PHYSICS AND ANESTHESIA

D-R Kazarin Peter

INTRODUCTION

- For the safe & efficient use of anaesthetic apparatus, the anaesthetist must have a clear concept of the physical aspects of the equipment in use.

- Understanding of basic concepts may avert unnecessary accidents & near misses.

INTRODUCTION

- Physics is the world in measurable terms and the physical laws apply to all states of matter (i.e. solids, liquids and gases).

- As anaesthesiolgists we deal with liquids & gases under pressure at varying temperatures and volumes.

- These inter-relationships are simple, measurable and their understanding ensures a safe outcome for the patient.

UNITS OF MEASUREMENT

- Base SI units
- - length (meter)
- - mass (kilogram)
- - time (second)
- - current (ampere)
- - temp (kelvin)
- - luminous intensity (candela)
- - amount of substance (mole)

UNITS OF MEASUREMENT

▣ DERIVED UNITS

▣ - temp in degrees celcius

▣ - force (newton)

▣ - pressure (pascal)

▣ - pressure (bar)

▣ - energy (electron volt)

▣ - power (watt)

▣ - frequency (hertz)

▣ - volume (liter)

UNITS OF MEASUREMENT

- UNITS NOT IN THE SI SYSTEM
- - pressure (mmHg)
- - pressure (cmh2o)
- - pressure (std atmosphere)
- - energy (calorie)
- - force (kilogram weight)

UNITS OF MEASUREMENT

- ▣ - 1 kilopascal = 7.5mmHg.
- ▣ - 1 Bar = 750mmHg
- ▣ - 1 kilopascal = 10.2cmH2O
- ▣ - 1 std atmosphere = 101.325kPa
- ▣ - 1 calorie = 4.18 J
- ▣ - 1 kilogram weight = 9.81N
- ▣ - Pounds / in2(PSI) -Atmospheric Pressure PATM=14.7 PSI)

PRESSURE

- Force = mass x acceleration
- $\quad\quad$ = kgms^{-2} = Newton

- Pressure = Force/Area

- 1 Pascal = I Newton acting over $1m^2$

PRESSURE

- I Bar = 100kPa = Atmospheric pressure at sea level

PRESSURE

- Normal thumb pressure on a syringe = 25N
- 2 ml syringe has an area of 5×10^{-5}
- Pressure is 500kPa – extravascular infusion easy

PRESSURE

- With a 20 ml syringe, the pressure exerted is 100kPA = 6X SBP of 120 mmHg (16Kpa)
- IVRA – rapid injection – pressure can exceed SBP or cuff pressure – decreased protection

PRESSURE

- Bed Sores --- 20kg of patient mass supported on an area of contact of 100cm^2

- Force = 196N (20kg x 9.81)

- Pressure = 19.6 kPa

- Normal SBP = 16kPa --- Risk of Ischemia

PRESSURE

- Pressure relief valves and expiratory valves

- Pressure in the circuit exerts a force on the diaphragm. If this force is greater that the force exerted by the valve, air escapes through the exp valve. They are typically low pressure valves(50Pa)

GAUGE AND ABSOLUTE PRESSURE

- Full oxygen cylinder has a gauge pressure of 137 bar
- Empty cylinder still has oxygen at atmospheric pressure
- Absolute Pressure = 138 bar

GAUGE PRESSURE

- Absolute P = Gauge P + Atmospheric P
- Most times we ignore atmospheric P
- Thus, ventilator pressures, gas cylinder pressures and arterial blood pressures are all gauge pressures

PRESSURE

- For ideal gases (air, nitrogen, oxygen)-Full cylinder pressure = 2000 PSI -Full cylinder volume= 660 liters

- 1000 PSI --> 330 L500 PSI-->165 L

- Volume remaining is proportional to pressure

FLUID FLOW

- Flow = quantity of fluid/gas passing a point in unit time
- Can be turbulent or laminar

LAMINAR FLOW

- Flow moves in a steady manner with no eddies or turbulence
- Flow is greatest in the centre
- Zero flow at the wall
- P/F = constant known as the resistance of the apparatus or tube
- Hagen- Poiseuille Equation

LAMINAR FLOW

- Flow = $\prod Pd^4/128\mu l$
- P = Pressure
- d = Diameter
- Ų = viscosity
- L = length

THE ANESTHESIA MACHINE

▫ The resistance to flow is a function of the viscosity of the gas, the length of the pipe and the radius of the pipe to the fourth power

▫ Called Poiseuille's Law

▫ A 7.0 ETT has almost twice the resistance of an 8.0 ETT

THE ANESTHESIA MACHINE

ID	R	Resistance factor	Resistance relative to 8.0
2.5	1.25	0.410	104.9
3	1.5	0.198	50.6
4	2	0.063	16.0
5	2.5	0.026	6.6
6	3	0.012	3.2
7	3.5	0.007	1.7
8	4	0.004	1.0
9	4.5	0.002	0.6

TURBULENT FLOW

- Swirls or eddies present
- Resistance is higher than laminar flow
- Reynold's Number = vpd/μ (velocity x pressure x density)/viscosity
- Re Number > 2000 = Turbulent Flow
- ET connector/ Kinked ETT
- Use of Helium reduces the density

TURBULENT FLOW

- Most important property is density which is mass/volume

CRITICAL FLOW

- Critical flow for a typical anesthetic gas has approx the same numerical value as the diameter of the airway concerned
- 9mm ETT has a critical flow of 9L/min
- Above 9L/min = turbulent flow

CRITICAL FLOW

- Air has a lower density than Nitrous Oxide – laminar flow prevails

- Air flow through the smaller airways is slower – laminar flow predominates

- Corrugated surfaces induces turbulence at low flow rates

CRITICAL FLOW

▫ Although the bronchi and smaller air passages are narrower than the trachea, the air flow through them is slower.

▫ Laminar flow is usual in the LRT

TENSION

- Tension is a tangential force in Nm acting on a length of wall

- A balance must be present between the pressure caused by the smooth muscle and elastic tissue and the fluid pressure in the tube to prevent the tube progressively distending or collapsing

TENSION

▫ A fall in pressure in an arteriole tends to distend it less and so would reduce its radius but the smooth muscle in the wall maintains tension.

▫ Ratio of tension to radius is increased and pressure across the wall is raised (La Place's law)

SURFACE TENSION

- Pressure = 2T/R (wall of a sphere)
- Surfactant decreases surface tension lining the alveoli – makes surface tension variable
- Tension decreases as the alveoli contract and increase as the alveoli distend

SURFACE TENSION

- On the surface of a liquid, some of the forces of attraction between molecules act in a direction parallel to the surface

- Also forces between molecules and the walls – results in a meniscus

- Water – concave meniscus

- Mercury – convex meniscus

THE ANESTHESIA MACHINE

- Tension in the wall of the bag equals Pressure x Radius x ½ (T = PxR /2)
- For a cylindrical structure such as an artery, the wall tension = PxR

BERNOULLI PRINCIPLE

- Fall in pressure at a narrowing of a tube
- Gas/Fluid has potential energy in the form of its pressure and kinetic energy associated with its flow
- At the narrowing – increase in fluid velocity – increase in kinetic energy

BERNOULLI PRINCIPLE

- Therefore decrease in potential energy
- If this pressure falls below atmospheric pressure, can entrain gas/fluid via the side hole at the constriction
- Example is a nebulizer and the oxygen mask

THE GAS LAWS

- Boyles Law
- Charles Law
- Third Perfect Gas Law
- Dalton's Law of Partial Pressures
- Universal Gas Constant

BOYLES LAW

- At constant temp, $V \propto 1/P$
- How much oxygen is available at atmospheric pressure in a tank?
- Internal capacity of cylinder = 10L
- Absolute Pressure = 138 bar
- Therefore, volume = 1380L
- $P_1V_1 = P_2V_2$
- 13800kPa x 10L = 100kPa x 1380L

CHARLES LAW

- At constant pressure, $V \infty Temp$
- Gases expand when heated

THIRD PERFECT GAS LAW

- At constant volume, P ∞ Temp
- STP – 273.15K and 101.325kPa

ADIABATIC CHANGE

▫ The three gas laws describe the behaviour of a gas when one of the three variables (pressure, temp or volume) is constant.

▫ For these conditions to apply, heat energy is required to be added or be taken from a gas

▫ The state of a gas can also be altered without allowing the gas to exchange heat energy with its surroundings

ADIABATIC CHANGE

- The state of a gas can be altered without allowing the gas to exchange heat energy with its surroundings

- An example is the use of the cryoprobe

- If a gas cylinder connected to an anesthetic machine is turned on quickly, the pressure of gas in the connecting pipes and gauges rises rapidly

ADIABATIC CHANGE

- Thus, the gas is compressed adiabatically and a large temp rise with the associated risk of fire can occur

DALTON'S LAW OF PARTIAL PRESSURES

- In a mixture of gases, the pressure exerted by each gas is the same as that which it would exert if it alone occupied the container

AVOGADRO'S NUMBER

- States that equal volumes of gases at the same temp and pressure contain equal number of molecules

- Avogadro's number = 6.022×10^{23}

- One mole of any gas occupies 22.4L at STP

BREATHING SYSTEMS

- Breathing Circuitsa)Open (non-rebreathing) •Simple face mask or nasal cannula (CO_2 diffuses away from the face) •Bag-Valve-Mask system (Ambu®): uses 3 valves to allow either spontaneous or controlledventilation while preventing rebreathing b)Semi-Open (Mapleson / Bain)•Most efficient removal of CO_2 for a given gas flow when the "pop off" valve is nearest the source of the ventilatory power -Spontaneous ventilation: Mapleson A -Controlled ventilation: Mapleson D•However, the "A" system is very inefficient (requires high gas flows) to prevent rebreathing during controlled ventilation, while the "D" system is reasonably efficient for both controlled and spontaneous ventilation, so the "D" is preferred for most applications. -Bain circuit is a coaxial Mapleson Dc)Semi Closed Circle System •Patient gas uptake < fresh gas flow < minute ventilation •Some rebreathing of exhaled gas (following removal of CO_2 by absorber)d)Closed System •Gas inflow = Patient Uptake •If using sidestream agent / CO_2 analyzer, must route exhaust back into circuit •Starting values-O2: 3-4 ml/kg/min

AVOGADRO'S NUMBER

- Typical Nitrous cylinder has 3.4kg of Nitrous Oxide
- Molec wt = 44 (1 mole)
- 1 mole occupies 22.4L at STP
- 3400g occupies 22.4 x 3400/44 = 1730L

UNIVERSAL GAS CONSTANT

- PV = nRT

- In a cylinder, the volume and temp is constant

- Therefore, P is ∞ n

- Implies that the pressure gauge acts as a contents gauge if the cylinder contains a gas

CRITICAL TEMP

- Defined as the temp above which a substance cannot be liquefied however much pressure is applied
- Critical Pressure is the vapour pressure at the critical temp
- Critical temp for nitrous is 36.5 degrees – it is a gas if the temp is above 36.5

CRITICAL TEMP

- Critical temp for oxygen is -119 degrees
- Impossible to turn oxygen into its liquid form at room temp

SOLUBILITY

- When a liquid is placed in a closed container, an equilibrium is eventually established at the surface between the vapour of the liquid and the liquid itself.

- In this equilibrium state, the partial pressure exerted by the vapour is known as saturated vapour pressure

SOLUBILITY

- Saturated Vapour Pressure
- Henry's Law – states that at a particular temp, the amt of a given gas dissolved in a given liquid is directly proportional to the partial pressure of the gas in equilibrium with the liquid
- As a liquid is warmed, less gas dissolves in it --- may see bubbles (Blood warmer)

SOLUBILITY

- The effect of high pressure on the solubility of nitrogen is particularly relevant to deep sea divers as nitrogen if breathed under pressure passes into solution in the tissues

- If a return to atmospheric pressure is made too rapidly, the nitrogen comes out of solution as small bubbles in the joints and elsewhere

SOLUBILITY

- Ostwald Solubility Coefficient is the volume of gas which dissolves in one unit volume of the liquid at the temp concerned
- Independent of pressure

SOLUBILITY

- Partition Coefficient is defined as the ratio of the amount of substance present in one phase compared with another, the 2 phases being of equal volume and in equilibrium

SOLUBILITY

- Ether has the highest Ostwald Solubility Coefficient (12). Halothane is 2.3 and Nitrous is 0.47

- Ether carried away more rapidly from the lungs – conc of ether builds up more slowly in the alveoli --- slower induction of anesthesia

SOLUBILITY

- Second Gas effect
- Diffusion hypoxia

SECOND GAS EFFECT

▫ During the inspiration of a gas mixture containing nitrous oxide, the N2O is absorbed into the bloodstream faster than the oxygen or nitrogen.

▫ So at peak inspiration, when the pressure in the alveoli has equalized with the ambient pressure, there is a net surplus of oxygen and N2 molecules

DIFFUSION HYPOXIA

- At the end of an anesthetic using N2O, the N2O diffuses faster into the alveoli diluting the gases there ---- leads to a fall in oxygen concentration

SOLUBILITY

- Fat is an impt constituent of tissue
- Oil is therefore used for measurements
- Agents with the highest oil solubility have the greatest potency
- Halothane = 224
- Nitrous Oxide = 1.4
- Sevoflurane = 55
- Desflurane = 18.7

SOLUBILITY

- High solubility = lower MAC values
- Anesthetics tend to interfere with the molecular configuration of the long fatty acid at a critical point within the neurones
- Attachment to the chain is loose and readily reversible with Van der Waals forces

SOLUBILITY

- Also attach to the long carbon chain molecules present in rubber and plastics

DIFFUSION AND OSMOSIS

- Diffusion is the process by which the molecules of a substance transfer through a layer such as the surface of a solution

- What is more likely to happen if diffusing capacity in the lungs are decreased?

DIFFUSION

- Pulmonary Diffusing Capacity
- Rate at which CO leaves the alveoli is dependent on the rate of diffusion through the membrane and not on pulmonary blood flow
- Sarcoidosis, Asbestosis

EFFECT OF MOLECULAR SIZE

- Grahams Law states that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight

- Example – Injection of local anesthetics – inject as close as possible to the nerve because diffusion only allows limited penetration of the LA into the tissues

OSMOLARITY

- Is the sum total of the molarities of the solutes in a solution

- RL has an osmolarity of 278mosm/l (Na 131, K 5, Cl 111, Ca 2, Lactate 29

- Plasma has an osmolarity of 300 >99% due to Na, Cl, HCO3. Plasma proteins account for 1 mosm/l

OSMOLARITY

- If a patient is transfused hypotonic fluids – get changes in the osmotic pressure gradient across cell membranes – fluid diffuses into cells.

- Albumin and globulin give rise to an oncotic pressure of 26mmHg

- Decreased oncotic pressure – decreased gradient at the venous end - edema

OSMOLARITY

▫ Number of osmoles per kg of water or clear solution

▫ Avoids the effect of temp which affects volume

HEAT CAPACITY

▫ Specific Heat Capacity is defined as the amount of heat required to raise the temp of 1kg of a substance by 1 kelvin. J per kg per kelvin

▫ Heat Capacity is the amount of heat required to raise the temp of a given object by 1 kelvin.

HEAT CAPACITY

- Body temp = 36 degrees
- Shivers – increases heat production 4 fold to 320W. Basal level of heat production is 80 W
- An extra 240W = 14.4 kJ/min
- 245kJ needed to increase temp by 1 degree . (total heat capacity = 3.5 x 70kg)

HEAT CAPACITY

- This patient will need to shiver for 17 minutes to produce the heat required to do this

HEAT CAPACITY
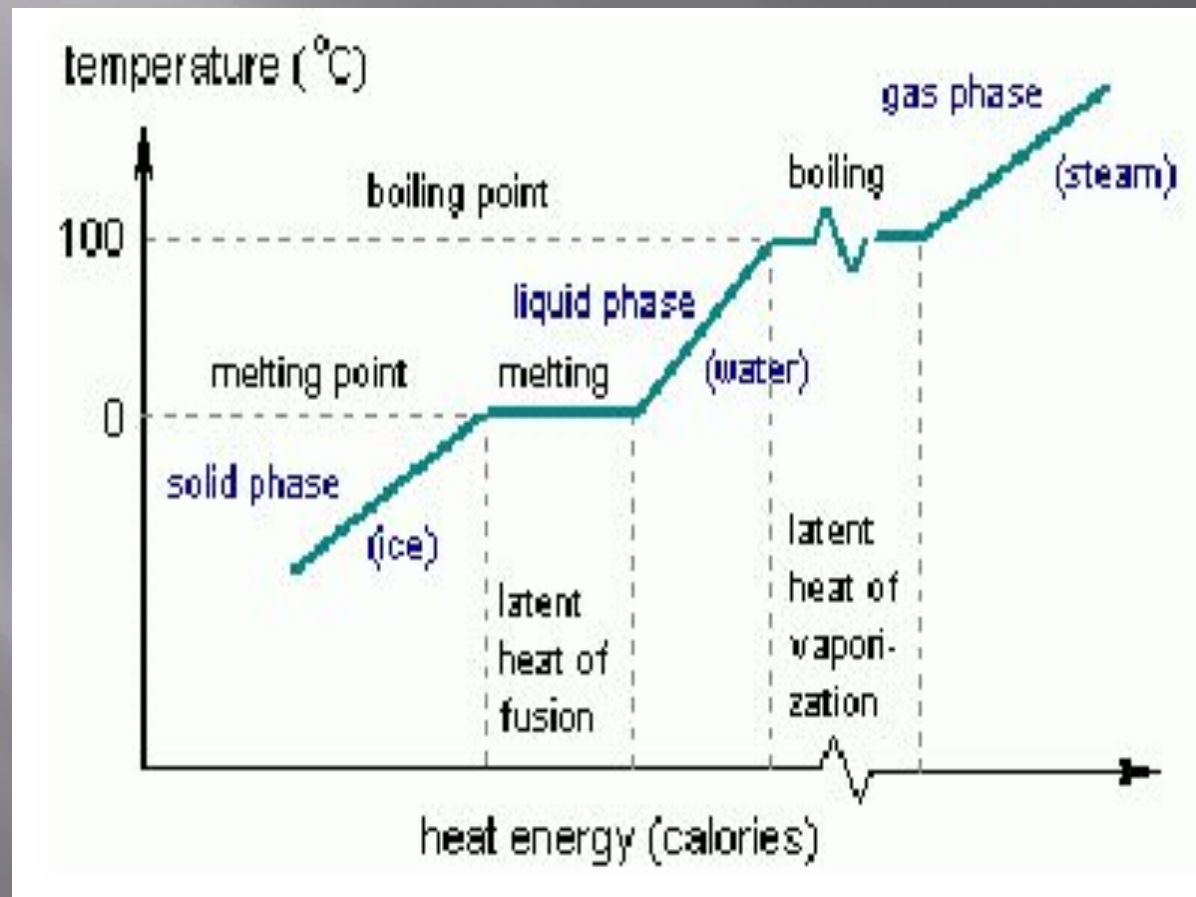
- Specific Heat Capacity of blood = 3.6kJ/kg/C
- Transfuse 2L of blood at 5 degrees
- Warmed to 35 degrees in the patient

HEAT CAPACITY

- Heat Required = 216kJ (2x3.6x30)
- Heat Capacity of 70kg person = 245kJ/C
- Therefore temp must fall by 1 degree

THE ANESTHESIA MACHINE

THE ANESTHESIA MACHINE

- N_2O is stored in the tank as a liquid in equilibration with the N_2O gas above it.
- As we draw N_2O gas from the tank, it is replaced with gas that boils off from the liquid below it.
- The heat required for this phase transition is drawn from the cylinder which draws it from the air around the tank
- Results in the cylinder cooling

THE ANESTHESIA MACHINE

- Why does the pressure go down as the gas cools?

THE ANESTHESIA MACHINE

- The pressure in the tank reflects the force of the molecules bouncing off every part of the wall tank.

- Pressure = Force of the molecules as they bounce off the surface divided by the surface area of the tank.

- Force of each molecule reflects the thermal energy of the molecule.

THE ANESTHESIA MACHINE

- Thermal energy is taken out of the nitrous tank by heat of vaporization.

- Therefore, the collision between each molecule and the wall of the tank is less energetic ---- therefore the pressure drops

- Gay- Lussac's Law – pressure is inversely related to temperature when volume is constant

THE ANESTHESIA MACHINE

▫ As oxygen is drawn from the tank, both the temp and pressure drop over time.

▫ The pressure drops because we are removing gas from the tank

▫ The temp drops because the released molecules take their thermal energy with them – also contributes to the loss of pressure

CIRCULATION

- Ohm's Law
- Pressure = Flow x Resistance
- Voltage = Current x Resistance
- Resistance = Pressure/Flow

CIRCULATION

- SVR = (MAP – CVP)/CO
- Poiseulle's equation – Resistance to flow is proportional to $1/r^4$
- Arterial blood pressure is measured
  - by the auscultatory method
  - by the oscillometric method
  - invasively

CIRCULATION

- $P = 2T/R$

- Failing heart – Increase in R and therefore a decrease in P. Unable to increase T

- Normal Heart – Increase in R due to increased VR. Also get an increase in T (Frank Starling). Therefore no change in P

CIRCULATION

- MAP dependent on SVR and CO
- Patient with a decreased SVR, a high BP indicates an increased CO
- In a patient with an increased SVR, a high BP indicates a decreased CO

AUSCULTATORY METHOD

- Based on the Korotkoff sounds
- The systolic and diastolic pressures are determined and the mean is calculated
- MAP = DBP +1/3PP
- Not readily calibrated

OSCILLOMETRIC METHOD

- Based on pressure waveform in an air filled cuff coupled to the arterial pulse
- Primarily determines MAP which is the point of maximum oscillation
- Systolic and diastolic is inferred from the MAP

INVASIVE MONITORING

▫ Transducer is a strain gauge that linearly converts pressure to electrical resistance

▫ The monitor measures the electrical resistance and calculates the corresponding pressure

▫ Compensate for atmospheric pressure by exposing the back side of the strain gauge to air

INVASIVE MONITORING

▫ Strain Gauge – movements of the diaphragm alter the tension in the resistance wire – changes resistance – changes current flow – amplified and displayed on an oscilloscope

INVASIVE MONITORING

- Wheatstone Bridge
- 4 resistors, a source and a galvanometer
- Variable resistor can be zeroed – adjusted until there is a null deflection on the galvanometer
- Strain gauge resistor

INVASIVE MONITORING

- What does it mean to "zero" the transducer?

INVASIVE MONITORING

▫ The act of zeroing the transducer tells the monitor the electrical resistance that should be considered zero pressure

▫ What you are correcting for is

 - minor imperfections in the calibration of the strain gauge

 - the column of water between the left atrium and the transducer

INVASIVE MONITORING

- Column of water between the point that is opened to air and the transducer itself

- Force that this water exerts on the strain gauge is subtracted from the subsequent force measured by the transducer

- Establishes a net pressure in the blood vessel relative to this point

CARDIAC OUTPUT

- Gold standard for measuring cardiac output is by applying Fick's Law to oxygen flow
- Net flow of oxygen into blood as it courses through the lungs = 200mls/min
- Net flow of oxygen out of the lungs = cardiac output x (Arterial oxygen content – Mixed venous oxygen content)

PULSE OXIMETRY

- Beer Lambert Law
- Absorption of light = Concentration x Thickness x extinction coefficient
- Has two diodes
- At 660nm, little absorption by oxyhemoglobin
- At 940nm, little absorption by deoxyhemoglobin

PULSE OXIMETRY

- Beer's Law states that the absorption of radiation by a given thickness of a solution of a given concentration is the same as that of twice the thickness of a solution of half the concentration

PULSE OXIMETRY

- Lambert's Law states that each layer of equal thickness absorbs an equal fraction of radiation which passes through it

PULSE OXIMETRY

▫ The diodes alternate at about 100 times a second between 660nm, 940nm and off

▫ A single photocell on the opposite side of te tissue records the transmitted signal and sends it to the microprocessor
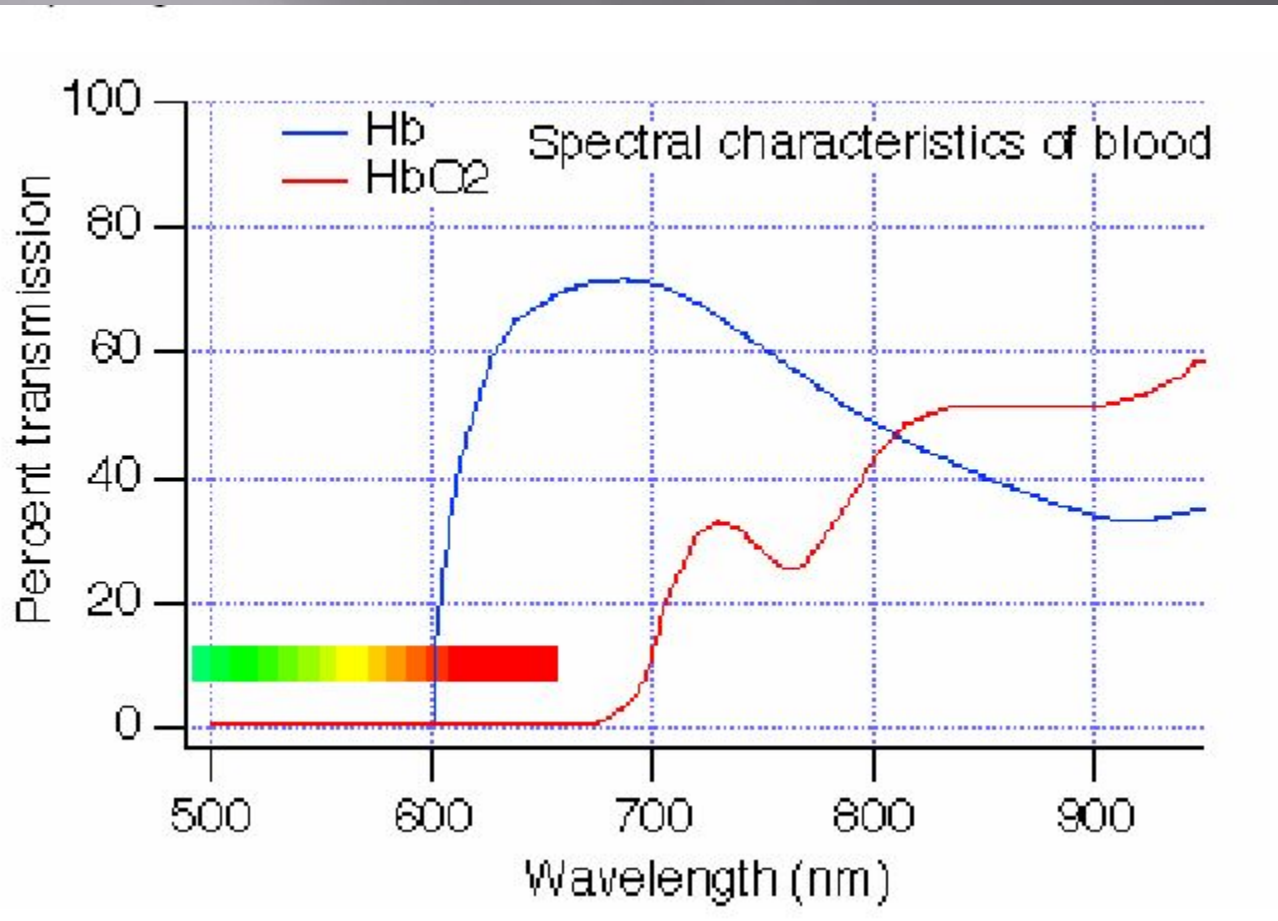
PULSE OXIMETRY

▫ Two parts to the waveform

- static component which represents the absorption of the tissue, venous blood, nail polish, etc

- oscillating component which represents the absorption by arterial blood

PULSE OXIMETRY

- ▫ On the assumption that the tissue thickness is the same for both oxyHb and deoxyHb, the microprocessor solves two simultaneous equations for the relative concentrations of oxyHb and deoxyHb

PULSE OXIMETRY

PULSE OXIMETRY

- Unable to distinguish more that two types of Hb

- Cannot identify carboxyHb --- to the pulse oximeter, it appears to be 90% oxyHb, 10% deoxyHb

- MetHb is interpreted as 85% oxyHb and 15% deoxyHb

- A proper blood gas machine has 9 to 13 wavelengths to distinguish multiple Hb moieties

ELECTRICAL SAFETY

- Two major hazards
  - burns
  - arrhythmias

ELECTRICAL SAFETY

Three types of electrical current

    - macroshock

    - microshock

    - radiofrequency currents

ELECTRICAL SAFETY

- A power station supplies electricity at very high voltage to a substation where the voltage is reduced by a transformer.

- Current the passes to the hospital along 2 wires – live and neutral. The neutral wire is connected to earth at the substation

- Mains electric sockets in the hospital provide connections to the live and neutral conductors and also to a third conductor

ELECTRICAL SAFETY

- Third conductor is connected to earth at the hospital.

- If a person touches a live wire at the hospital, an electric current can be completed through the body, through the earth and back to the substation

ELECTRICAL SAFETY

- 1 mA = tingling sensation on touching the live parts of the apparatus

- Current which flow through the anesthetist depends on the impedence presented to this flow

- Impedence of antistatic footwear and the floor is about 240kohms

- Current is therefore less than 1mA

ELECTRICAL SAFETY

- If you are wearing non standard footwear and standing in a pool of saline on the floor while in contact with faulty equipment, a higher current flows.

- A current of greater than 1mA flows. A current of 24 mA would result in being unable to release your hand from the equipment.

ELECTRICAL SAFETY

- Most of the impedence now occurs at the points of contact with the skin and the feet with the shoes. May be around 5kohms
- Current = 120 volts/ 5000ohms x1000

$\qquad$ = 24mA

ELECTRICAL SAFETY

- Risk of VF

- Risk is much greater if the current passes through the heart during repolarization – early T wave of the EKG

- Mains alternating current of 50 Hz is more dangerous than high frequency current of 1kHz or greater

- Underlying myocardial disease

CLASS 1 EQUIPMENT

- Any conducting part that is accessible to the user, such as the metal case of an instrument, is connected to an earth wire which becomes the third wire connected via the plug to the mains supply socket
- If a fault occurs, a high current flows which melts a protecting fuse and disconnects the circuit

CLASS 2

- Double insulated equipment
- All accessible parts are protected by 2 layers of insulation or reinforced insulation
- An earth wire is not required

CLASS 3

- Internally powered equipment
- Has its own power source located within the equipment
- Although the risk of electric shock may still be present, the particular risks associated with mains electricity are avoided

ISOLATED PATIENT CIRCUITS

- Some equipment requires electrical connections be made to the patient (monitors)
- A deliberate attempt is made to reduce the impedance at the junction between the electrode and the skin
- Decreases the protection that the skin might otherwise offer

ISOLATED PATIENT CIRCUITS

- To counteract this, use an isolated patient circuit or a floating circuit

- The electrical circuit is divided into two parts – a mains part which contains a power supply driven directly by the mains and an isolated part which is separated from the mains part by an electrical barrier

ISOLATED PATIENT CIRCUIT

- Intended to provide protection should a fault develop in the mains part and to reduce flow of mains leakage currents in the patient circuit.

LEAKAGE CURRENT STANDARDS

- Electromedical equipment is classified according to the maximum leakage current permissible for particular applications

- CF – electrodes which may contact the heart directly. Indicates cardiac use and a floating circuit. Leakage current should be less than 50uA

LEAKAGE CURRENT STANDARDS

▫ B or BF it it has a floating circuit. Leakage current of 500uA

▫ All new equipment in a hospital is subjected to an acceptance test which will verify leakage currents.

ELECTRICAL SAFETY

▫ Electrical currents flow in circuits

▫ A path must exist from the electrical source to the patient and another path from the patient back to the electrical source for a shock hazard to exist

▫ Ohm's Law $I = V/R$

▫ Current density is the amount of current flowing per unit area

ELECTRICAL SAFETY

- Standardized voltage is about 120V
- The "120" is the root mean square voltage
- Alternating current cycles at 60 Hz
- Average voltage is therefore 0
- If one squares all the voltages and the takes the average, the result is 120V
- The peak voltage is about 150V – is the potential driving energy

ROOT MEAN SQUARE

- If all the values of the sine wave are squared, all the amplitudes are converted to positive numbers

- By taking the mean of this, a value is obtained which is related to the amplitude of the wave

- Square root of this figure is the equivalent DC value

MACROSHOCK

▢ Potential for both burns and arrhythmias

▢ Current must flow through the thorax

▢ In the thorax it is split between the chest wall and the great vessels – delivers the current density to the myocardium.

MACROSHOCK- FACTORS FOR ELECTROCUTION

- Patient unclothed and wet
- Patient is on a large metal table, frequently electrically operated
- Patient is surrounded by electrical devices. These electrical devices are exposed to spilled fluids and operator abuses
- Anesthetized patient is unable to respond or withdraw from an electric shock

MACROSHOCK

How much current can we deliver to the anesthetized patient?

MACROSHOCK

- Patient may receive 150 volts with direct contact
- The current he receives will depend on the resistance to flow ($I = V/R$)
- Main resistance to flow is the skin
- Resistance of dry skin is 50000 ohms
- Current through dry skin is 150V/50 000 which is 0.003A or 3 mA

MACROSHOCK

- Current required to produce VF is 80mA
- Therefore 3mA will not cause VF
- Resistance of wet skin is about 500 – 1000 ohms (this is also about the resistance of EKG electrodes)
- Current could therefore be 300mA ----- VF is a major risk

MACROSHOCK

What is the voltage required to produce an 80mA current across wet skin?

V = I x R ----- 500 x 80 = 40 volts

MACROSHOCK

- ▫ How could a patient come into contact with 40 volts in the OR?

MACROSHOCK
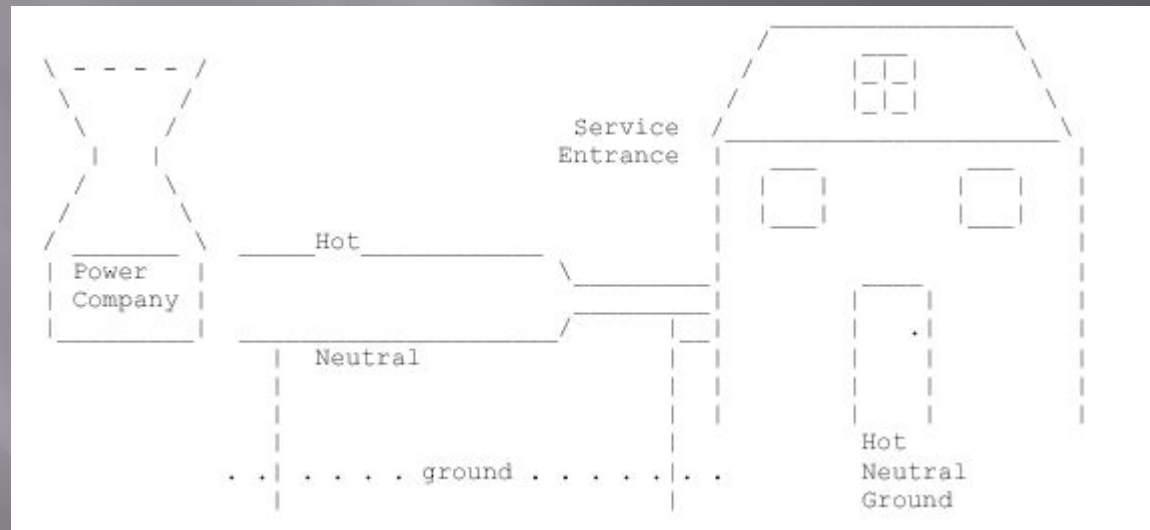
MACROSHOCK

- Hot and neutral leads power the device
- Ground lead connects to the chassis of the device to return any leaking current back to the ground
- If the chassis is properly grounded, then current will flow through the ground wire which has very little resistance – current will be high and a fuse will blow

MACROSHOCK
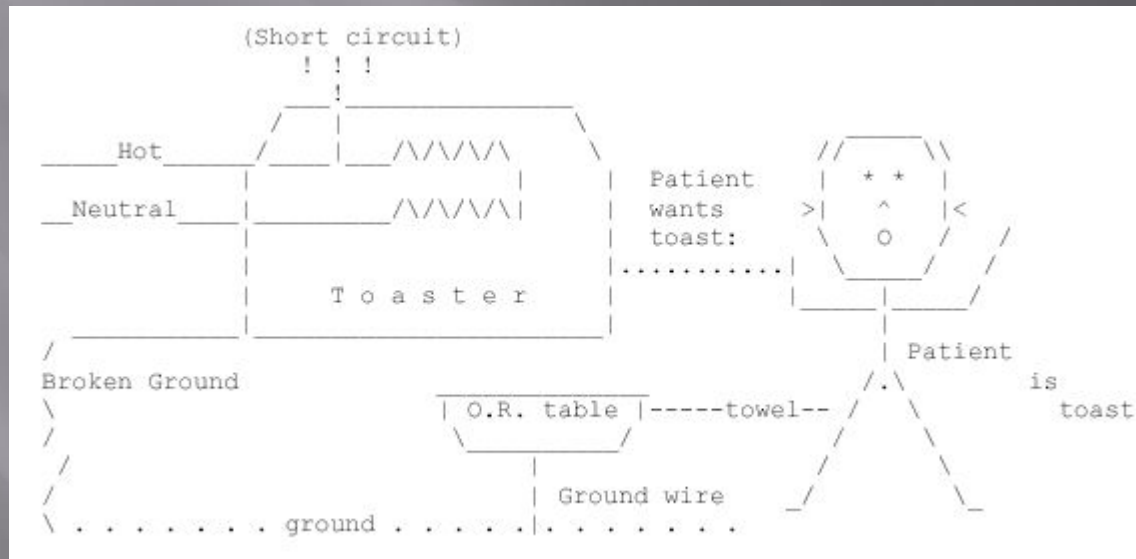
MACROSHOCK

- To avoid helping electrocute the patient, no properly functioning modern monitoring device will complete a circuit between the patient and ground
- The ground plate on the electrocautery unit is merely the return electrode and not a true ground
- NOT GROUNDING PATIENTS IS AN IMPORTANT ASPECT OF ELECTRICAL SAFETY IN THE OR

MACROSHOCK

- Equipment must be designed so the the hot wire cannot easily short out with the chassis
- Every chassis must be grounded
- Ground wires must be regularly inspected
- Patient should not be connected to potential grounds
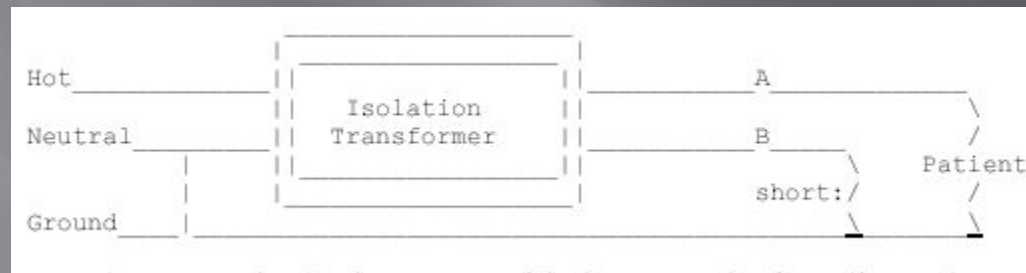- Line Isolation Monitors

LINE ISOLATION TRANSFORMER

▫ Simple device that prevents a circuit from being completed by connection to ground
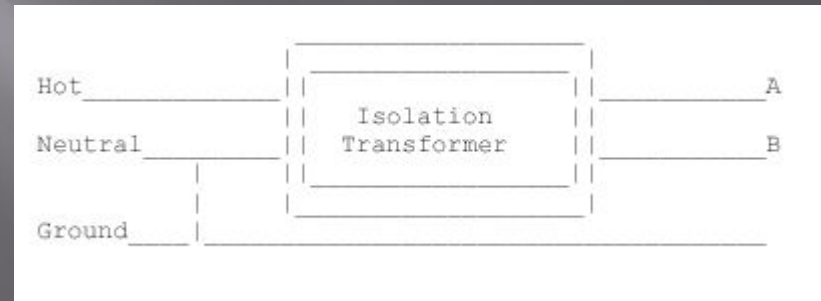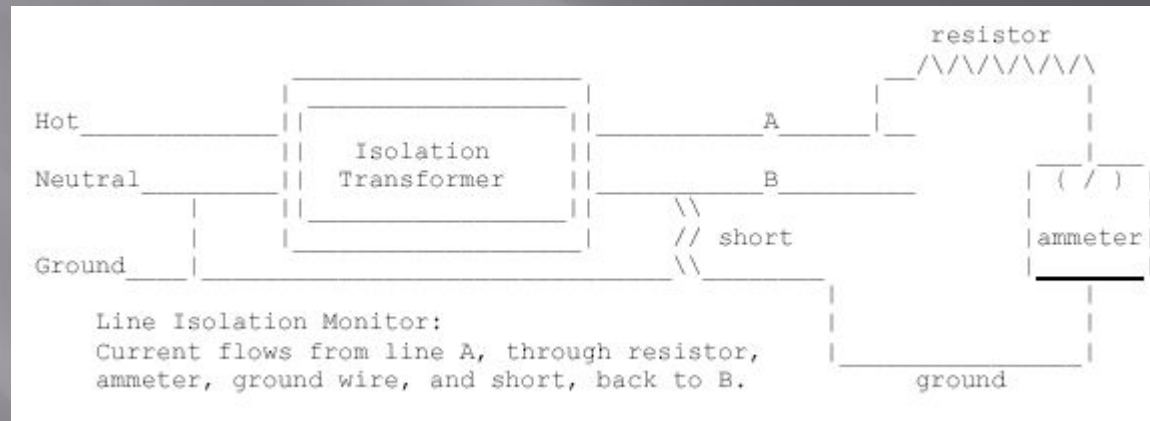
LINE ISOLATION TRANSFORMER

LINE ISOLATION TRANSFORMER

How do you monitor a line isolation transformer to see if there is any connection between both wire and ground?

LINE ISOLATION TRANSFORMER

LINE ISOLATION MONITOR

▫ Resistor has a resistance of about 150 000 ohm's so that the maximum current that can pass through the circuit is 1mA

▫ When the resistance detected by the Lim falls to less than 75 000 ohm's, a warning is signalled ---- should the other line come into full contact with ground, a current of 2mA could flow

MICROSHOCK

- Refers to currents delivered directly to the myocardium via intracardiac electrodes or catheters.
- Minimum fibrillation threshold is 10 microamps

MICROSHOCK

- How much safety does the isolation transformer provide against microshock hazard?

MICROSHOCK

- Ground wire should be intact
- LIM signals a warning if the resistance between the ground and either wire is less than 75 000 ohm's, which corresponds to a 2mA current running through the ground wire

MICROSHOCK

- In the presence of a LIM, it takes two shorts to the chassis of two devices, with both ground wires broken, to detect a macroshock hazard

- A single short to the chassis of the device with a broken ground can create an undetected microshock hazard

ELECTROCAUTERY

- Current density = current flow per unit area
- Explains the heating effect of the electrosurgical equipment
- Passage of direct current or low frequent alternating current may cause physical sensation, stimulate muscular contraction and gives a risk of VF

ELECTROCAUTERY

▫ These effects become less as the frequency of the current increases being small above 1 kHz and negligible above 1 MHz. The burning and heating effect can occur at all frequencies

ELECTROCAUTERY

- Electrosurgical equipment is used to pass a current of a high frequency (1Mhz) through the body to cause cutting and coagulation by local heating of the tissues

- Degree of heating depends on the current density

ELECTROCAUTERY

- Two connections – neutral or patient plate and the active or cutting electrode
- The same current flows through both plates
- At the cutting electrode, heating or burning occurs because of the small area
- No burning should occur at the neutral plate due to the large surface area

ELECTROCAUTERY

- If the neutral plate is not properly applied, the area of contact can be reduced so that burns can now result at points where the plate is in contact with skin.

- If the neutral plate is completely detached, the current may return to the cautery unit via any point at which the patient is in contact with an earthed metal object

ELECTROCAUTERY

- Current density can reach a hazardous value when the electrosurgical current flows through parts of the body that have small cross sections
- Current density can be increased by metallic prosthesis
- Bipolar cautery

ELECTROCAUTERY

- Frequencies of 500 00- to 2000 000 Hz are used by electrocautery
- Too high to fibrillate the heart
- Major concern is burn protection

ELECTROCAUTERY

- The grounding plate does not ground the patient to ground

- It is the return electrode to the electrocautery unit

- Ground plates should not be placed over metallic prosthesis

CAPACITANCE

- Is a measure of the ability of an object to hold electric charge
- Charge is the measure of the amount of electricity
- Coulomb = amperes x seconds

DEFIBRILLATOR

- Is an example of an instrument in which electric charge is stored and then released in a controlled fashion.

BREATHING SYSTEMS

- Open (non-rebreathing)
- Simple face mask or nasal cannula (CO_2 diffuses away from the face)
- Bag-Valve-Mask system (Ambu®): uses 3 valves to allow either spontaneous or controlled ventilation while preventing rebreathing

BREATHING SYSTEMS

▫ Semi-Open (Mapleson / Bain)

▫ Most efficient removal of CO_2 for a given gas flow when the "pop off" valve is nearest the source of the ventilatory power

▫ Spontaneous ventilation: Mapleson A

▫ Controlled ventilation: Mapleson D

BREATHING SYSTEMS

- However, the "A" system is very inefficient (requires high gas flows) to prevent rebreathing during controlled ventilation, while the "D" system is reasonably efficient for both controlled and spontaneous ventilation, so the "D" is preferred for most applications.
- Bain circuit is a coaxial Mapleson D

BREATHING SYSTEMS

- Semi Closed Circle System

- Patient gas uptake < fresh gas flow < minute ventilation

- Some rebreathing of exhaled gas (following removal of CO_2 by absorber

BREATHING SYSTEMS

▫ Closed System

▫ Gas inflow = Patient Uptake

▫ If using sidestream agent / CO2 analyzer, must route exhaust back into circuit

▫ Starting values-O2: 3-4 ml/kg/min

CO2 ABSORPTION

- **CO2 Absorption Granules**
- **Small enough to have large surface area but large enough to avoid "channeling"**
- **Typically 4-8 mesh**

CO2 ABSORPTION

- Composition
- Sodalime: NaOH, Ca(OH)2
- Baralyme: KOH, Ca(OH)2, Ba(OH)2 -More likely to react with anesthetics to form CO (desflurane) or compound A (sevoflurane)

CO2 ABSORPTION

- Absorption Chemistry • $CO_2 + H_2O \rightarrow H_2CO_3$

- $H_2CO_3 + 2 NaOH \rightarrow Na_2CO_3 + 2H_2O$ + heat

- $Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$ When the NaOH is gone, acidification causes indicator (ethyl violet) to turn "violet"