Introduction to Energy and Building Science Fundamentals

Course No. ENRG 52

Outline

A. Introduction to fundamentals of lighting

- Lighting terminology
- Physics and principles of lighting
- Units of measurement
- Vision and colors
- Ambient, directional and task lighting
- Over- and under-illuminance

B. Lighting systems

- Components
- Types of lamps
- Ballasts
- Lamp comparison matrix
- Types of lighting luminaires and intensities
- Energy efficiency measures (EEMs)

C. Lighting controls

- Basic concepts of effectiveness of lighting control
- Types and appropriate applications of lighting controls
- Lighting control equations
- Energy efficiency measures (EEMs)

D. Additional EEMs

- De-lamping
- Scotopic lighting
- Task and ambient light levels
- Circadian rhythms

E. Lighting measurements

- Tools
- Data loggers and applications

F. Lighting calculations

- Equation and method of calculating lumens (zonal cavity formula)
- Equation and method of calculating energy savings
- Method of calculating skylight energy savings

G. Lighting standards, codes and regulations

- Underwriters' Laboratory (UL)
- Uniform Building Code (UBC)
- Americans with Disabilities Act (ADA)
- Title 24 applications

H. O&M measures to assure optimal performance

F. Psychrometrics theory and applications

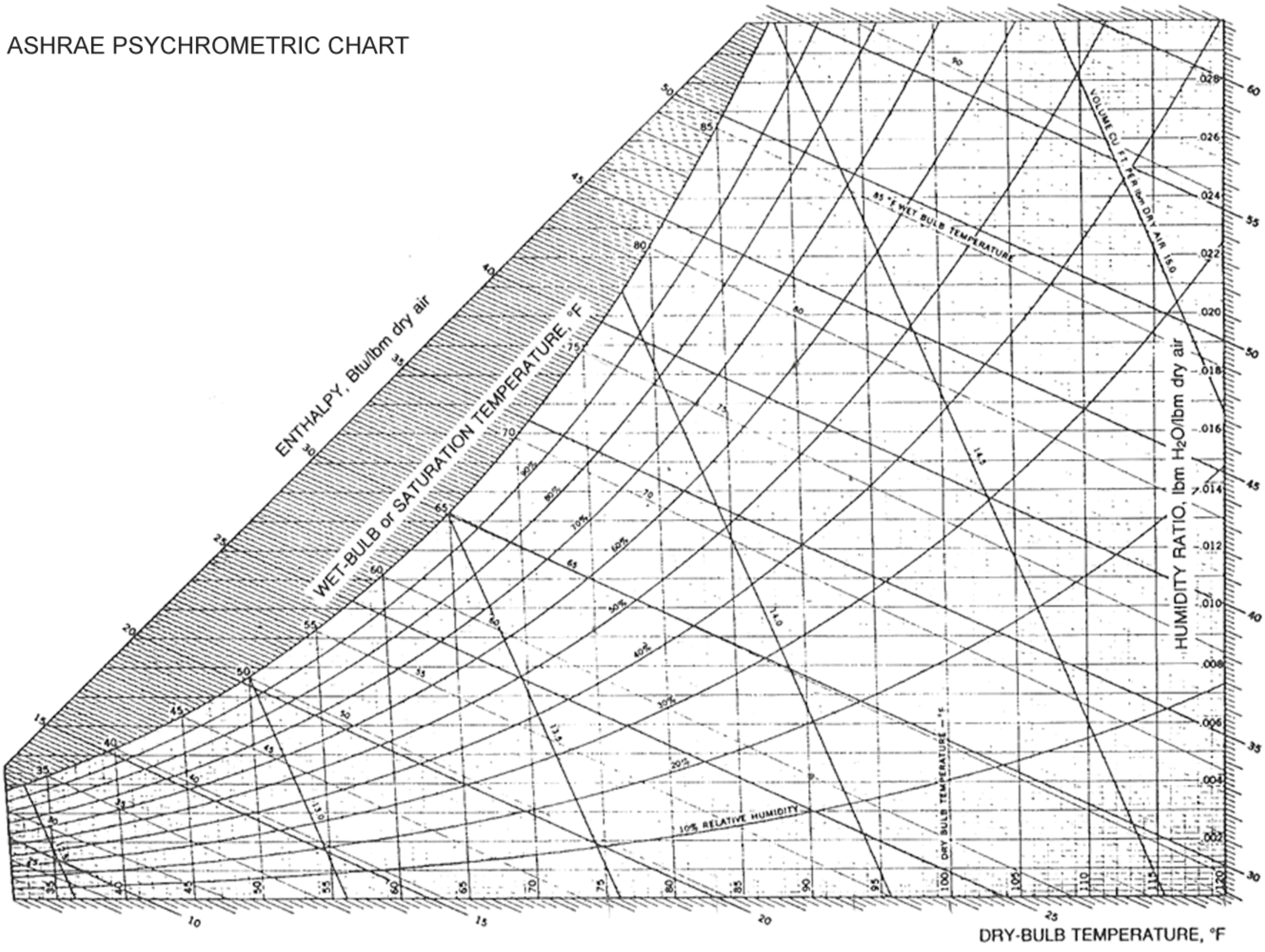
1. Understanding and reading the psychrometric chart
2. Psychrometric processes

Psychrometrics

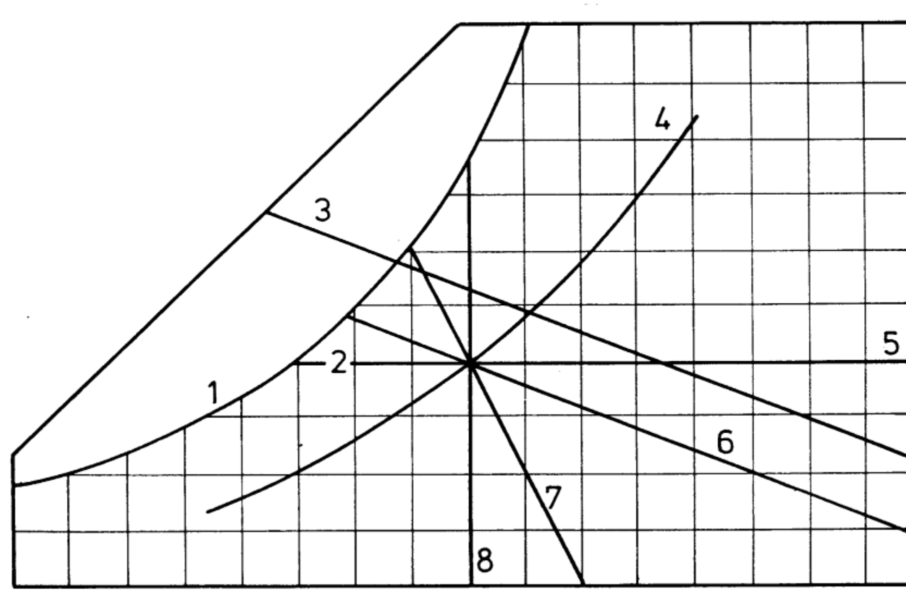
- Psychrometrics is the study of moist air
- The psychrometric chart is an industry-standard tool used to visualize the interrelationships between dry air, moisture, and energy
- The chart is built upon two simple concepts:
  - Indoor air is a mixture of dry air and water vapor
  - There is a specific amount of energy in the mixture at a specific temperature and pressure

The Chart

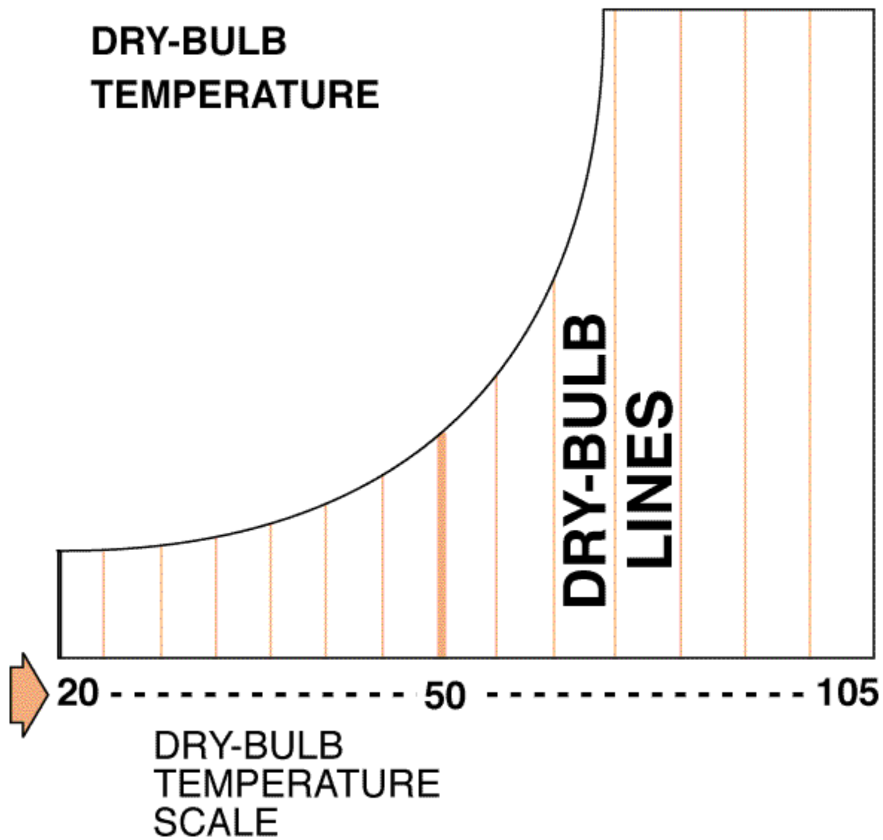
- Rather than go through calculations every time we need some information about the properties of air, psychrometric charts have been devised to graphically represent the values of those properties


ASHRAE PSYCHROMETRIC CHART
ENTHALPY, Btu/lbm dry air
WET-BULB or SATURATION TEMPERATURE, °F
HUMIDITY RATIO, lbm H2O/lbm dry air
DRY-BULB TEMPERATURE, °F
VOLUME CU. FT. PER lbm DRY AIR
85 °F WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE — °F

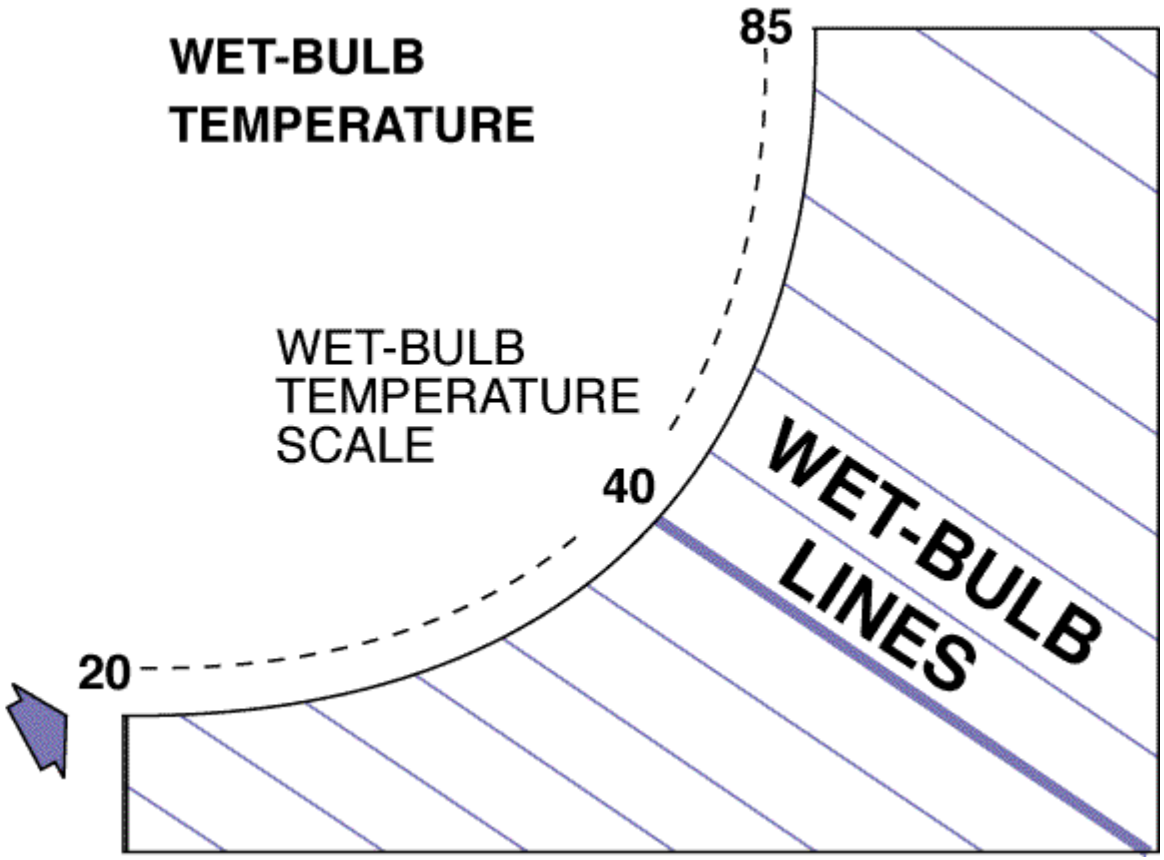
- This outline of chart shows the arrangement of the various lines and/or coordinates:
  1. saturation temperature
  2. dewpoint temperature
  3. enthalpy
  4. relative humidity
  5. humidity ratio (moisture content)
  6. wet bulb temperature
  7. volume of mixture
  8. dry bulb temperature.



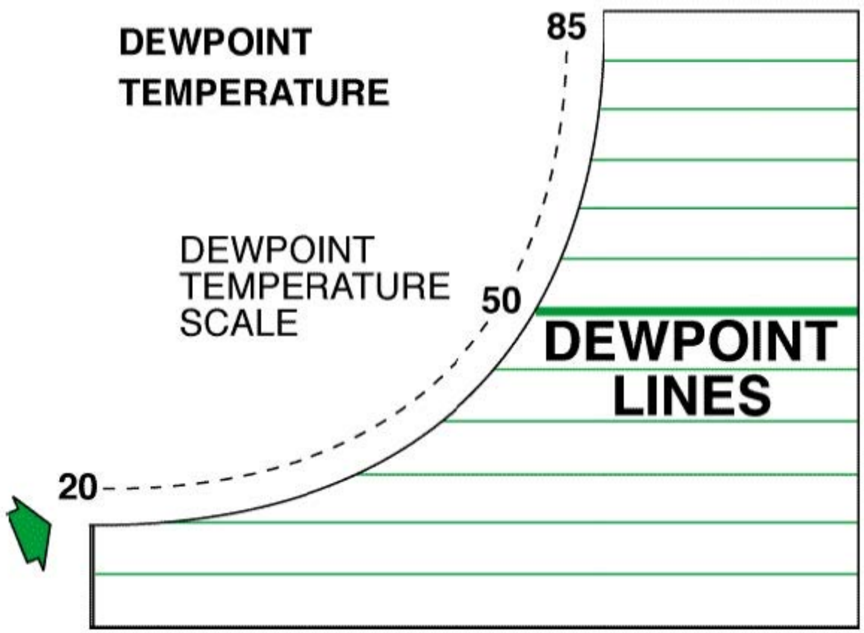
Dry Bulb Temperature



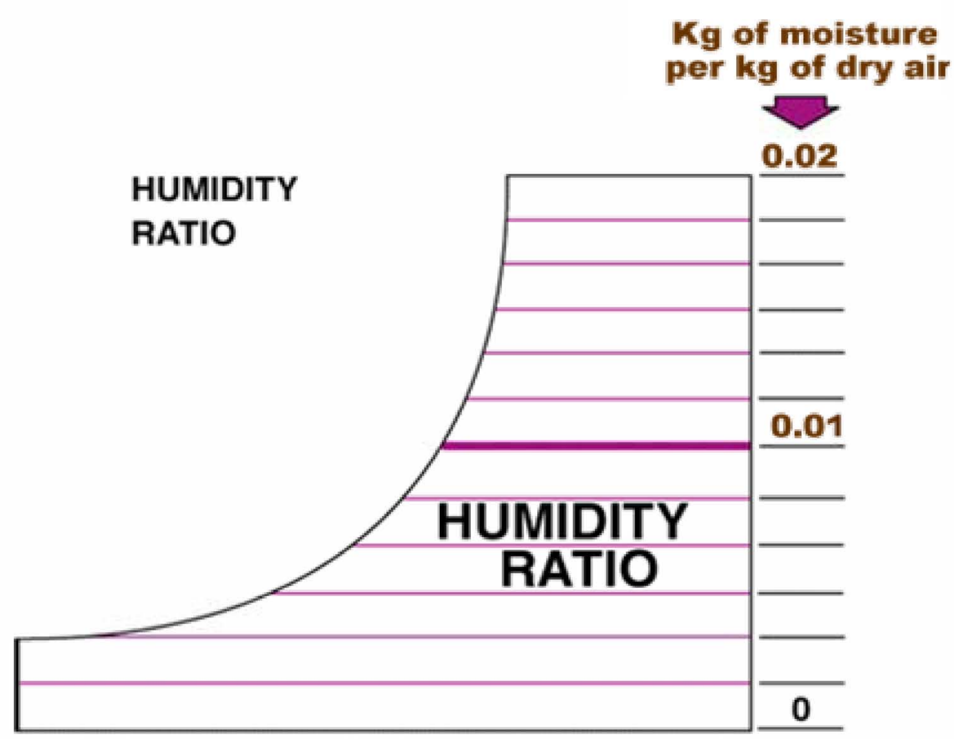
Wet Bulb Temperature



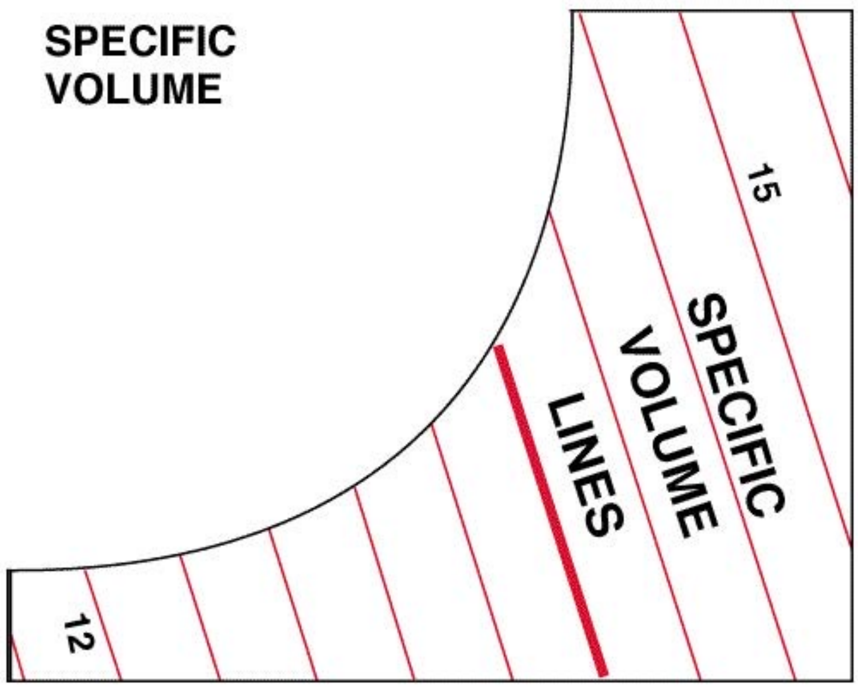
Dew Point Temperature



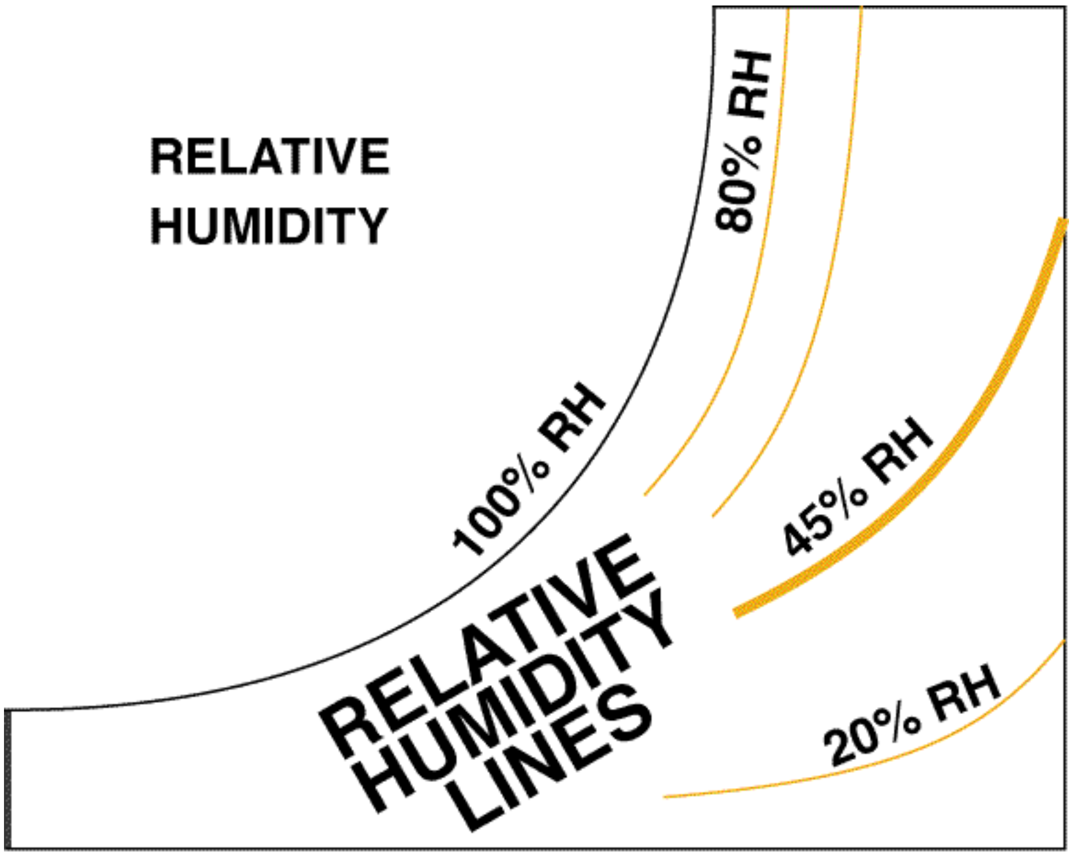
Specific Humidity



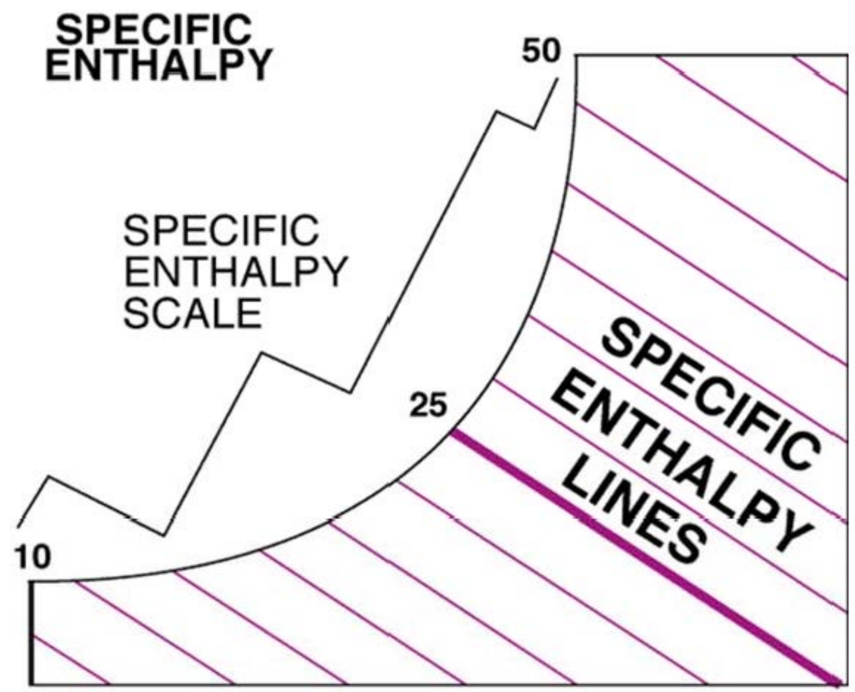
Specific Volume



Relative Humidity



Enthalpy


SPECIFIC
ENTHALPY
50
SPECIFIC
ENTHALPY
SCALE
25
10
SPECIFIC
ENTHALPY
LINES

F. Psychrometrics theory and applications

1. Understanding and reading the psychrometric chart
2. Psychrometric processes

Psychrometric Processes

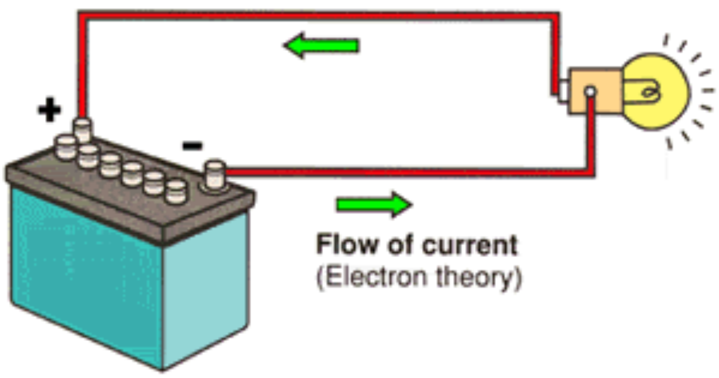
- Sensible Heating or Cooling:
  - Involves the increase or decrease in the temperature of air without changing its humidity ratio
- Heating and Humidifying
  - Involves the simultaneous increase in both dry bulb temperatures and humidity ratio of the air
- Cooling and Dehumidifying
  - Involves the removal of water from the air as the air temperature falls below the dew point temperature
- Evaporative Cooling
  - Involves cooling the air with heat loss or gain
- Mixing Air
  - Involves no net heat loss or gain during the mixing of two streams

G. Quantifying Characteristics

1. Basic electricity
2. Heat basics
3. Pressure basics
4. Lighting basics

Fundamental Electron Theory

- Electron Theory
  - The Electron Theory states that current flows from NEGATIVE to POSITIVE. Electrons move from atom to atom as they move through the conductor towards positive.



Basic Electricity

- Current
  - Current flow is unidirectional and of constant magnitude
    - Flows in one direction
    - Flows through conductors, such as wires
  - Ohm's Law: current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance

$$\mathbf{I = V/R}$$

Voltage

- Voltage is the electrical force that moves electrons through a conductor. Voltage is electrical pressure also known as EMF (Electro Motive Force) that pushes electrons.
- The greater the difference in electrical potential push (difference between positive and negative), the greater the voltage force potential.

Voltage Units

- Voltage is measured in units called VOLTS.
- Voltage measurements can use different value prefixes such as millivolt, volt, Kilovolt, and Megavolt.

VOLTAGE	LESS THAN BASE UNIT	BASIC UNIT	LARGER THAN BASE UNIT
Symbol	mV	V	kV
Pronounced	millivolt	Volt	Kilovolt
Multiplier	0.001	1	1,000

CURRENT (AMPERES)

- CURRENT is the quantity or flow rate of electrons moving past a point within one second. Current flow is also known as amperage, or amps for short.
- Higher voltage will produce higher current flow, and lower voltage will produce lower current flow.

AMPERAGE UNITS

- Current flow is measured in units called Amperes or AMPS.
- Amperage measurements can use different value prefixes, such as microamp, milliamp, and Amp.

AMPERAGE	LESS THAN BASE UNIT	LESS THAN BASE UNIT	BASIC UNIT
Symbol	µA	mA	A
Pronounce d	Microamp	milliamp	Amp
Multiplier	0.000001	0.001	1

AFFECTS OF CURRENT FLOW

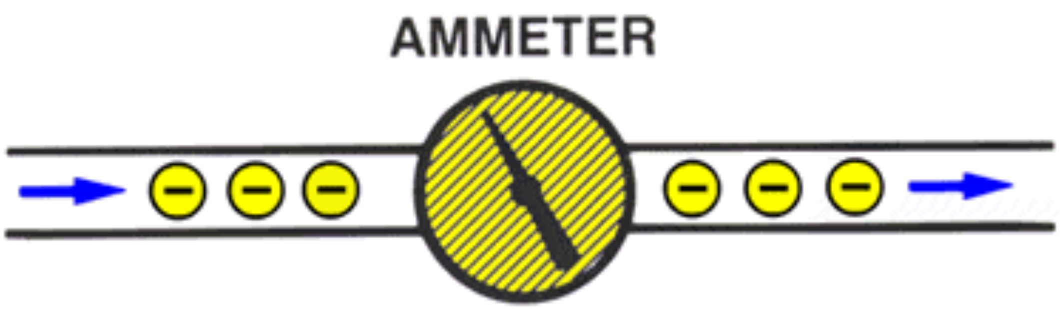
- Two common effects of current flow are Heat Generation and Electromagnetism.
  - HEAT: When current flows, heat will be generated. The higher the current flow the greater the heat generated.
    - An example would be a light bulb. If enough current flows across the filament, it will glow white hot and illuminate to produce light.

AFFECTS OF CURRENT FLOW

– ELECTROMAGNETISM: When current flows, a small magnetic field is created. The higher the current flow, the stronger the magnetic field.
  - An example: Electromagnetism principles are used in alternators, ignition systems, and other electronic devices.

MEASUREMENT

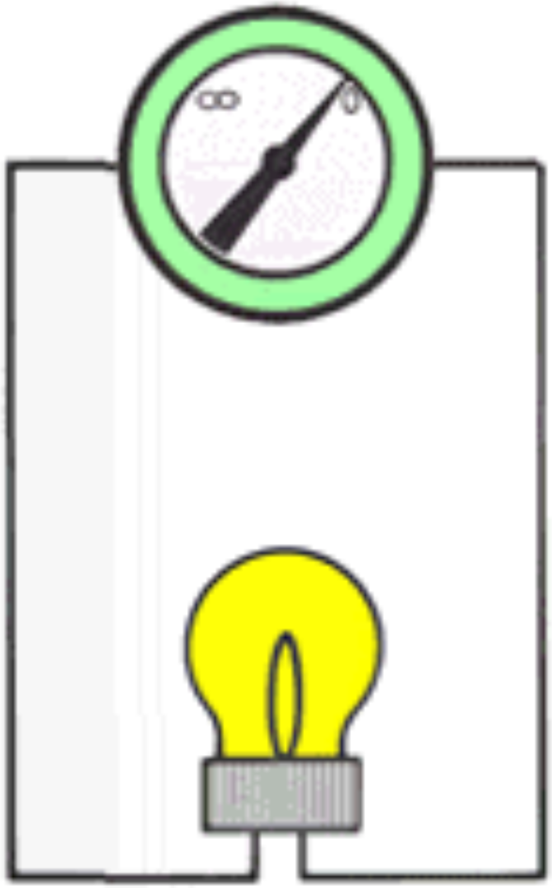
- An AMMETER measures the quantity of current flow. Ammeters are placed in series (inline) to count the electrons passing through it.
- Example: A water meter counts the gallons of water flowing through it.



Measurement

- A VOLTMETER measures the voltage potential across or parallel to the circuit
- The Voltmeter measures the amount of electrical pressure difference between tow points being measured
- Voltage can exist between two points without electron flow

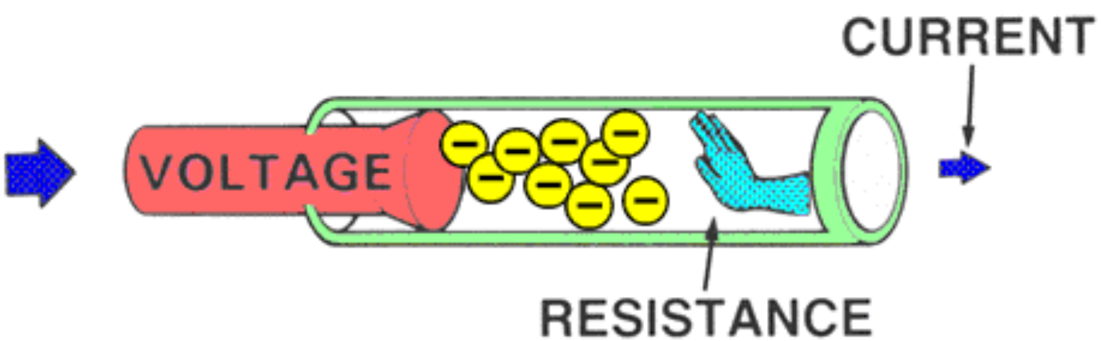
MEASUREMENT



- An OHMMETER measures the resistance of an electrical circuit or component. No voltage can be applied while the ohmmeter is connected, or damage to the meter will occur.

RESISTANCE

- Resistance is the force that reduces or stops the flow of electrons. It opposes voltage.
- Resistance is the force that reduces or stops the flow of electrons. It opposes voltage.



RESISTANCE UNITS

- Resistance is measured in units called OHMS.
- Resistance measurements can use different value prefixes, such as Kilo ohm and Megaohms.

AMPERAGE	BASIC UNIT	MORE THAN BASE UNIT	MORE THAN BASE UNIT
Symbol		K	M
Pronounced	Ohm	Kilo ohm	Megaohm
Multiplier	1	1,000	1,000,000

RESISTANCE FACTORS

- Various factors can affect the resistance. These include:
- LENGTH of the conductor. The longer the conductor, the higher the resistance.
- LENGTH of the conductor. The longer the conductor, the higher the resistance.

RESISTANCE FACTORS

- TEMPERATURE of the material. Depending on the material, most will increase resistance as temperature increases.
- PHYSICAL CONDITION (DAMAGE) to the material. Any damage will increase resistance.
- TYPE of MATERIAL used. Various materials have a wide range of resistances.

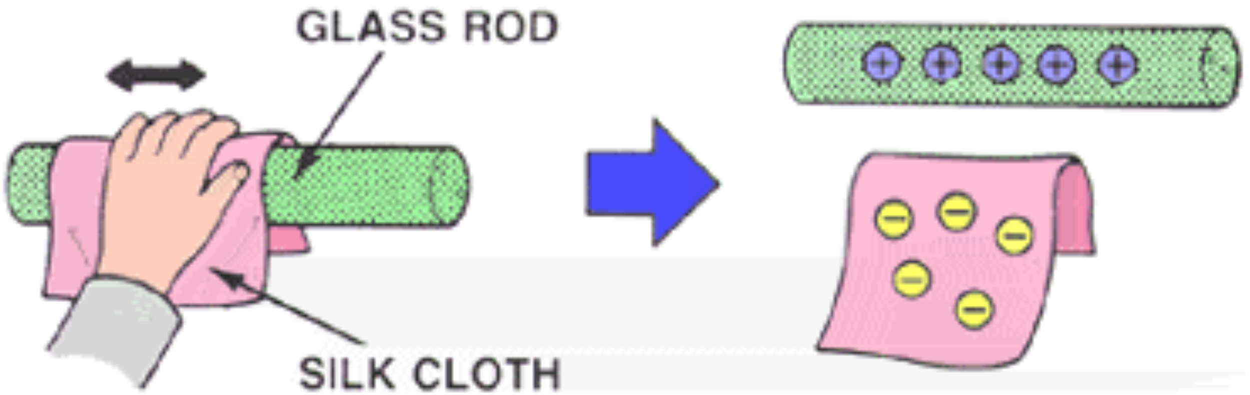
TYPES OF ELECTRICITY

Two basic types of Electricity classifications:

- **STATIC ELECTRICITY** is electricity that is standing still. Voltage potential with **NO** electron flow.
- **DYNAMIC ELECTRICITY** is electricity that is in motion. Voltage potential **WITH** electron flow. Two types of Dynamic electricity exist:

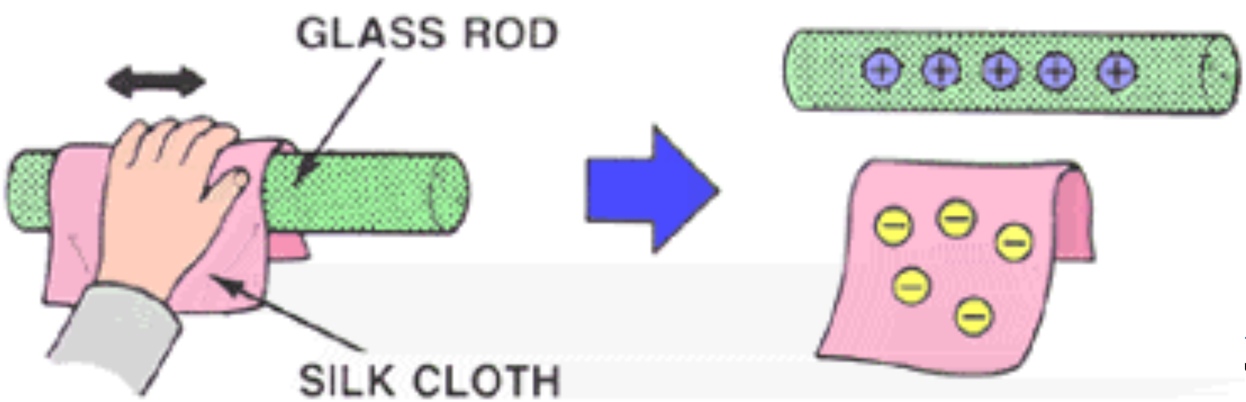
STATIC ELECTRICITY

- Voltage potential with **NO** electron flow.



STATIC ELECTRICITY

- Example: By rubbing a silk cloth on a glass rod, you physically remove electrons from the glass rod and place them on the cloth. The cloth now has a surplus of electrons (negatively charged), and the rod now has a deficiency of electrons (positively charged).

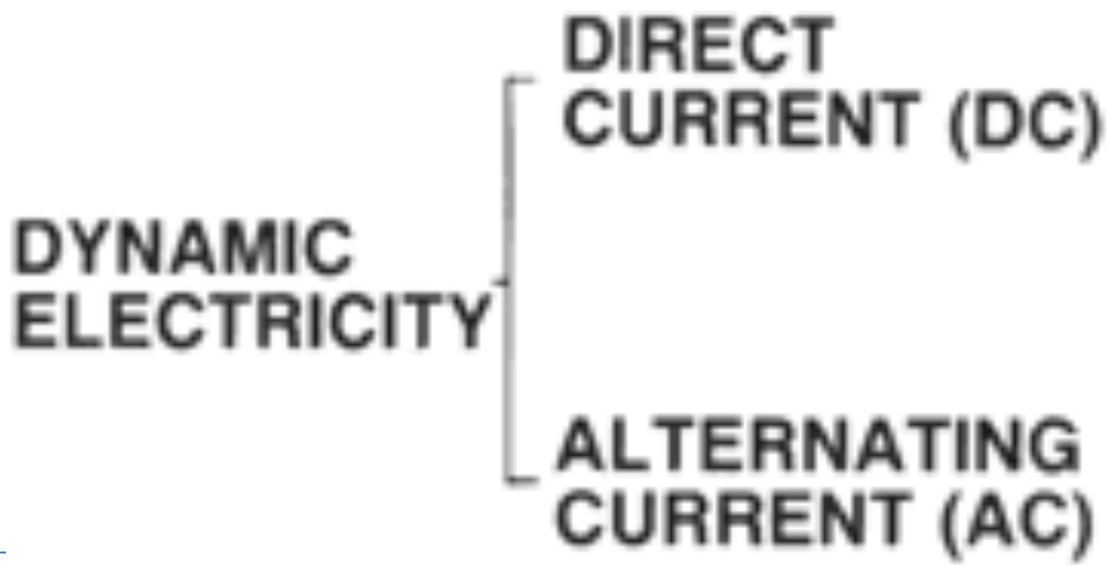


STATIC ELECTRICITY

- Another example: Rub your shoes on a rug and then touch a metal table or chair .... Zap!! The shock you felt was the static electricity dissipating through your body.

DYNAMIC ELECTRICITY

- Is electricity in motion, meaning you have electrons flowing, in other words voltage potential WITH electron flow.



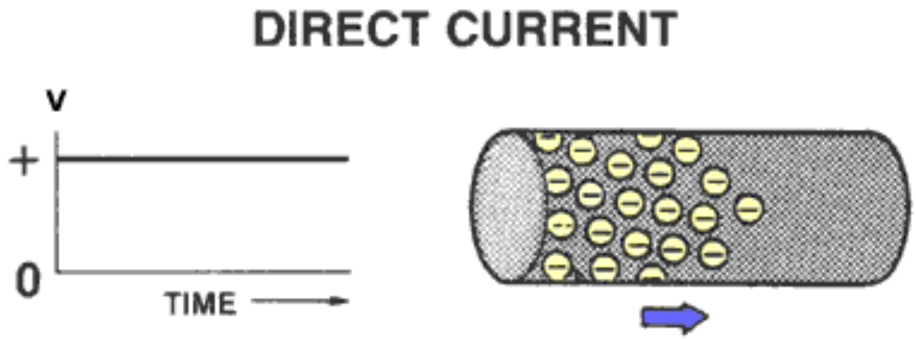
TYPES OF ELECTRICITY

Two basic types of Electricity classifications:

- **Direct Current (DC)** Electron Flow is in only one direction.
- **Alternating Current (AC)** Electron flow alternates and flows in both directions (back and forth).

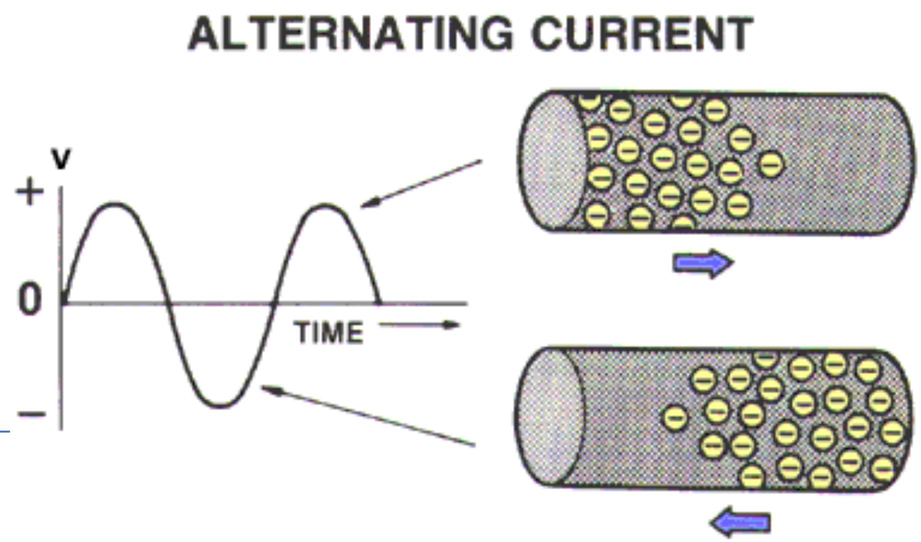
DIRECT CURRENT (DC)

- Electricity with electrons flowing in only one direction is called Direct Current or DC.
- DC electrical systems are used in cars.



ALTERNATING CURRENT (AC)

- Electricity with electrons flowing back and forth, negative - positive- negative, is called Alternating Current, or AC.
- The electrical appliances in your home use AC power.



SOURCES OF ELECTRICITY

- **Friction** creates static electricity.
- **Heat** can act upon a device called a thermo couple to create DC.
- **Light** applied to photoelectric materials will produce DC electricity.
- **Pressure** applied to a piezoelectric material will produce DC electricity.
- **Chemical Action** of certain chemicals will create electricity.

G. Quantifying Characteristics

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Heat Basics

- Heat is the energy an object has because of the movement of its atoms and molecules which are continuously moving around, hitting each other and other objects.
- When we add energy to an object, its atoms and molecules move faster increasing its energy of motion or heat.
- Even objects which are very cold have some heat energy because their atoms are still moving.

Heat and Temperature

- Heat and temperature are related to one another but they are not the same
  - Heat is energy
  - Temperature is a measure of the energy
    - Temperature is a measures of the average heat or thermal energy of the particles in a substance
    - Temperature does not depend on the size or type of object

Heat and Temperature

- Temperature: *Average* energy of molecules or atoms in a material
- Heat: *Total* energy of molecules or atoms in a material
- Can have large amount of heat but low temperatures
- Can have high temperatures but little heat

Heat and Temperature

- The Arctic Ocean has a large amount of heat (because of large mass) even though the temperature is low.
- Air in an oven at 500 F has high temperature but little heat.
- However, touch anything solid in the oven, and you’ll get burned. Same temperature, much larger amount of heat.

Heat and Temperature

- The earth's outermost atmosphere is extremely "hot" but its heat content is negligible
- The surface of the moon can reach 250 F in sunlight and -200 F in shadow, but the vacuum around the Apollo astronauts contained no heat.
- It takes time for things to warm up and cool off.

Temperature Scales

- Fahrenheit
  - Water Freezes at 32 F
  - Water Boils at 212 F
- Centigrade or Celsius
  - Water Freezes at 0 C
  - Water Boils at 100 C
- Two scales exactly equal at -40

Converting C to F – In Your Head

- Double the Centigrade
- Subtract the first Digit
- Add 32

Converting F to C – In Your Head

- Subtract 32
- Add the first Digit
- Divide by two

Absolute Temperature

- Once atoms stop moving, that's as cold as it can get
- Absolute Zero = -273 C = -459 F
- Kelvin scale uses Celsius degrees and starts at absolute zero
- Most formulas involving temperature use the Kelvin Scale

Measurement Tools

- Tools for measuring temperature include:
  - Traditional (mercury) thermometers
  - Electronic thermometers
  - Temperature sensors
  - Thermocouples
  - Thermistors
  - Resistance Temperature Detector
  - Pyrometer
  - Infrared

Latent and Sensible Heat

- Latent heat is the heat released or absorbed by a chemical substance or a thermodynamic system during a change of state that occurs without a change in temperature
- Sensible heat, in contrast to latent heat, is the heat exchanged by a thermodynamic system that has as its sole effect a change of temperature.
  - Sensible heat only increases the thermal energy of a system

G. Quantifying Characteristics

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Pressure Basics

- Definition of Pressure
  - Pressure is the force acting per unit of area
  - The Units of pressure are *Newtons per square meter*, which are sometimes called *Pascals (Pa)*.

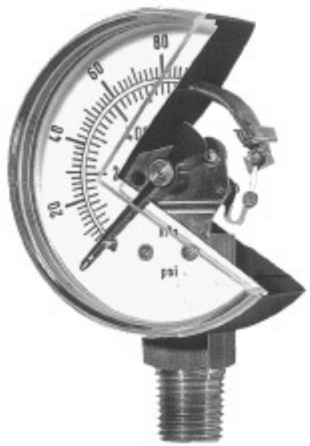
$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

pressure in **Pascals**
force in **Newtons**
area in **metres squared** (m^2)

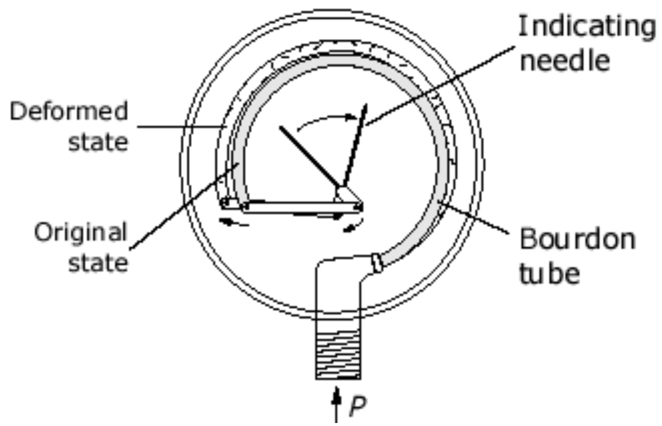
Pressure Measuring Devices

Bourdon Gage:

http://www.cpigauges.com/images/gauges/WeldGageStlCsBM400psi.jpg



http://www.hydraulicspneumatics.com/FPE/images/sensors1_1.jpg



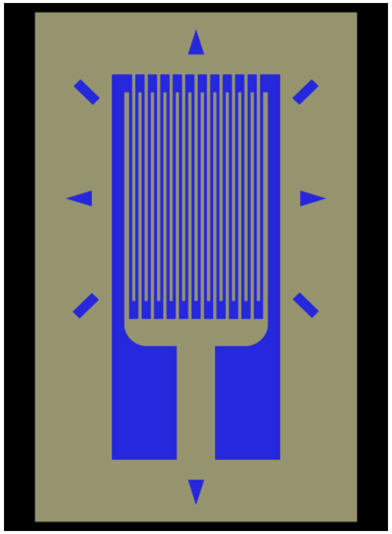
http://www.efunda.com/DesignStandards/sensors/bourdon_tubes/images/Bourdon_tube_A.gif

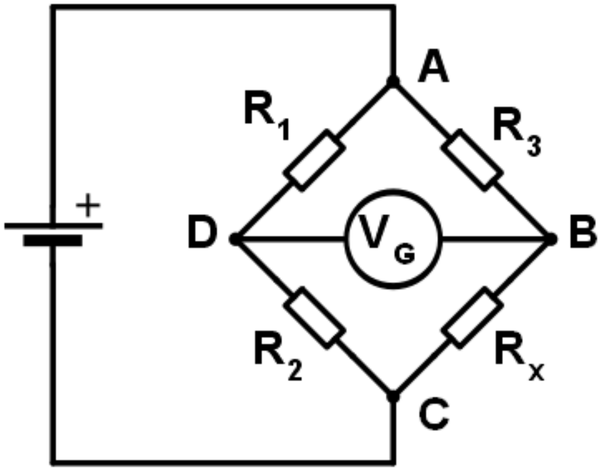
Principles: change in curvature of the tube is proportional to difference of pressure inside from that outside the tube

Applications: tire pressure, pressure at the top or along the walls of tanks or vessels

Pressure Measuring Devices

<u>Strain Gage</u>



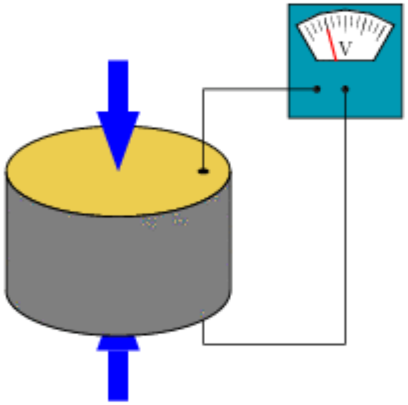


Principles: Δ P → Δ Resistance → Δ Voltage

Applications: Sensors for internal combustion engines, automotive, research etc.

Pressure Measuring Devices

Quartz Gage



http://upload.wikimedia.org/wikipedia/commons/c/c4/SchemaPiezo.gif

Principles: Δ Pressure → Δ Charge → Δ Voltage

Applications: measurements with high accuracy, good repeatability, high resolution.
e g. Quartz Clock

Pressure Measuring Devices

Piezoresistive Gage

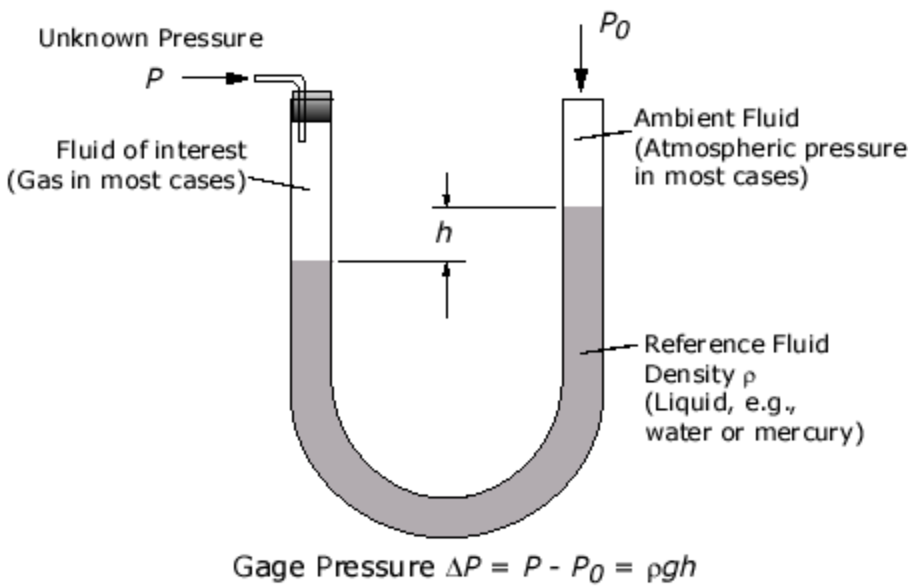
Digital Manometer

Principles: ΔPressure = ΔCharge = ΔResistance = ΔVoltage

Applications: Very accurate for small pressure differentials
e.g. Difference between indoor and outdoor pressure

Pressure Measuring Devices

U-tube Manometer



http://www.efunda.com/formulae/fluids/images/Manometer_A.gif

Principles: Hydrostatic Law

$$\Delta P = \rho \; g \; h$$

Pressure Measuring Devices

U-tube Manometer

http://www.armfield.co.uk/images/H12.gif

http://hyperphysics.phy-astr.gsu.edu/Hbase/fluids/flupic/bern5.jpg

Mercury Water Manometer

Air Water Manometer

Applications: air pressure, pipe pressure, etc.

Atmosphere

- An atmosphere is a layer of gas that surrounds the world
- It is obtained by:
  - Gains in volatiles through comet impacts
  - Out-gassing during differentiation
  - On-going out-gassing by volcanoes

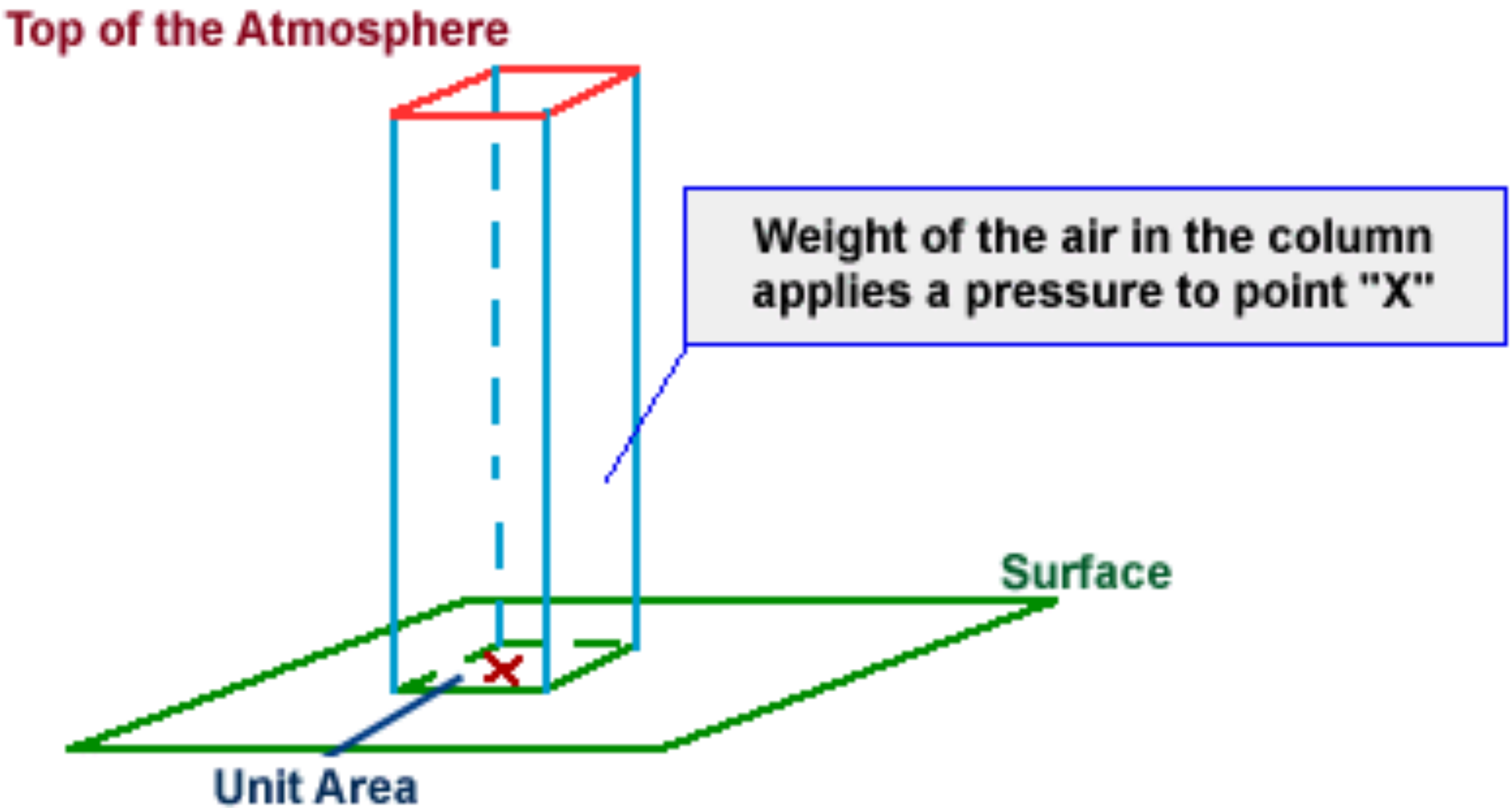
Keeping an Atmosphere

- Atmosphere is *kept* by the world's gravity
  - **Low mass (small) worlds= low gravity**
    =almost no atm.
  - **High mass(large) worlds = high gravity**
    = thick atm.

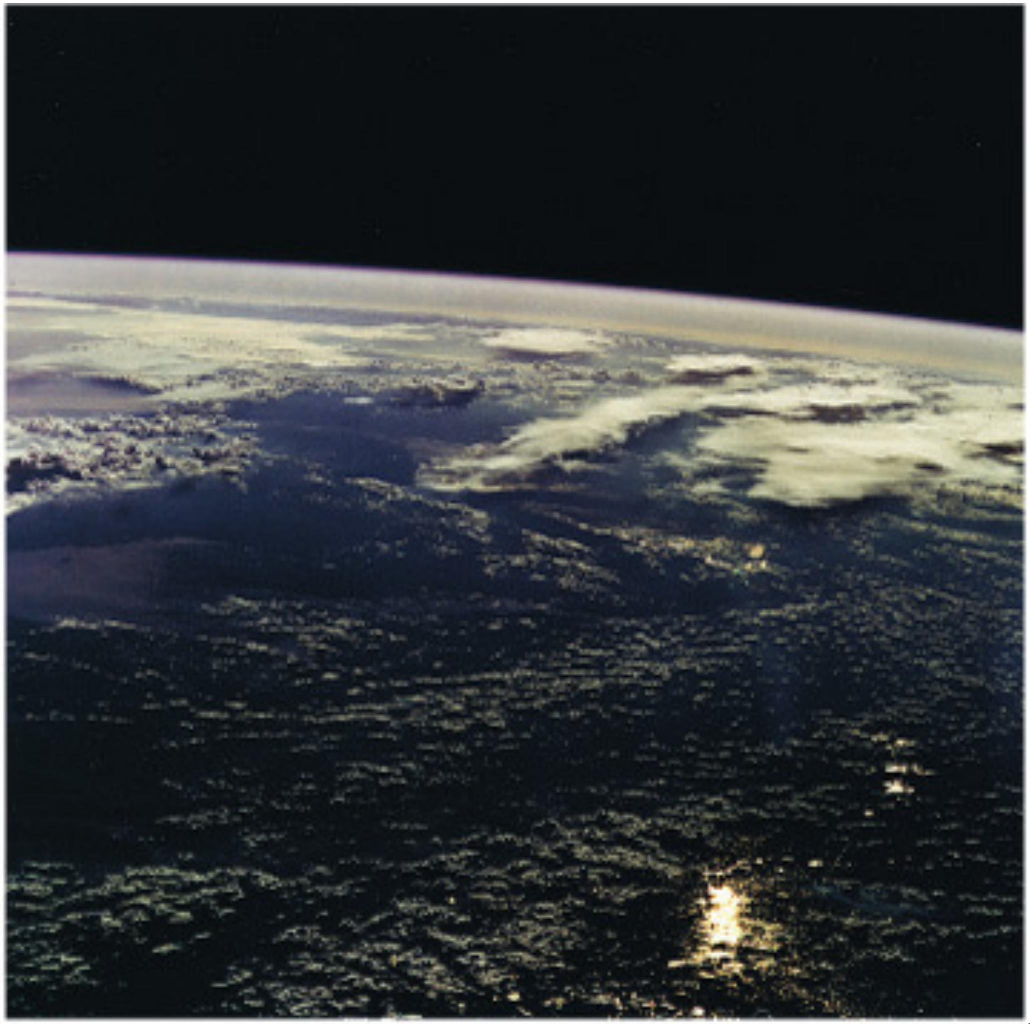
- Gravity and pressure
  - **Air pressure depends on how much gas is there ie. The atmospheric thickness.**

Gravity and Atmospheric Pressure

- The stronger the gravity, the more gas is held by the world and the greater the weight of atm. on a point

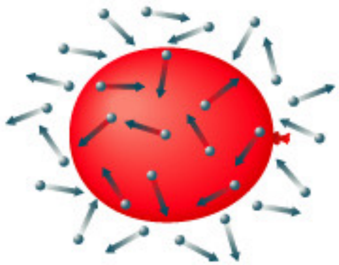


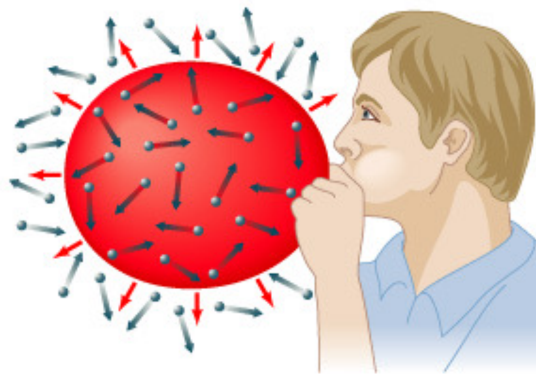
Earth's Atmosphere



- About 10 km thick
- Consists mostly of molecular nitrogen (N_2) and oxygen (O_2)

Atmospheric Pressure



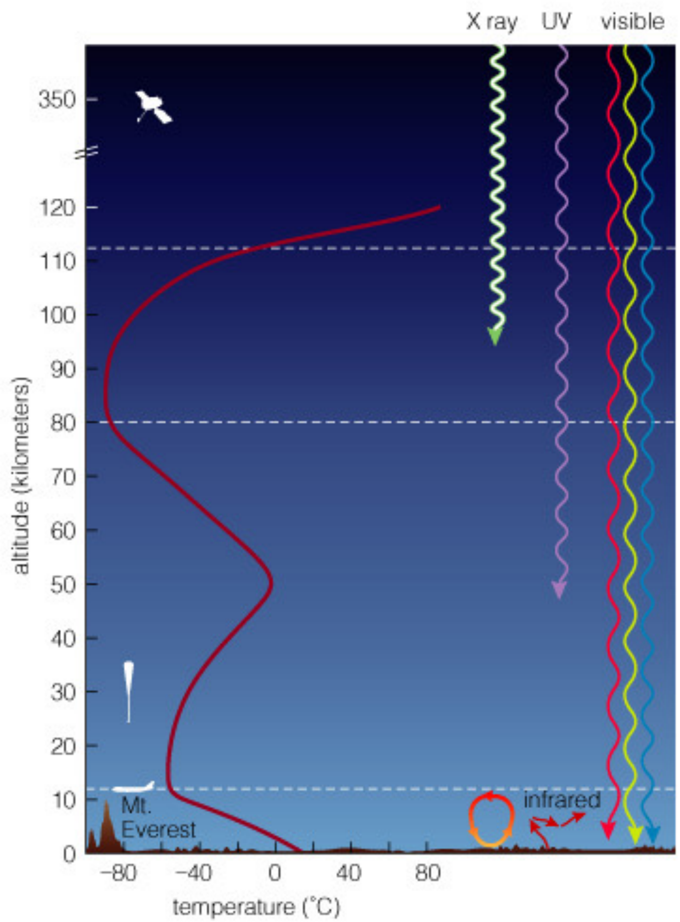


Gas pressure depends on both density and temperature.

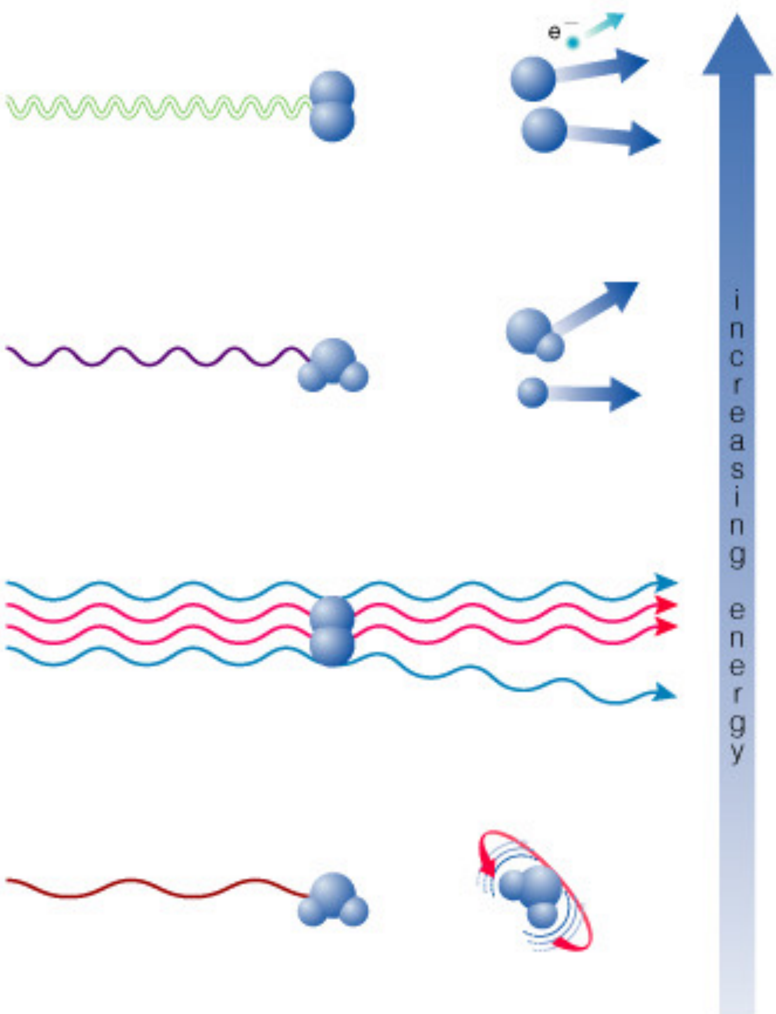
Adding air molecules increases the pressure in a balloon.

Heating the air also increases the pressure.

What do atmospheric properties vary with altitude?

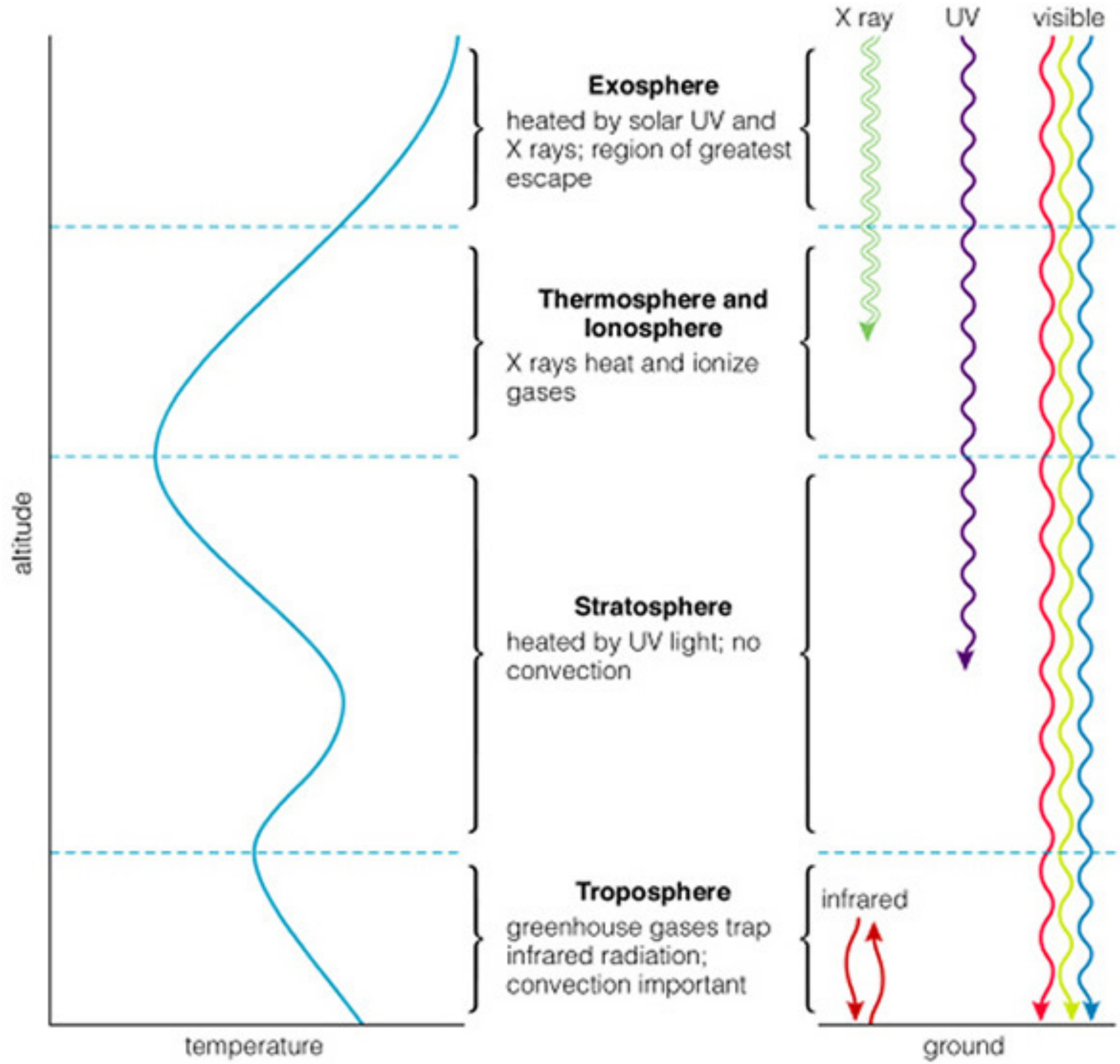


Light's Effects on Atmosphere

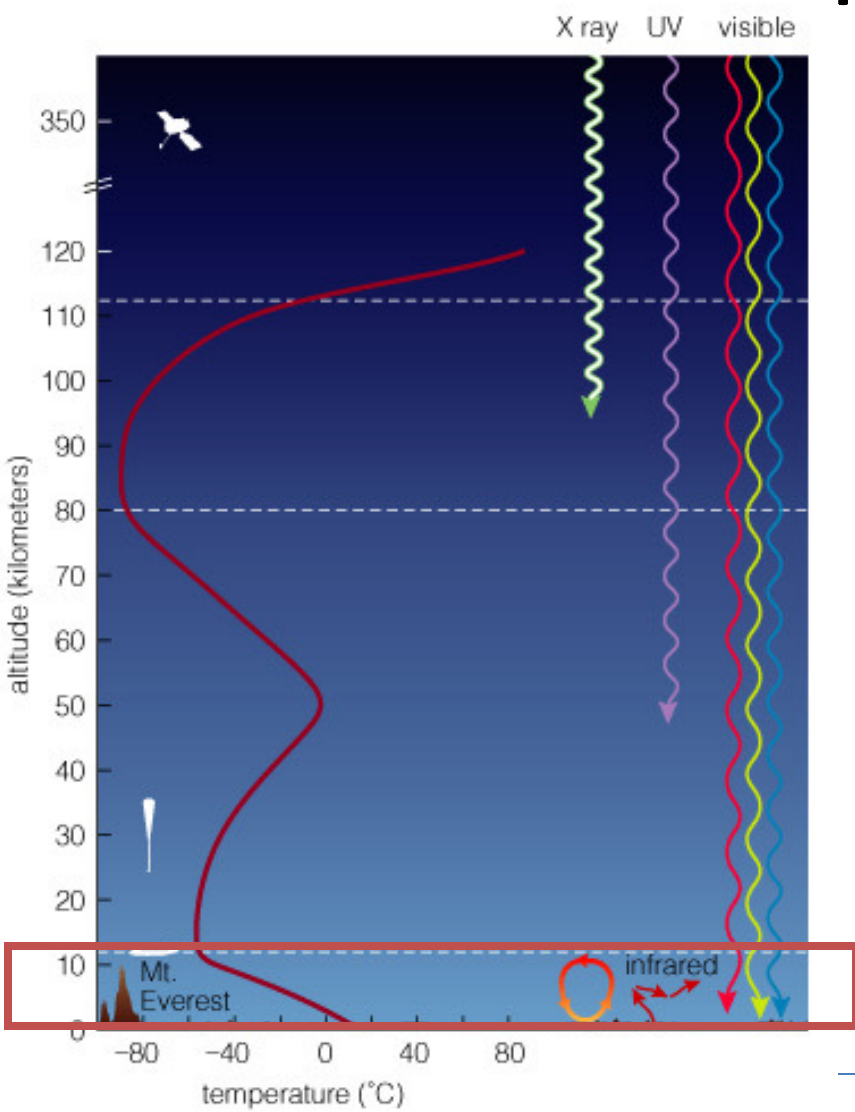


- **Ionization:** Removal of an electron
- **Dissociation:** Destruction of a molecule
- **Scattering:** Change in photon's direction
- **Absorption:** Photon's energy is absorbed

Temperatures and composition change with Height giving structure to an atmosphere

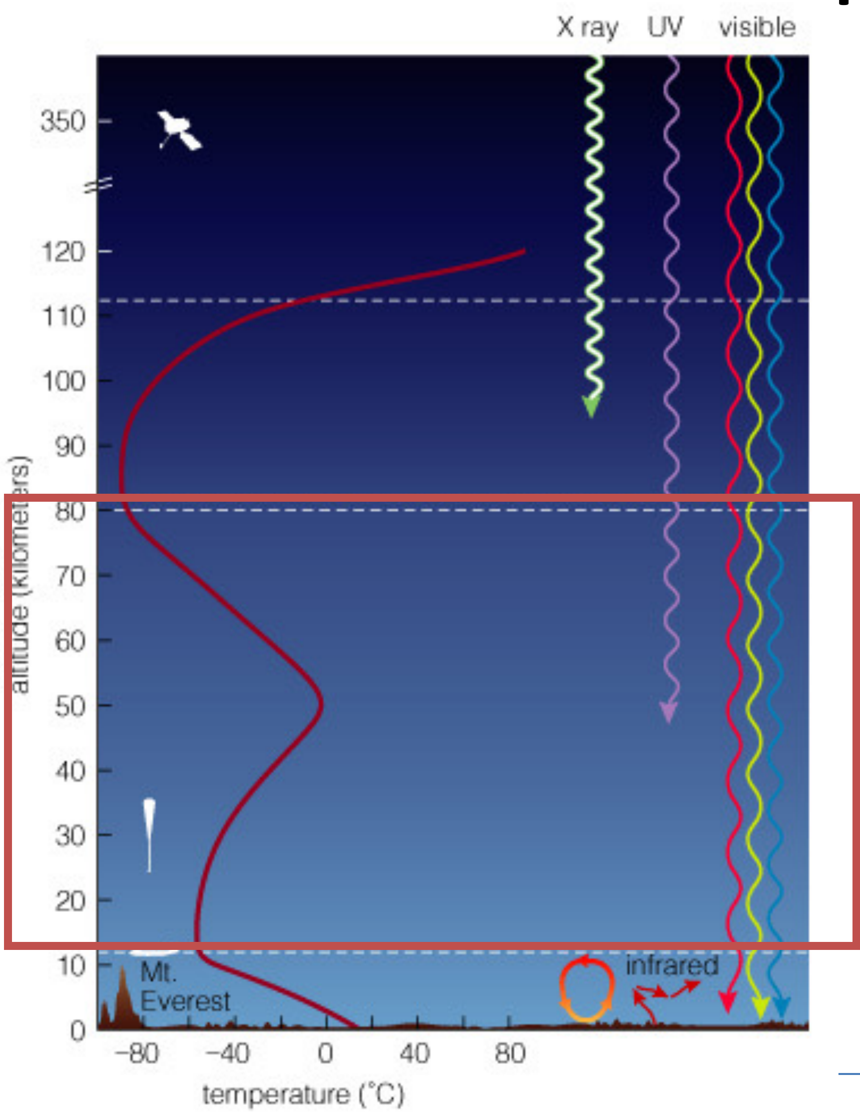


Earth's Atmospheric Structure



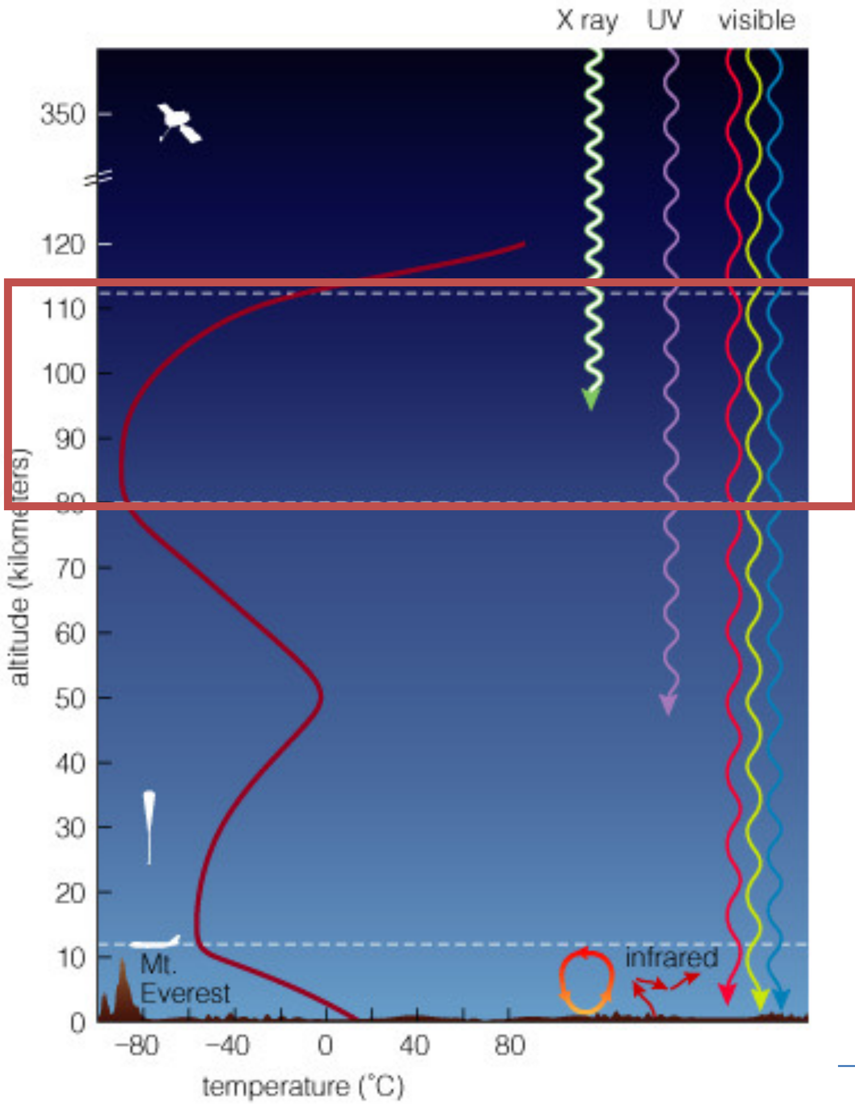
- **Troposphere:** lowest layer of Earth's atmosphere
- Temperature drops with altitude
- Warmed by infrared light from surface and convection

Earth's Atmospheric Structure



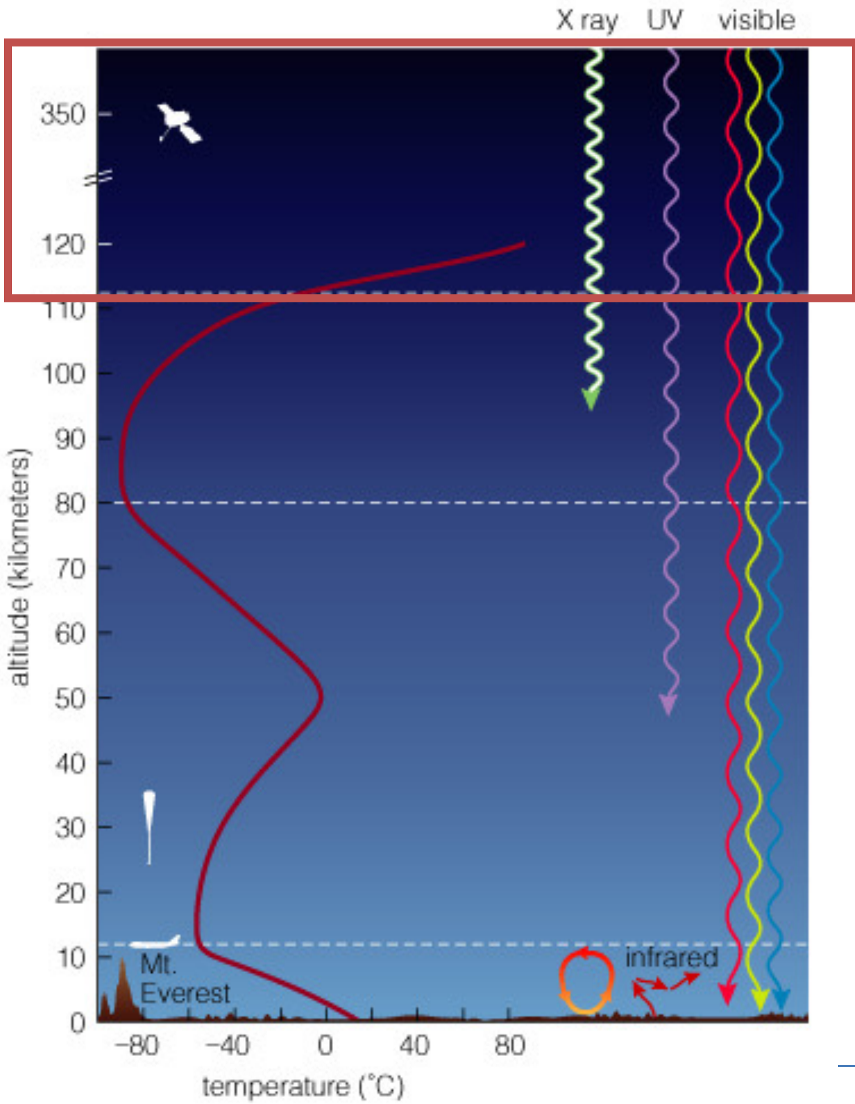
- **Stratosphere:** Layer above the troposphere
- Temperature rises with altitude in lower part, drops with altitude in upper part
- Warmed by absorption of ultraviolet sunlight

Earth's Atmospheric Structure



- **Thermosphere:** Layer at about 100 km altitude
- Temperature rises with altitude
- X rays and ultraviolet light from the Sun heat and ionize gases

Earth's Atmospheric Structure



- **Exosphere:** Highest layer in which atmosphere gradually fades into space
- Temperature rises with altitude; atoms can escape into space
- Warmed by X rays and UV light

Atmospheric Measurements

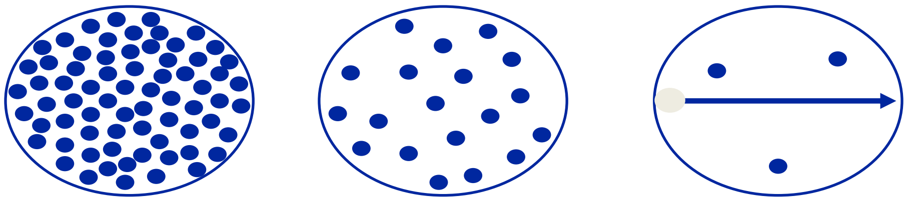
- Temperature -- Thermometer
- Pressure -- Barometer
- Humidity -- Hygrometer
- Wind Velocity and Direction – Anemometer and Wind Van

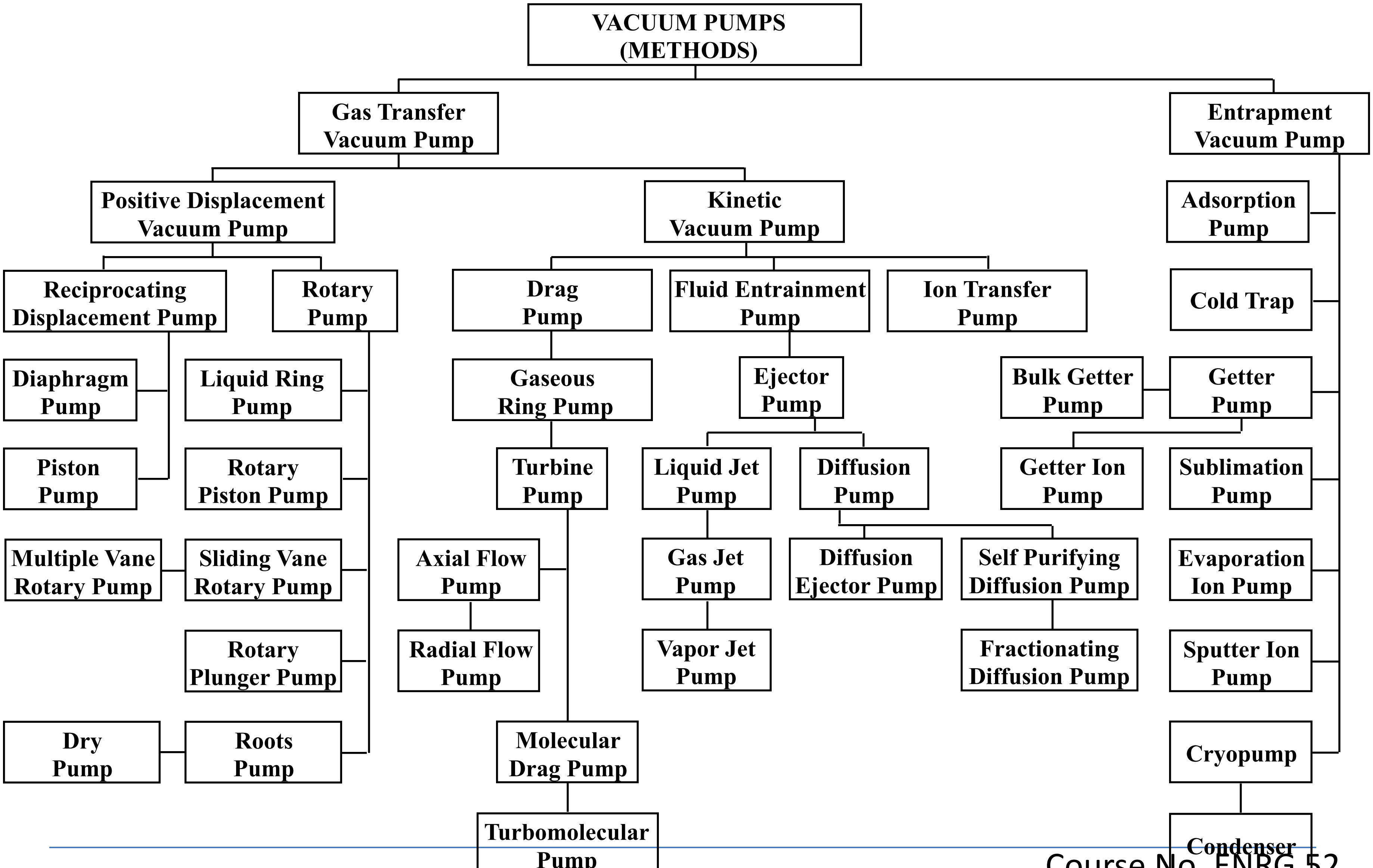
What is Vacuum?

- Vacuum in the strictest sense is the absence of everything.
- On the absolute pressure scale a pressure of zero. i.e. 0 psi, 0 torr, 0 atm, 0 bar . . .
- There is nothing less than zero, no negative values of pressure.
- Zero is absolutely the lowest pressure.

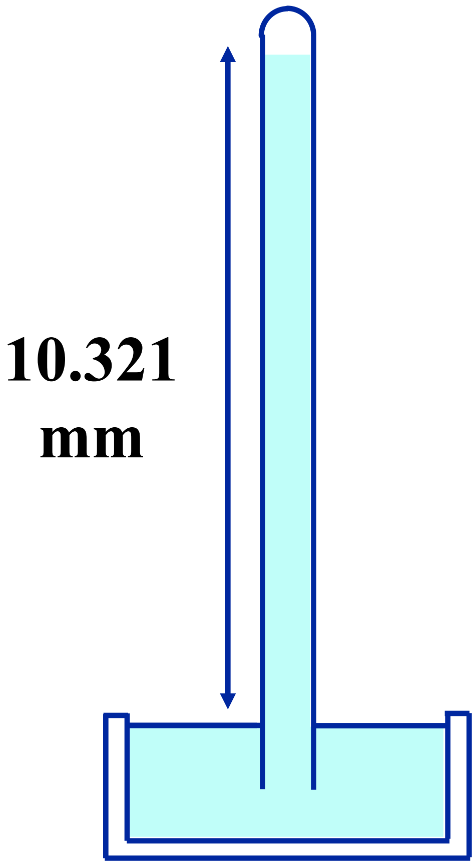
Vacuum Pressures

- Why is a vacuum needed?
  - To move a particle in a straight line over a large distance, and
  - To provide a clean surface
- How do you create a vacuum?
  - Pumping methods

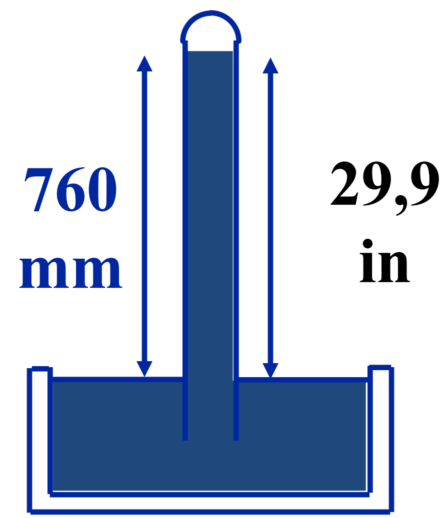



VACUUM PUMPS (METHODS)
Gas Transfer Vacuum Pump
Entrapment Vacuum Pump
Positive Displacement Vacuum Pump
Kinetic Vacuum Pump
Adsorption Pump
Reciprocating Displacement Pump
Rotary Pump
Drag Pump
Fluid Entrainment Pump
Ion Transfer Pump
Cold Trap
Diaphragm Pump
Liquid Ring Pump
Gaseous Ring Pump
Ejector Pump
Bulk Getter Pump
Getter Pump
Piston Pump
Rotary Piston Pump
Turbine Pump
Liquid Jet Pump
Diffusion Pump
Getter Ion Pump
Sublimation Pump
Multiple Vane Rotary Pump
Sliding Vane Rotary Pump
Axial Flow Pump
Gas Jet Pump
Diffusion Ejector Pump
Self Purifying Diffusion Pump
Evaporation Ion Pump
Rotary Plunger Pump
Radial Flow Pump
Vapor Jet Pump
Fractionating Diffusion Pump
Sputter Ion Pump
Dry Pump
Roots Pump
Molecular Drag Pump
Cryopump
Turbomolecular Pump
Condenser

BAROMETER



Mercury: 13.58 times heavier than water:
Column is 13.58 x shorter :
10321 mm/13.58=760 mm
(= 760 Torr)



WATER

MERCURY

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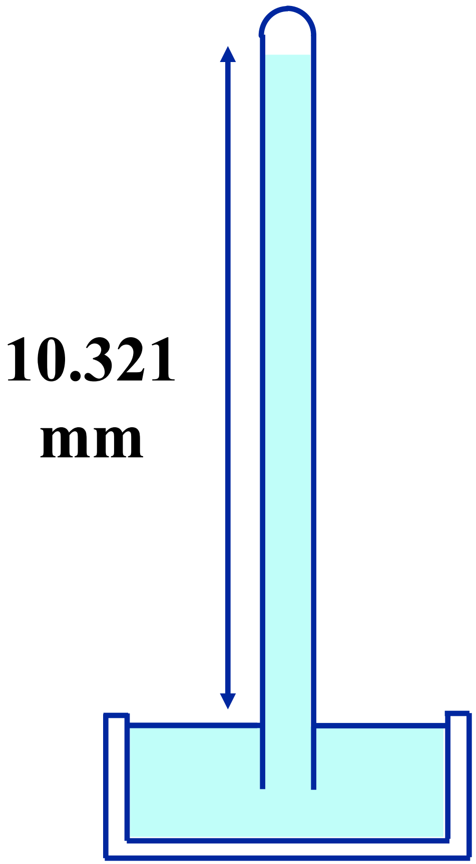
BAROMETER



WATER

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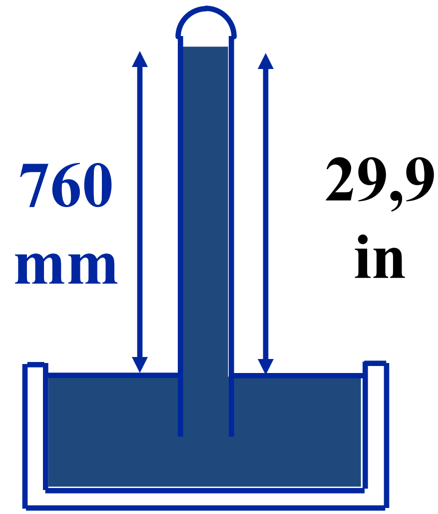

MERCURY

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PRESSURE OF 1 STANDARD ATMOSPHERE:

760 TORR, 1013 mbar

AT SEA LEVEL, 0^{O} C AND 45^{O} LATITUDE

Pressure Equivalents

Atmospheric Pressure (Standard) =	
0	gauge pressure (psig)
14.7	pounds per square inch (psia)
29.9	inches of mercury
760	millimeter of mercury
760	torr
760,000	millitorr or microns
101,325	pascal
1.013	bar
1013	millibar

THE ATMOSPHERE IS A MIXTURE OF GASES

PARTIAL PRESSURES OF GASES CORRESPOND TO THEIR RELATIVE VOLUMES

GAS	SYMBOL	PERCENT BY VOLUME	PARTIAL PRESSURE TORR	PARTIAL PRESSURE PASCAL
Nitrogen	N_2	78	593	79,000
Oxygen	O_2	21	158	21,000
Argon	A	0.93	7.1	940
Carbon Dioxide	CO_2	0.03	0.25	33
Neon	Ne	0.0018	1.4×10^{-2}	1.8
Helium	He	0.0005	4.0×10^{-3}	5.3×10^{-1}
Krypton	Kr	0.0001	8.7×10^{-4}	1.1×10^{-1}
Hydrogen	H_2	0.00005	4.0×10^{-4}	5.1×10^{-2}
Xenon	X	0.0000087	6.6×10^{-5}	8.7×10^{-3}
Water	H_2O	Variable	5 to 50	665 to 6650

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VAPOR PRESSURE OF WATER AT VARIOUS TEMPERATURES

T (^{O}C)		P (mbar)
100	(BOILING)	1013
25		32
0	(FREEZING)	6.4
-40		0.13
-78.5	(DRY ICE)	6.6×10^{-4}
-196	(LIQUID NITROGEN)	10^{-24}

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PRESSURE RANGES

RANGE	PRESSURE
ROUGH (LOW) VACUUM	759 TO 1×10^{-3} (mbar)
HIGH VACUUM	1×10^{-3} TO 1×10^{-8} (mbar)
ULTRA HIGH VACUUM	LESS THAN 1×10^{-8} (mbar)

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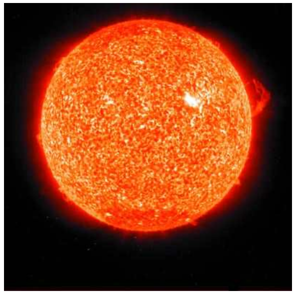
G. Quantifying Characteristics

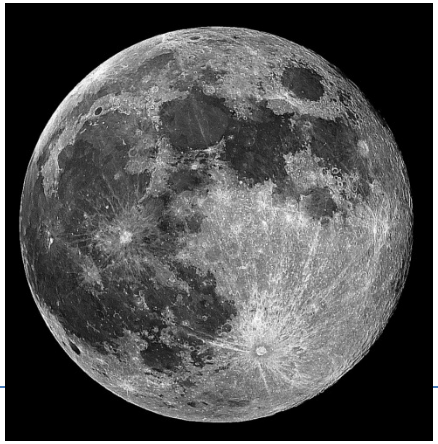
1. Basic electricity
2. Heat basics
3. Pressure basics
4. Lighting basics

Lighting Basics

- Luminous source – an object that produces and emits light.



- Illuminated source – an object that reflects light.



Possibilities for Light/Matter Interactions

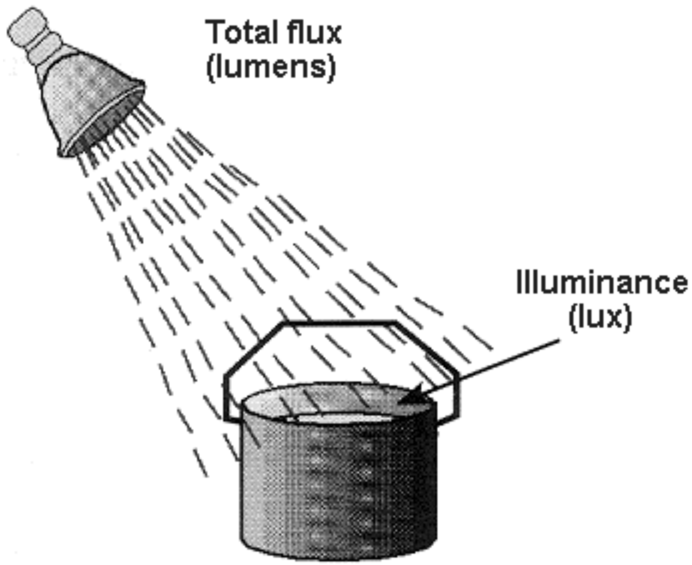
- Opaque – object that does not transmit light but does reflect light.

- Transparent – object that does transmit light

- Translucent – object that transmits and scatters light.

Quantity of light

- Luminous Flux – P – lumen (lm) – rate at which light energy is emitted from a source. (measure of the rate light rays come out of a source) 100W = 1750 Lm
- Illuminance – E – lux (lx) – rate at which light strikes the surface of an object. (measure of the number of light rays that strike a surface) lux = lm/m^2



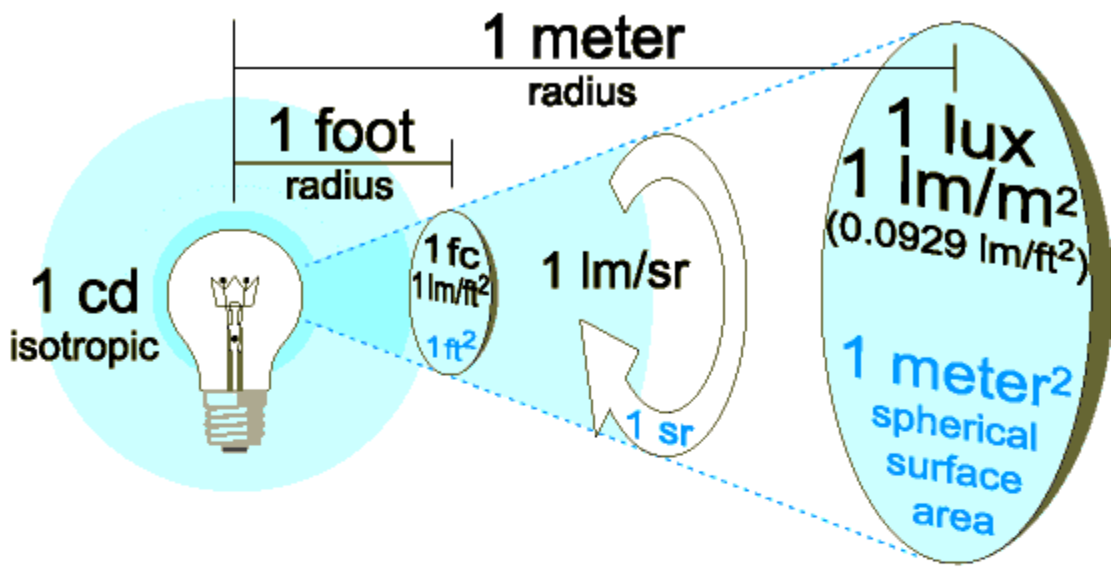
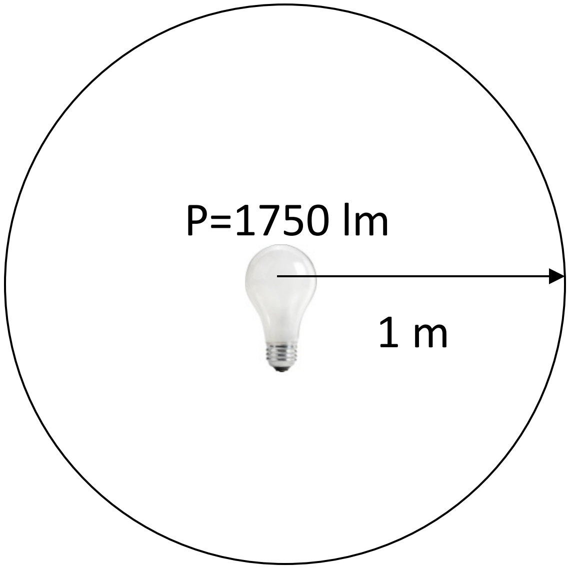


Fig. 7.4 Irradiance.



Luminous Flux compared to Illuminance of a 100W light bulb at 1 and 2 meters

Note: Inverse square relationship

As distance doubles Illumunance decreases by a factor of four

$$E_1 = \frac{1750}{4\pi(1)^2} = 139lx$$

$$E_2 = \frac{1750}{4\pi(2)^2} = 34.8lx$$

Luminous Intensity – Candela (cd)

- Fundemental unit of light intensity
- The luminous intensity of a point source is the luminous flux that falls on one square meter of the inside of a one meter radius sphere.
- 100 W bulb = 1750 lm = 139 cd

luminous flux   luminous intensity

Point Source Illuminance

$$E = \frac{P}{4\pi r^2}$$

E – Illuminance

P – Luminous Flux

r – distance from the source

Measuring Light

- There are many different units for measuring light and it can get very complicated. Here are a few common measurement terms:
- **Candela (cd)**
  Unit of luminous intensity of a light source in a specific direction. Also called *candle*.
  Technically, the radiation intensity in a perpendicular direction of a surface of 1/600000 square metre of a black body at the temperature of solidification platinum under a pressure of 101,325 newtons per square metre.
- **Footcandle (fc or ftc)**
  Unit of light intensity, measured in lumens per square foot. The brightness of one candle at a distance of one foot. Approximately 10.7639 lux.
- **Lumen (lm)**
  Unit of light flow or luminous flux. The output of artificial lights can be measured in lumens.
- **Lux (lx)**
  Unit of illumination equal to one lumen per square metre. The metric equivalent of foot-candles (one lux equals 0.0929 footcandles). Also called metre-candle.

What is Photometry?

- Photometry focuses on assigning numerical values to light energy emitted from wavelengths between 400nm and 700nm. This is the visible light portion.
- A subject called Radiometry focuses of most of the EM spectrum (400nm to 1000nm).
- A photometer is a light meter that is just used for Photometry
- The values it issues should be through of as what Amps or Volts is to electricity.

What is Photometry

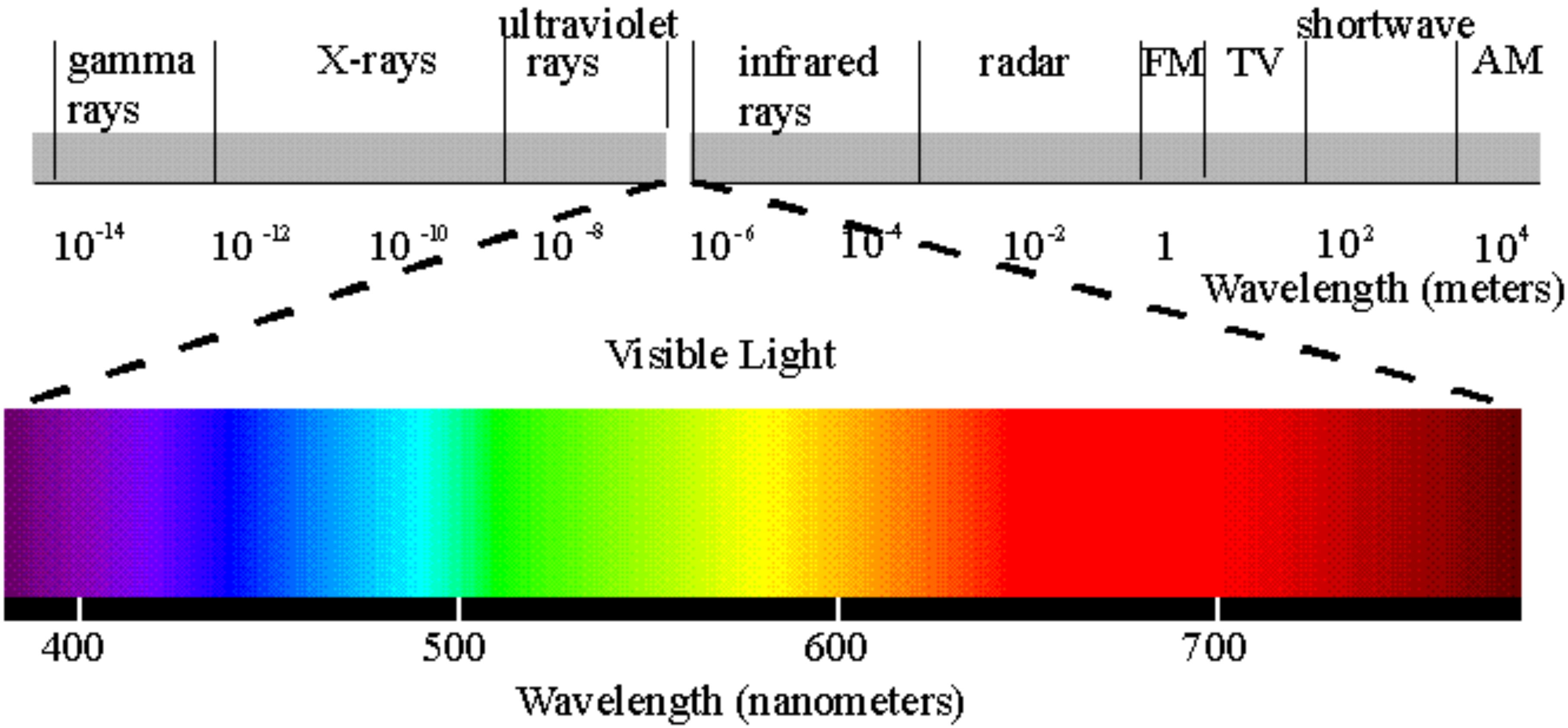


Table of Contents

Visual Stimulus

The Light Meter

- All light meters holds a plain silicon detector inside of it (Silicon Photo Diode) which can be used for radiometry or photometry.
- For photometry, a green filter is present that only allows wavelengths from 400nm to 700nm to arrive to the detector
- This filter simulates the energy or light our eyes can see and assigns numerical values for them
- It is called a light meter, Photo Meter, and sometimes Photometer

What Exactly Does the Light Meter Measure?

- They may vary in features, however for the most part they light meters read/measure:
  - Foot-candles
  - Foot-lamberts
  - Lux **(illuminance)**
  - Candela per square meter **(luminance)**

Illuminance

- Illuminance measures the intensity or power of the light over a surface, per unit area. [lm/m^2] or [Lux]
- A White filter in the photometer is used to collect light from all angles and get rid of the dimensional aspects of where the light is coming from.

Luminance

- Luminance is the measure of the intensity of the light per unit area of light traveling in a certain direction.
- This direction of the light is the difference between Illuminance and Luminance
- Luminance is measured in [cd/m^2]

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