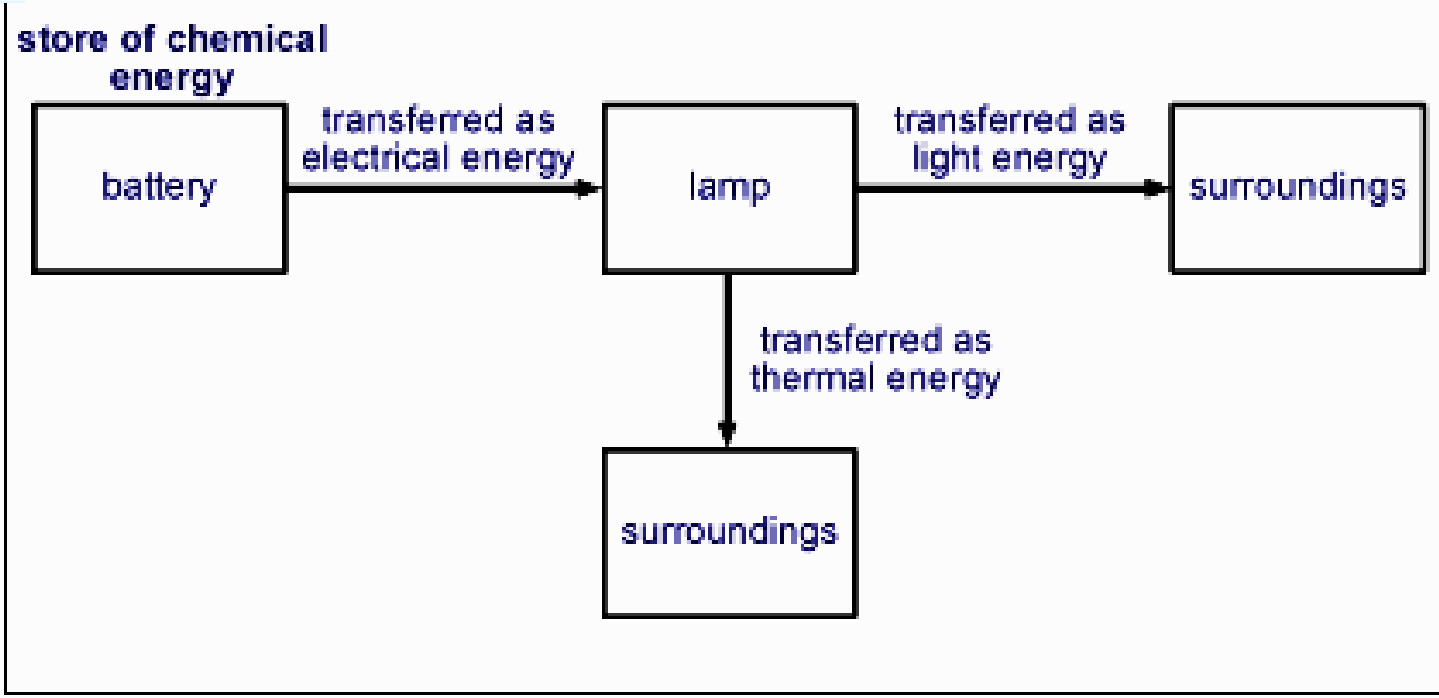
Perspective Drawing

Chemical energy stored in it is transferred to the surroundings as **thermal energy**, **sound energy** and **kinetic energy**.

Potential Energy



The battery transfers stored **chemical energy** as **electrical energy**. The electrical energy is transferred to the surroundings by the lamp as **light energy** and **thermal energy** (heat energy).



Potential Energy

Gravitational Energy

The energy an object or substance has because of its position; anything "up high"

Kinetic Energy

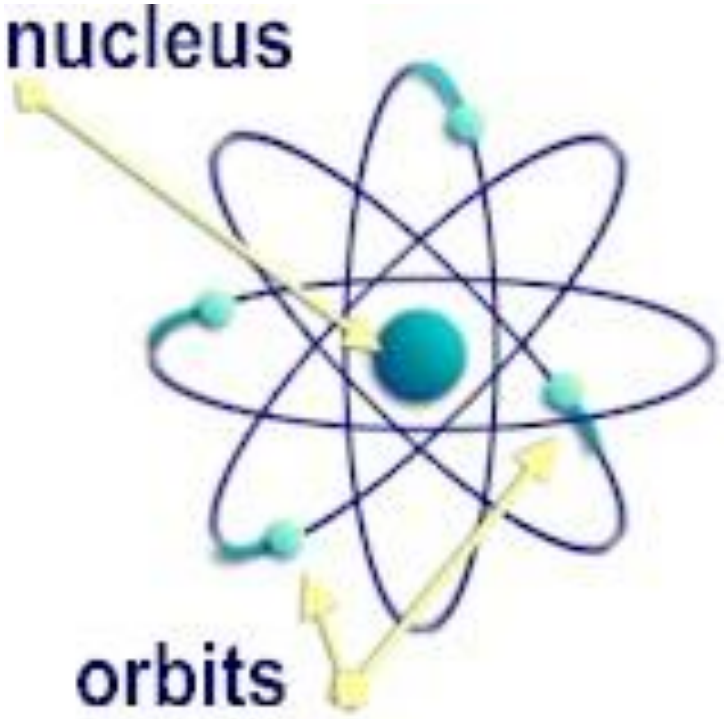
Mechanical Energy (Motion)

Movement of objects or substances from one place to another

Electrical Energy

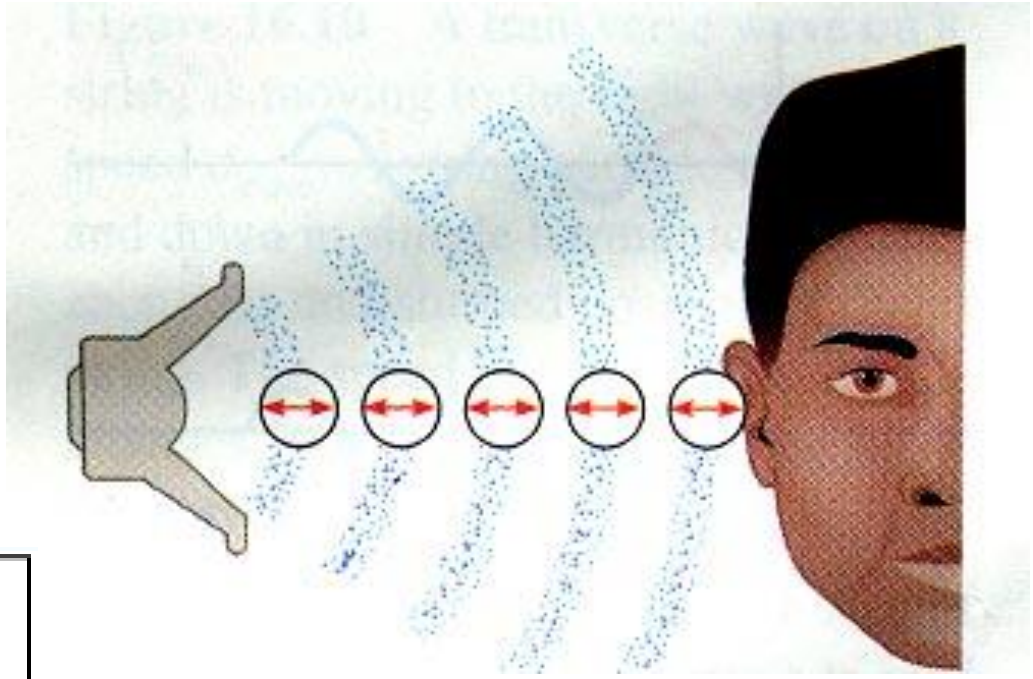
Movement of electrons in one direction

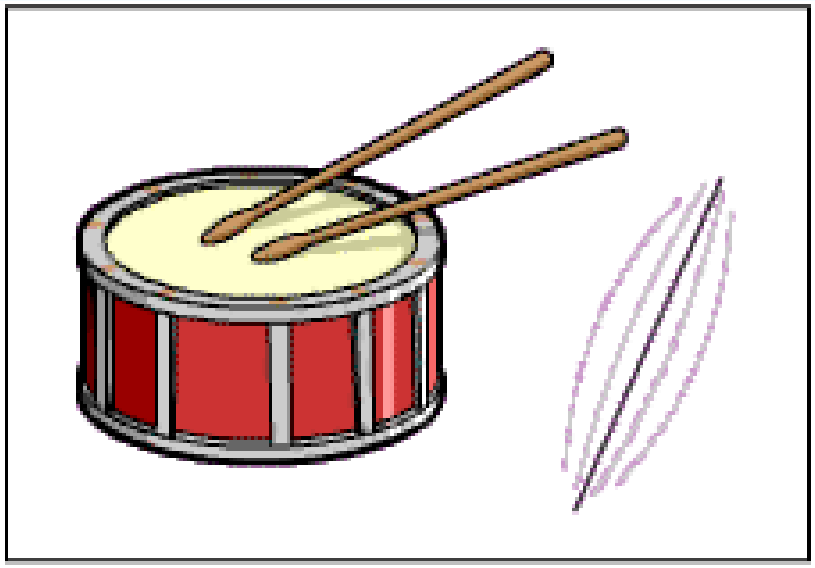
NOT AN ELECTRON PARADE!



Sound Energy

Movement of energy through substances in the form of longitudinal (compression) waves

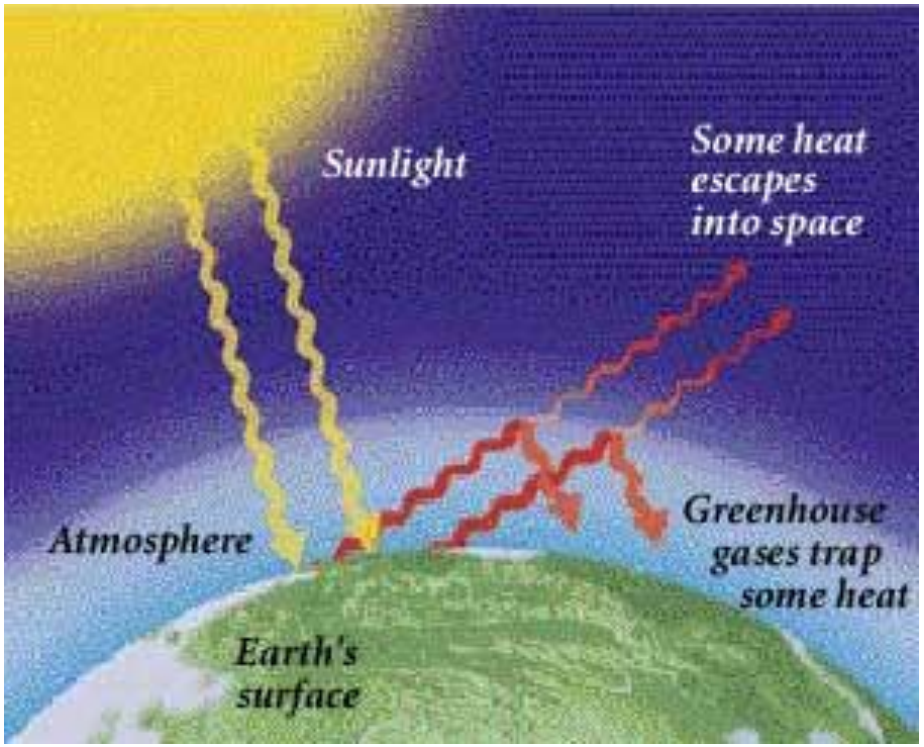




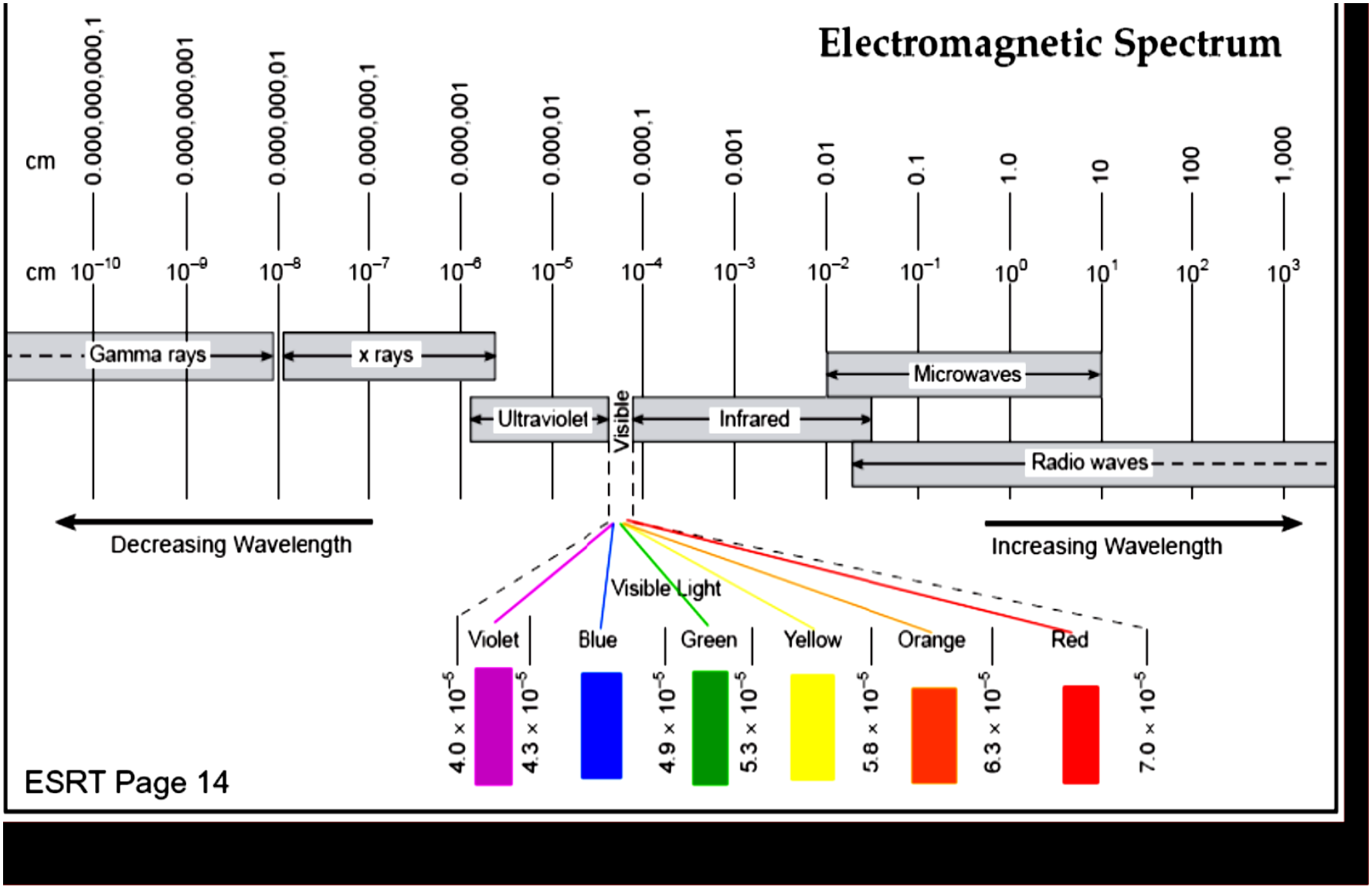
Sound energy can be transferred to your eardrum as **kinetic energy** (movement energy).

Radiant Energy

Electromagnetic energy that travels in transverse waves



Electromagnetic energy is a type of energy that is radiated by the sun in the form of transverse waves vibrating at right angles to the direction of movement


Electromagnetic Spectrum
cm
0.000,000,000,1
0.000,000,001
0.000,000,01
0.000,000,1
0.000,001
0.000,01
0.000,1
0.001
0.01
0.1
1.0
10
100
1,000
cm 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}
Gamma rays
x rays
Ultraviolet
Visible
Infrared
Microwaves
Radio waves
Decreasing Wavelength
Increasing Wavelength
Visible Light
Violet
Blue
Green
Yellow
Orange
Red
4.0×10^{-5}
4.3×10^{-5}
4.9×10^{-5}
5.3×10^{-5}
5.8×10^{-5}
6.3×10^{-5}
7.0×10^{-5}
ESRT Page 14

Newton and Gravitation

- Newton concluded that the gravitational force is:
  - Directly proportional to the masses of both objects.
  - Inversely proportional to the distance between the objects.

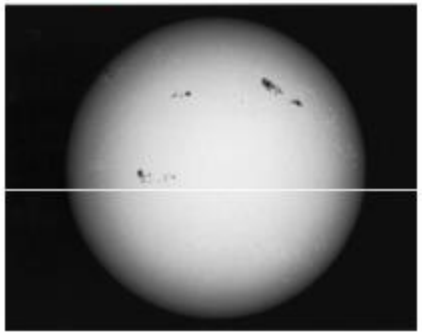
$$F = G\frac{m_1 m_2}{r^2}$$

Where G is a constant of proportionality.

$G = 6.67 \times 10^{-11}\ N\ m^2/kg^2$

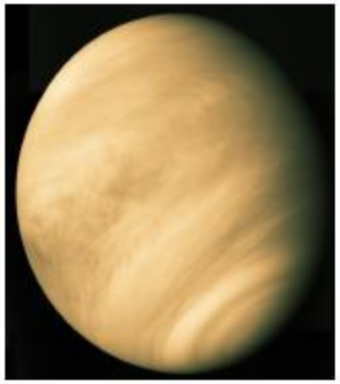
GRAVITY keeps the moon orbiting Earth . . . . . .

It holds stars together . . .



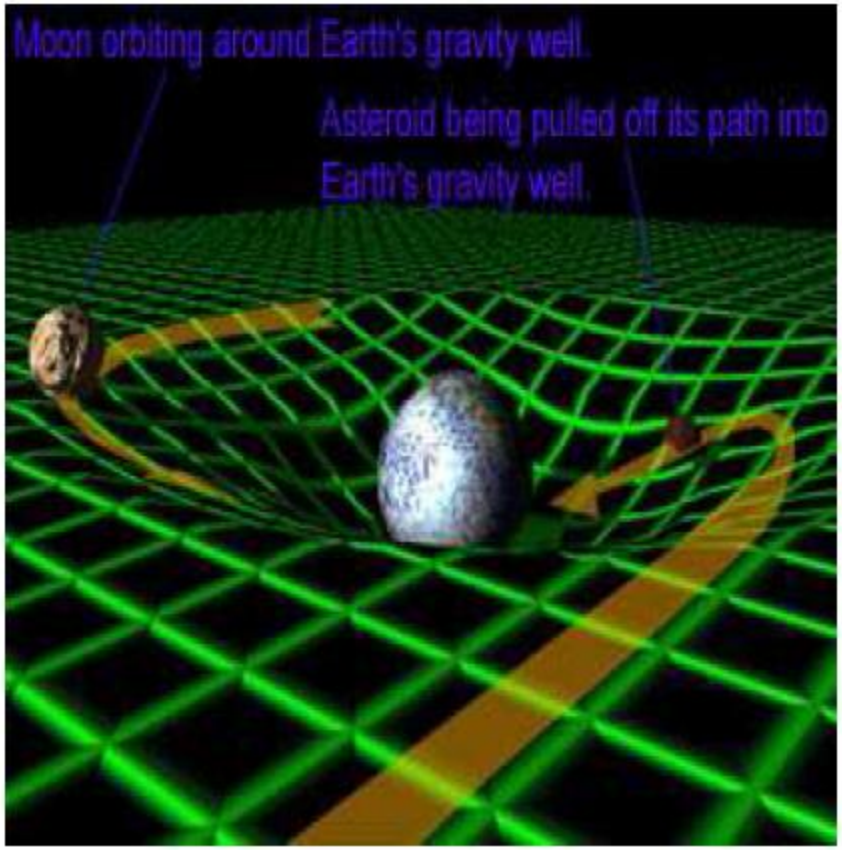
And binds galaxies together for billions of years . . .

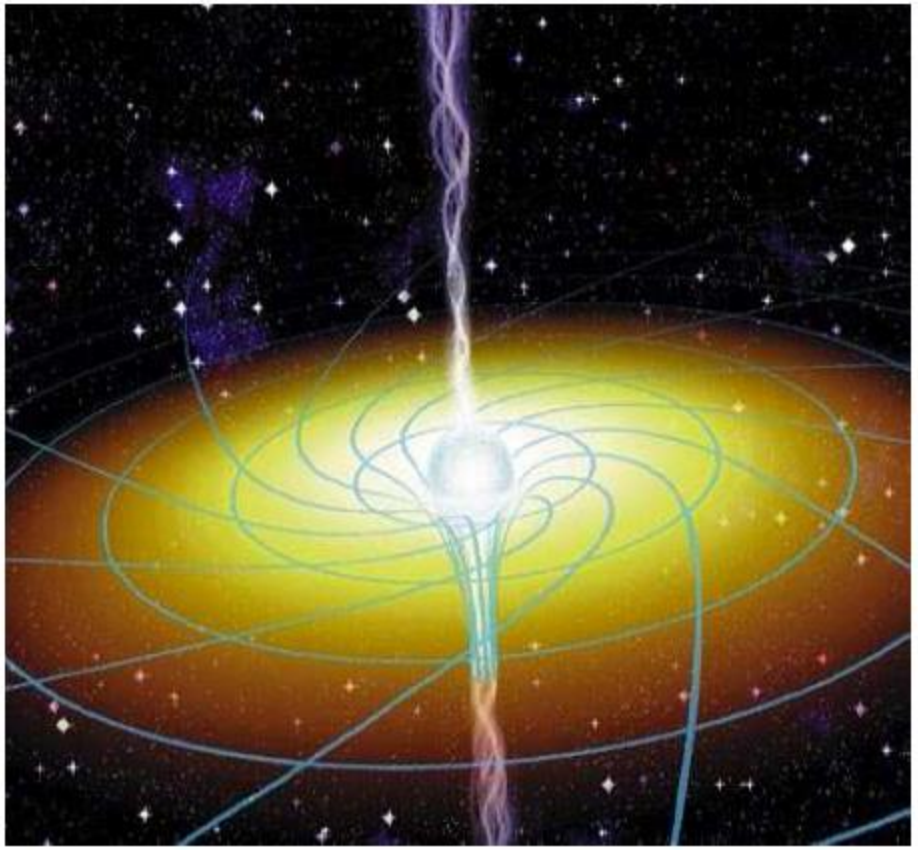
Prevents planets from losing their atmospheres . . .



Einstein and Gravitation

- Space & time are bent, or curved, by matter.

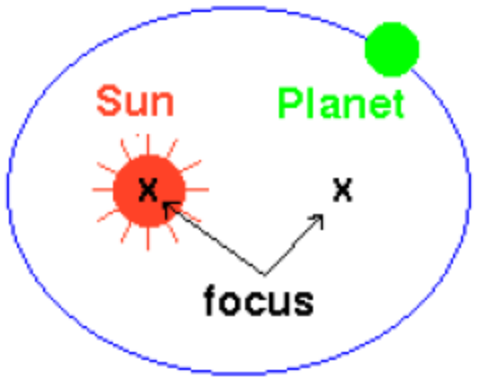




Kepler's Law

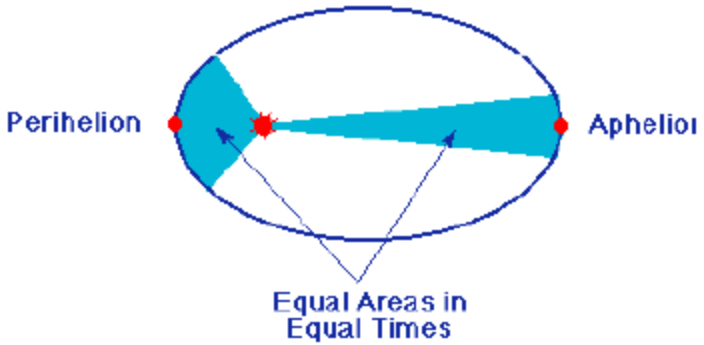
Kepler's 1st Law:

The orbital paths of the planets are elliptical with the Sun at one focus.



Kepler's 2nd Law:

An imaginary line connecting the Sun to any planet sweeps out equal areas of the ellipse over equal intervals of time.



Kepler's 3rd Law:

The Squared of the period of planet's is proportional to the cube of its semi major axis

$$T^2 \propto a^3$$

Maxwell's Equation

Gauss's Law	Electric field due to charges	$\int \vec{E} \bullet d\vec{a} = \frac{q_{enc}}{\varepsilon_\circ}$
Gauss's Law (Magnetism)	Nonexistence of magnetic monopole	$\int \vec{B} \bullet d\vec{a} = 0$
Faraday's Law	Electric Field due to Changing magnetic flux	$\oint \vec{E} \bullet d\vec{l} = -\frac{d\Phi_B}{dt}$
Ampere-Maxwell's Law	Magnetic field due to currents and Changing electric flux	$\oint \vec{B} \bullet d\vec{l} = \mu_\circ i + \mu_\circ \varepsilon_\circ \frac{d\Phi_E}{dt}$

WHY THIS SCIENCE MATTERS

History reveals, time and again, that achieving a better fundamental understanding of how the universe works can lead to the creation of transformative technologies, with innumerable benefits to society. *The reason is simple: since any technology relies on the laws of nature, the better we understand those laws, the more powerful and beneficial the technologies we can create.*

For example, electricity and magnetism were once thought to be unrelated forces. Building largely on the experimental work of Faraday, the theorist Maxwell discovered *electromagnetism* – a single, deeper theory that unifies these two forces. Faraday and Maxwell's work eventually led to the development of electric motors, generators, and a safe electric power distribution system ("the grid"), giving ready access to the cleanest and most versatile form of energy the world has ever seen, and having an enormous impact on industry and residential life. As a further example, when Marconi applied Maxwell's electromagnetism to send the first wireless message between continents, the Communications Age was born, changing our lives with radio, television, and now cell phones and wireless internet.

By pondering the nature of space and time, Einstein unexpectedly discovered that matter is a concentrated form of energy, which soon led to an understanding of how stars like our Sun work, by a process called *fusion*. These ideas are currently being applied or contemplated in some of the largest-scale science and engineering projects in human history to harness the power of fusion. Over the 21st century, these projects may play a role in helping to solve the world's energy problems, and as a by-product, reducing human impact on the environment and global warming. As a further example, Einstein's deeper understanding of the nature of gravity provided the know-how required to build the Global Positioning System (GPS), a profoundly useful technology across a wide spectrum of human endeavours.

To unravel the mysteries of the atom, theoretical physicists developed quantum theory, which has had innumerable spinoff technologies ranging from the transistor (the basis of most of our current computing technology, and at the heart of virtually every electronic device on the planet), the laser (used everywhere from home DVD players to extensive fibre optic communication networks spanning the globe), Magnetic Resonance Imaging (MRI) and numerous other life-saving medical technologies, and many more.

This is how fundamental understanding drives innovation. Theoretical physics is always at the root of it. There is perhaps no other field of science that can have as deep and as broad of an impact on society and how we understand the universe and our place in it.