

# **PHYSICS IN ANAESTHESIA**

- Dr Narendra

# PHYSICS!!!

- Physics is the science of matter and energy and their interaction.
- As anaesthesiologists 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.

# PHYSICS IN ANAESTHESIA

- Measurement Of Mass And Energy
- Pressure Measurement
  - Dynamic Pressure Measurement (Transducer)
  - Signal Processed Pressure Measurements (Noninvasive)
- Measurement Using Sound Energy
  - Passive Sound Examination (Stethoscope)
  - Active Sound Examination (Percussion, Echo, Doppler)

- Measurements Using Electrical Energy
  - Passive Electrical Examination (ECG, EEG)
  - Active Electrical Examination (Neuromuscular Block Monitor, Somatosensory Evoked Potential)
- Measurements Using Light Energy
  - Simple Absorbance Monitors (Capnometers, Anaesthetic Analysers)
  - Processed Absorbance Monitors (Pulse Oximeters)

- Measurements Using Temperature
  - Temperature Monitors (Thermometers, Thermistors, Thermopile, Liquid Crystal)
- Measurement Of Flow
  - Mass And Volume Flowmeters (Urometers, Volumeters)
  - Dilutional Flowmeters (Thermodilution Fick Principle)
  - Velocity And Pressure Flowmeters (Venturi, Pitot)
  - Pressure Flowmeters (Thorpe Tube, Bourdon Tube)
  - Kinetic Energy Flowmeter (Wright Spirometer)

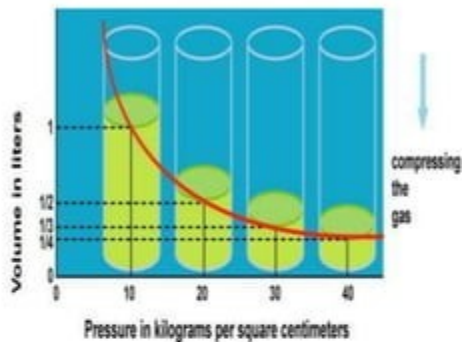
# GAS LAWS

- The relationship between the three variables,
  - Volume
  - Pressure
  - Temperature
- **Volume**: Space occupied by a substance measured in three dimensions
- **Pressure**: Force / unit area
- **Temperature**: measures heat, a form of energy, kinetic energy which comes from movement of the molecules

- **Boyle's law** - at a constant temperature, the product of pressure and volume is equal to a constant,

- $P \times V = \text{Constant}$  (at constant T).

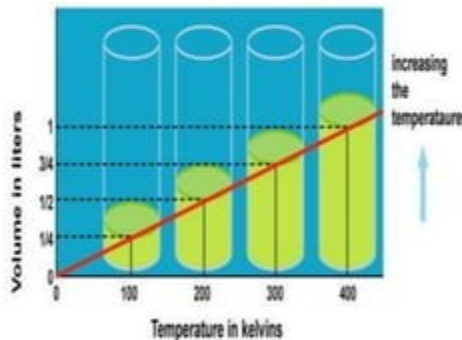
Boyle's Law



- **Charles' law** states that, at a constant pressure, volume is proportional to temperature,

- V is proportional to T (at constant P).

Charles' Law



- **Gay-Lussac's law** states that, at a constant volume, pressure is proportional to temperature,

- P proportional to T (at constant V).

- The most important law of gas flow in airways is the ideal (or perfect) gas law, which can be written as:

$$PV = nRT$$

*where*

P = pressure of gas (pascals or mm hg)

V = volume of gas ( $M^3$  or  $cm^3$  or ml)

N = number of moles of the gas in volume V

R = gas constant ( $8.3143 \text{ J g-mol}^{-1} \text{ K}^{-1}$ , assuming P in pascals, V in  $M^3$ )

T = absolute temperature (in kelvins or K,  $273.16 \text{ K} = 0^\circ\text{C}$ )

- A mole of gas contains  $6.023 \times 10^{23}$  molecules, and this quantity is represented as **avogadro's number**. One mole of an ideal gas takes up 22.4138 liters at standard temperature and pressure (STP)
- Avogadro also stated that equal volumes of all ideal gases at the same temperature and pressure contain the same number of molecules

- **MOLECULAR WEIGHT** - The molecular weight is the sum of the atomic weights, of all atoms forming a molecule of the compound.
- **GRAM MOLECULAR WEIGHT** - The molecular weight expressed in grams is called gram molecular weight.
- **ANAESTHETIC IMPORTANCE:**
- At STP, one gram molecular weight of all gases contain the same number of molecule and occupy the same volume. (22.4 litres).
- The number of molecules in one gram molecule weight of any substance is called Avogadro's number –  $6.023 \times 10^{23}$ .
- Thus 32gms of  $O_2$ , 44gms of  $N_2O$  and 28gm of  $N_2$  will occupy the same volume (22.4 l) and have the same number of molecules.

- **PARTIAL PRESSURE** - In a mixture of gases, the pressure exerted by each gas is the partial pressure and the pressure of a mixture of gases is the sum of the partial pressures of its constituents – **Dalton's law of partial pressure.**
- $P_{\text{Total}} = P_A + P_B + P_C$

- The partial pressure of a gas is important, it decides the movement of the gas across the membranes.
- In alveoli, the process of oxygenation and carbon dioxide elimination occurs on the basis of partial pressure gradient.
- Likewise, the movement of the inhalational agents is also governed by the law of partial pressure

- **NONIDEAL GASES:**

- **THE VAN DER WAALS EFFECT** - Ideal gases have no forces of interaction.

- Real gases have intramolecular attraction and interaction which requires that the pressure-volume gas law

$$\left[ P + \frac{an^2}{V^2} \right] (V - nb) = nRT$$

# DISSOLUTION OF GAS IN A LIQUID:

- **SOLUBILITY COEFFICIENT** - When a gas is kept in a closed container containing water, or any liquid, the molecules of that gas tend to get dissolved in that liquid. The dissolved molecules in that liquid also exert a pressure.
- The amount of gas which goes into the solution into a liquid depends upon various factors.
  - At a particular temp, the amount of a given gas dissolved in a given liquid is directly proportional to the partial pressure of the gas in equilibrium with the liquid- Henry's law.
  - Temperature : the amount of gas dissolved in a hot liquid is far more lesser than in cold liquid.
  - Molecular weight - Rate of diffusion is inversely proportional to the square root of its molecular size – Graham's Law

- **PARTITION CO-EFFICIENT** – The ratio of the amount of substance present in one phase compared with another, the two phases being of equal volume and in equilibrium.
- Determines induction and recovery
- If 1 litre of N<sub>2</sub>O is kept above 1 litre of blood in a closed container, N<sub>2</sub>O tends to get dissolved in blood. At equilibrium, if we measure the amount of N<sub>2</sub>O dissolved in blood, then it will be 0.47 litre. Then, the ratio of 0.47 to 1 is the blood – gas partition co-efficient for N<sub>2</sub>O.
- Application – induction fastest with xenon (0.14) /desflurane (0.42) and slowest with halothane (2.4)

- **OIL SOLUBILITY -**
- **Meyer – Overton theory of anaesthesia.**
- Oil gas solubility coefficient for N<sub>2</sub>O is 1.4, ether is 65, and halothane is 224. So, halothane is a very potent anaesthetic.
- High solubility = lower MAC values
- 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 – concentration of ether builds up more slowly in the alveoli - slower induction of anesthesia.

- **Concentration gradient - Fick's Law** - Rate of diffusion of substance across unit area is directly proportional to the concentration gradient / partial pressure across a membrane.
- **Tension gradient / Partial pressure - Modified Fick's Law** - Rate of diffusion of a substance across a membrane is directly proportional to the tension gradient / partial pressure.
- Flux =  $-D \times C/X$
- Flux is the number of molecules/cm<sup>2</sup>/s crossing the membrane, C is the concentration gradient (molecules/cm<sup>3</sup>), X is the diffusion distance (cm), and D is the diffusion coefficient (cm<sup>2</sup>/s)

- Applications :
  - Helps determine the diffusion of gas across membrane esp alveoli
  - Rate of CO<sub>2</sub> production or oxygen consumption can be used to measure cardiac output by modification of Fick formula

## SECOND GAS EFFECT

- During the inspiration of a gas mixture containing nitrous oxide, the  $N_2O$  is absorbed into the bloodstream faster than the oxygen or nitrogen – Concentration Effect
- So at peak inspiration, when a constant high concentration of anaesthetic is inspired,  $N_2O$  increases the concentration of anaesthetic agent

## **DIFFUSION HYPOXIA (FINK EFFECT/THIRD GAS EFFECT)**

- When water insoluble gases are breathed in large quantity they get dissolved in body fluids rapidly.
- While recovering from N<sub>2</sub>O anaesthesia, large quantities of this gas cross from blood into the alveolus, O<sub>2</sub> and CO<sub>2</sub> in alveolus are diluted.
- Application : Entonox 50:50 (N<sub>2</sub>O+O<sub>2</sub>) provides sufficient pain-relief and avoid hypoxia

- **Vapour pressure** - The partial pressure contributed by various liquids. When a liquid's vapor pressure equals atmospheric pressure, a liquid boils.
- The vapour pressure of a liquid increases with its temperature.

| Vapor Pressure (mmHg) at 20°C |     |
|-------------------------------|-----|
| Halothane                     | 243 |
| Isoflurane                    | 239 |
| Enflurane                     | 175 |
| sevoflurane                   | 157 |
| Methoxyflurane                | 23  |

- **Raoult Law** – reduction in vapour pressure of solvent is proportional to the molar concentration of the solute. Useful to calculate concentration on volatile anaesthetics in azeotropic mixtures.

- **Application**

- Anaesthetic vapour diffusing into breathing circuits and later acting as Vaporizer at the time of discontinuation of anaesthetic.
- $N_2O$  diffusion into the cuff of Endotracheal tube.
- Diffusion of  $N_2O$  into air filled cavities e.g. pneumothorax, intestinal distension, middle ear cavity, air embolism.
- Alveolar capillary membrane – CO TRANSFER TEST

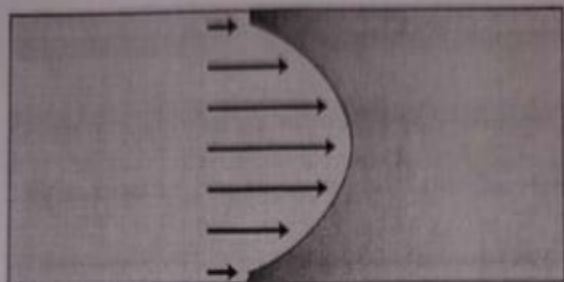
- Pressure is defined as a force per unit area
- Flow (or the rate of flow) is equal to the change in pressure (pressure drop or pressure difference) divided by the resistance experienced by the fluid
- **Hagen- Poiseuille's law** - The fluid flow rate through a horizontal straight tube of uniform bore is proportional to the pressure gradient and the fourth power of the radius and is related inversely to the viscosity of the gas and the length of the tube.

$$P = \frac{8\mu L}{\pi r^4} \times \text{Flow}$$

- When the flow rate exceeds a critical velocity, the flow loses its laminar parabolic velocity profile, becomes disorderly - turbulent.
- The pressure gradient required (or the resistance encountered) during turbulent flow varies as the square of the flow rate.

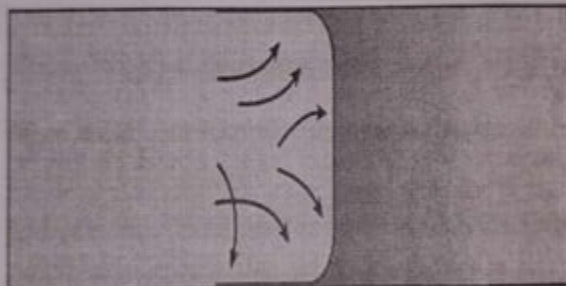
|              |     |                                        |            |   |                   |
|--------------|-----|----------------------------------------|------------|---|-------------------|
| i- Tubes     | Q = | $\frac{\sqrt{\Delta P}}{\sqrt{L P}}$   | P          | = | rho (density)     |
|              |     |                                        | L          | = | length            |
|              |     |                                        | $\Delta P$ | = | Pressure gradient |
| ii- Orifices |     |                                        | $r^2$      | = | Radius            |
|              | Q = | $\frac{r^2 \sqrt{\Delta P}}{\sqrt{P}}$ |            |   |                   |

Laminar flow



A

Turbulent flow



B



Low flows



High flows

- **Application:**

- Using an undersized ETT may cause a tremendous decrease in the flow of gases.
- Every piece of anaesthetic equipment; because of diameters & shape of connectors, number & arrangement will effect FGF. Wide bore & curved rather than sharp angles should be preferred.
- In respiratory tract obstruction, oxygen – helium mixtures are given to reduce density and improve the flow.
- Laminar flow during quiet breathing is changed to turbulent during speaking & coughing leading to dyspnea.
- In the flow meter at low flows, Hagen – Poiseuille's Law applies because the flow is laminar while at higher flows, the law applicable to turbulent flow is applicable.

- **BERNOULLI THEOREM** - The fall in pressure at points of flow constriction
- This phenomenon is used in apparatus employing the Venturi principle
- for example, gas nebulizers, Venturi flowmeters, and some oxygen face masks. The lower pressure due to the Bernoulli effect sucks in (entrains) air to mix with oxygen. It can also be used as a source of laboratory suction.

Energy per unit volume before = Energy per unit volume after

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$$

Pressure  
Energy

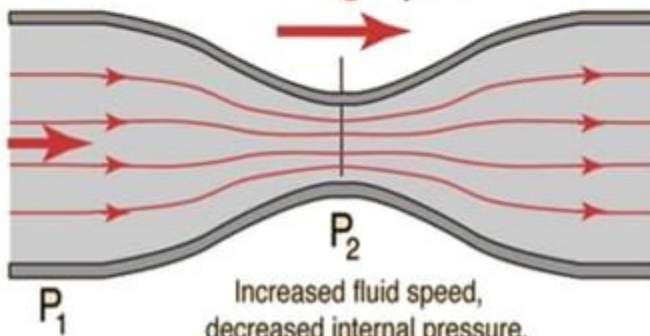
Kinetic  
Energy  
per unit  
volume

Potential  
Energy  
per unit  
volume

The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.

Flow velocity  
 $v_1$

Flow velocity  
 $v_2$



$$A_2 < A_1$$

$$v_2 > v_1$$

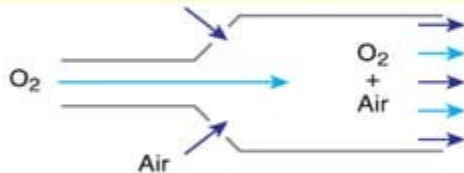
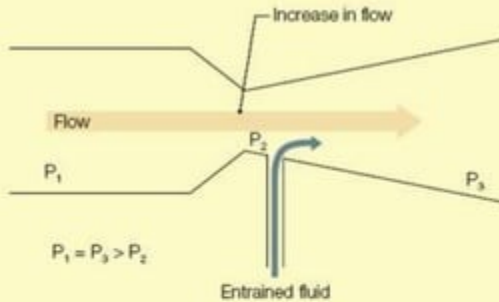
$$P_2 < P_1!$$

## **VENTURI PRINCIPLE –**

- If the flow is laminar, the velocity of all the layers of the fluid will be the same. If the pressure exerted by the running fluid is measured, the pressure will be the maximum at the centre and least near the side walls.
- If this tube is narrowed at the right end, then the velocity of the fluid increases.
- As the velocity of the fluid increases, the pressure loss near the side walls also becomes more. So it records a lesser pressure than before. If the tube is further narrowed on the right end, the velocity of the fluid further gets augmented. If the tube is further narrowed down, at one point, the pressure near the side walls becomes negative.

- The reason for the fall of pressure - Flowing fluid contains energy in two forms; potential energy associated with its pressure and kinetic energy associated with its flow. When the fluid gets speeded up, there is great gain of kinetic energy. Such an increase of kinetic energy can only occur if there is a fall in potential energy, because the total energy present must remain constant. In consequence, a marked fall in pressure occurs at a point, where the fluid flows very fast to that extent that it becomes sub atmospheric. This forms the basis of venturi principle.
- APPLICATION OF VENTURI PRINCIPLE:
  - Diffuser or injector - A jet of gas, say oxygen, is delivered from the cylinder through a high pressure tube and its nozzle. Since the velocity of the jet is high, a negative pressure develops on the two sides of jet.
    - The ambient air is sucked in through the side openings (A&B), so that a mixture of oxygen and air is delivered to the patient. The air sucked in is called 'entrained air'. This device gives a fixed concentration of mixture of two gases.
    - The size of the side openings can be varied so that the amount of entrained air can be altered, so that the final concentration of mixture can be decided by the size of the side openings.
  - Instead of air getting sucked in, fluid can also made to run into the side openings, so that the fluid gets mixed with the fast jet and made to hit upon an object. This hit will break up the fluid into fine droplets which will be carried in the oxygen jet. This is the basic principle behind nebulizers
  - This same venturi principle can also be used in designing suction apparatus, ventilators, & gas mixers.

## Principle of Venturi



For 24% Venturi mask, the typical oxygen flow of 2 L/min gives a total gas flow of 51 L/min.

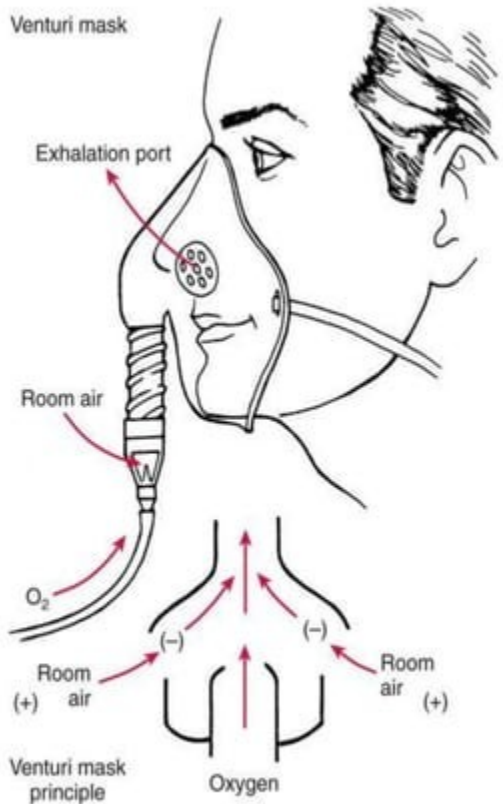
For 28% Venturi mask, 4 L/min oxygen flow gives a total gas flow of 44 L/min.

### Venturi Device / Venturi Mask Valves



Specific and/or Venturi Devices are Responsible for most accurate Oxygen Delivery Systems

## Venturi mask



- **Coanda Effect** - If a constriction occurs at bifurcation because of increase in velocity and reduction in the pressure, fluid (air, blood) tends to stick to one side of the branch causing maldistribution.
- **Application**
  - Mucus plug at the branching of tracheo-bronchial tree may cause maldistribution of respiratory gases.
  - Unequal flow may result because of atherosclerotic plaques in the vascular tree.
  - Fluid logic used in ventilators employs this principle to replace valves or mobile parts.

- **Poynting Effect** – The change in vapour pressure of a liquid when a non-condensable gas is mixed with the vapour at saturated conditions.
- When  $O_2$  and  $N_2O$  are mixed in a cylinder, then critical temperature becomes  $-6^\circ C$  and so mixture remains as gas at room temperature.
- Pseudocritical temperature.

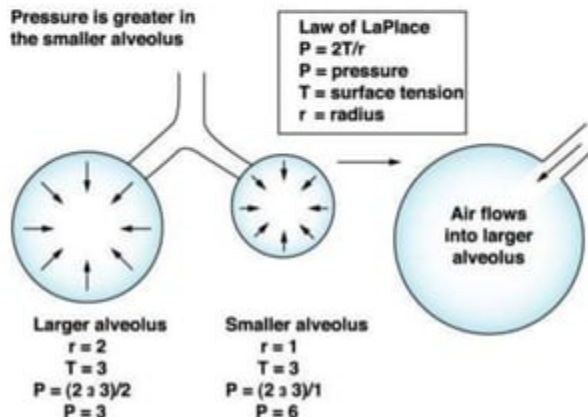
- LAPLACE'S LAW** - for a sphere with one air-liquid interface (e.g., an alveolus), the equation relating the transmural pressure difference, surface tension, and sphere radius is
 
$$P = \frac{2T}{R}$$

Where

P = transmural pressure difference (dynes/cm<sup>2</sup>)

T = surface tension (dynes/cm)

R = sphere radius (cm)

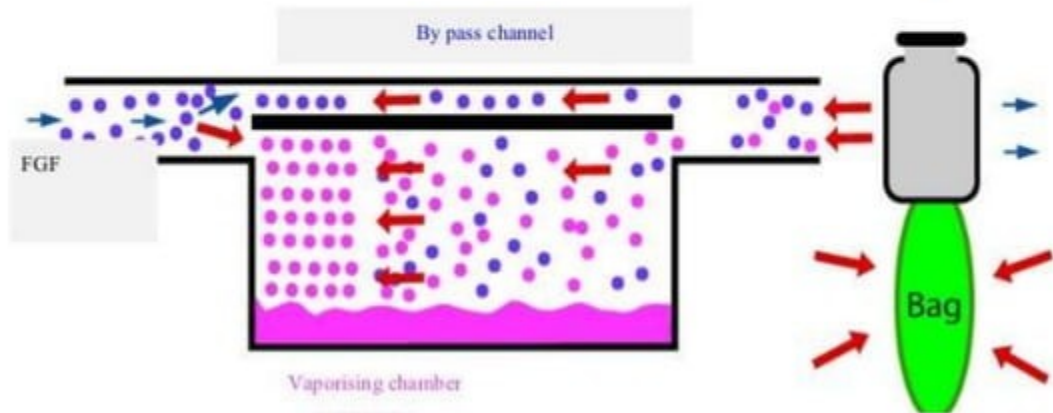
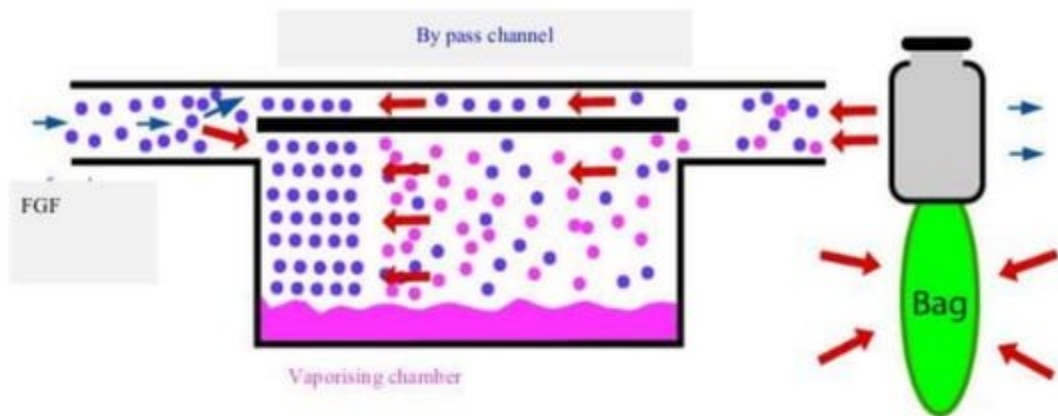


# ADIABATIC CHANGE

- When gas is subjected to sudden compression, heat energy is produced rapidly and the reverse occurs when there is sudden expansion. There is no exchange of energy with surrounding - Adiabatic Change.
- This process is called Adiabatic Process.
- When gas escapes through a narrow opening, there is sudden drop in temperature called Joule Thompson Effect.

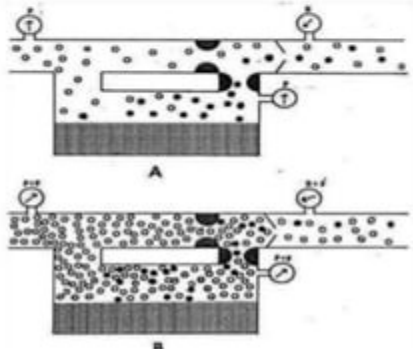
## **PUMPING EFFECT (HILL AND LOWE EFFECT)**

- During positive pressure ventilation, pressure changes are transmitted back into the vaporiser and affects the concentration of anaesthetic gas delivered.
- This effect of changing pressure, affecting the output of the vaporisers – Pumping Effect
- The pumping effect delivers increased concentration of anaesthetic agent.
- Mostly seen with low flows.



# PRESSURISING EFFECT (COLE EFFECT)

- Increased pressure is applied to vaporiser outlet.
- Compress carrier gas so that there will be more molecules delivered.
- Net effect is decrease in concentration of anaesthetic delivered.
- Mostly seen with high flows.

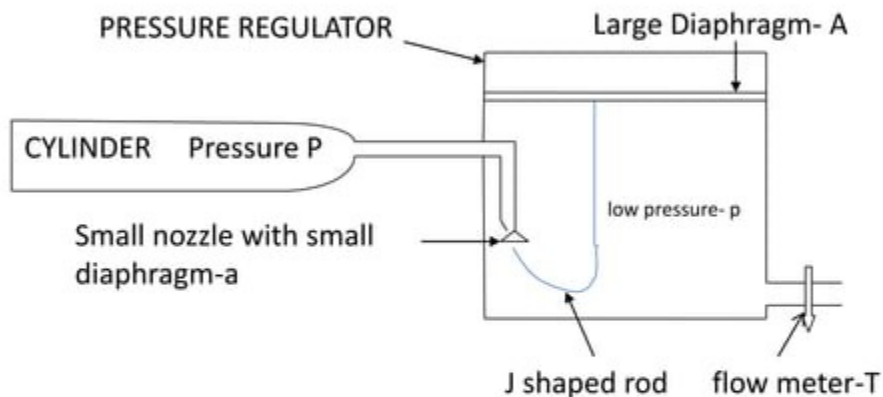


# PRESSURE REDUCING VALVES

- As in equilibrium, pressure in both the containers are same

$$P \times a = p \times A$$

- Large force acting on a small area can be balanced by small force acting on a large area. This is the basic principle governing the pressure regulators.



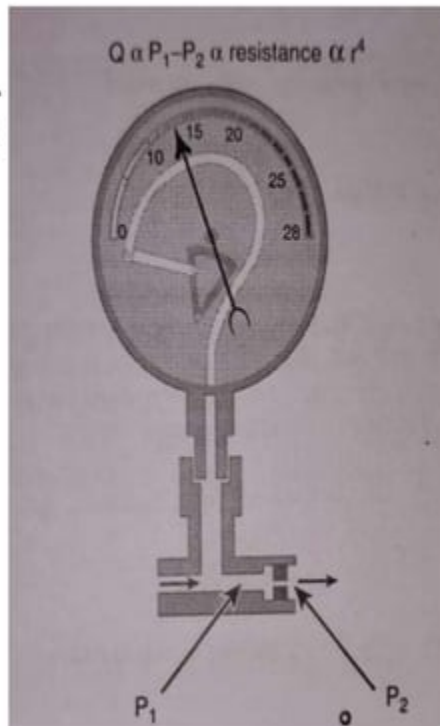
- Modern regulators are called as 'preset regulators', meaning that the output pressure has been set at the factory. In fact, the output pressure can be altered by altering the spring tension

# **SAFETY RELIEF VALVE**

- Pressure regulator valve – this valve relieves the excess pressure beyond a specific limit.
- Spring is attached to plunger, which prevents escape of air in a closed position
- Spring tension can be varied to maintain a set pressure.

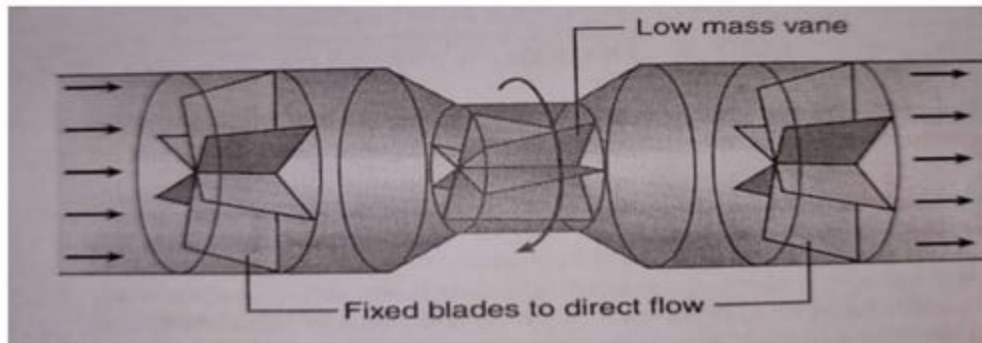
# BOURDON PRESSURE GAUGE

- The soft metal coiled tube is connected to the cylinder gas line. Once the cylinder is open, the gas from the cylinder and yolk enters into the hollow tube and the coiled, hollow tube straightens out.
- This movement is magnified with the aid of levers and a needle is attached to it. The needle moves over a calibrated scale to show the pressure of the cylinder.



# FLOWMETER

- Vanes or propellers placed in confined flow turn at rate proportional to volume flow if there is no friction.
- Wright spirometer
- These devices tend to be less accurate at very high and low flow rate.



# OXYGEN SENSORS

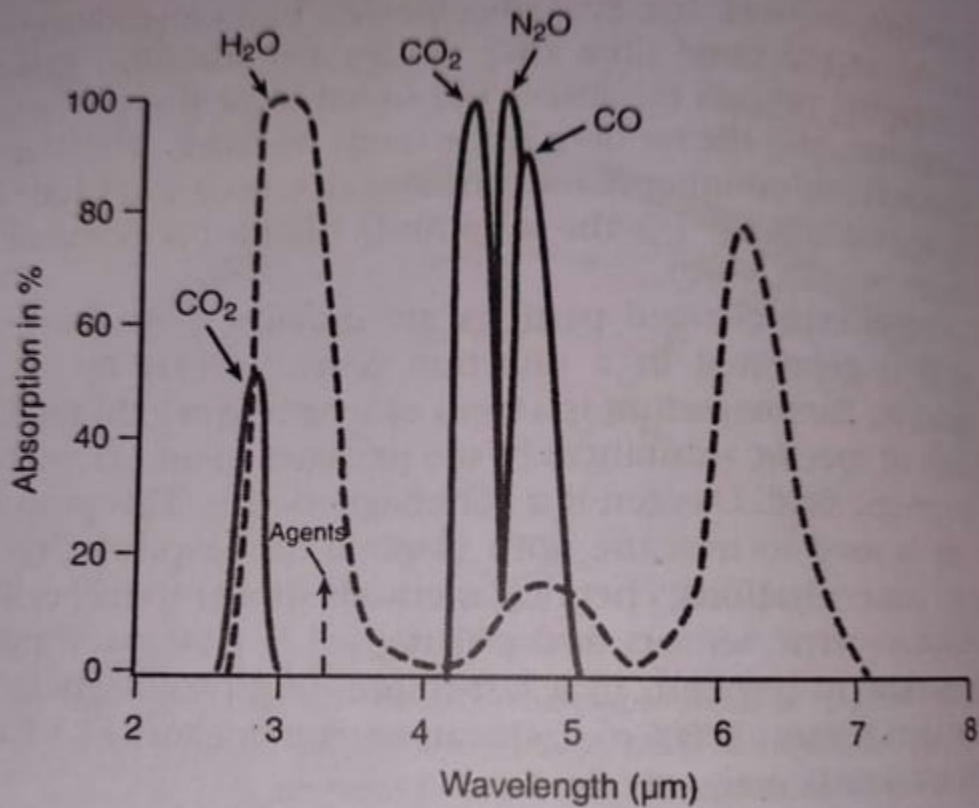
- Fast Responding - Paramagnetism is form of magnetism exhibited only in specific substances in presence of external magnetic field.
  - Oxygen is paramagnetic gas.
  - This property is used to determine oxygen concentration.
  - 100% oxygen exerts 3 Pa in 2.4 tesla magnetic field
- Slow Responding – chemical method - fuel cell amperometric sensor and polarographic electrodes

# SPECTROPHOTOMETRY

- Radiation is of different wave lengths. If radiation is passed through a solution, different wavelengths are absorbed by different substances.
- **Beers Law** - Absorption of radiation by a given thickness and concentration of a solution is the same as twice the thickness with half the concentration.
- **Lamberts Law** - Equal thicknesses absorb equal amounts of radiation.

# PULSE OXIMETRY

- **Principle** - Light absorbed by the blood depends on the quantities of Haemoglobin and DeoxyHb and the wavelengths of the light.
- Absorbance of oxyHb at a wavelengths of 660 nm (red light) is less and that of DeoxyHb is less in 940nm (blue light).
- Absorption of light = Concentration x Thickness x extinction coefficient
- Static component and Oscillating component



# CAPNOGRAPHY

- Follows Beer- Lambert law of absorption to analyse the constituents of gas stream.
- It provides continuous plot of  $P_{CO_2}$  versus time.
- Mainstream and sidestream.
- Volatile anaesthetic analysers and capnographs function by same principle but use different wavelength of light.

# BLOOD PRESSURE MEASUREMENT

- $SVR = (MAP - CVP) / CO$
- Poiseuille'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

# NON-INVASIVE METHOD

- **AUSCULTATORY METHOD** - Based on the Korotkoff sounds, the systolic and diastolic pressures are determined and the mean is calculated
- $MAP = DBP + 1/3PP$
- **OSCILLOMETRIC METHOD** - Based on pressure waveform in an air filled cuff coupled to the arterial pulse
- Primarily determines MAP

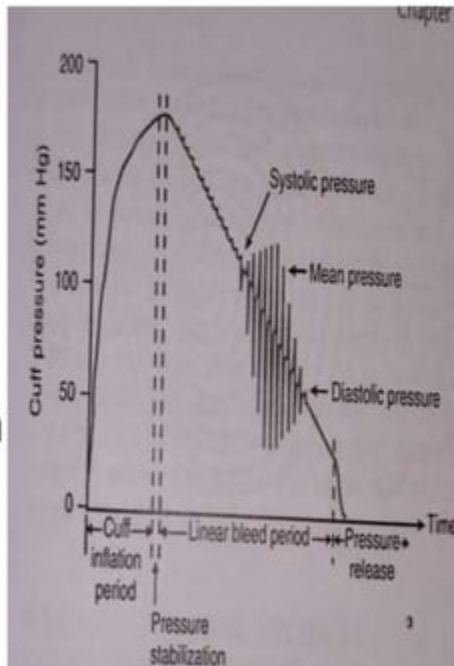


**Figure 44-17.** Noninvasive blood pressure measurement. Using the signal from the arterial pulse, oscillometric blood pressure measurements are obtained by determining the point at which the signal is

# INVASIVE METHOD

- 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

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

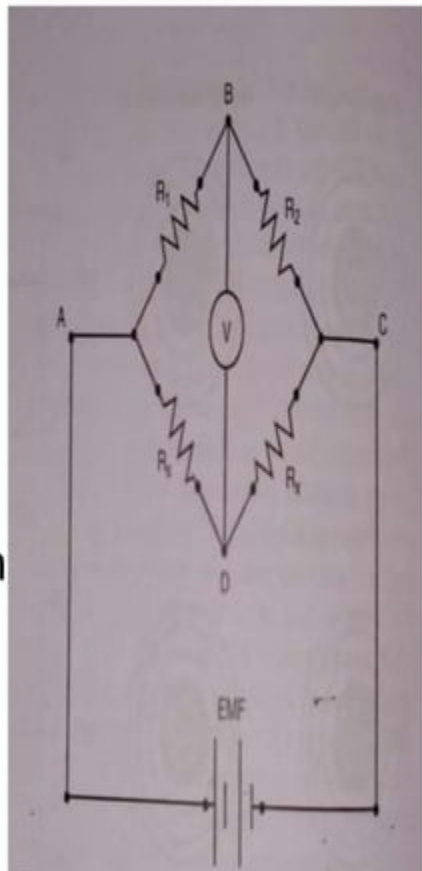
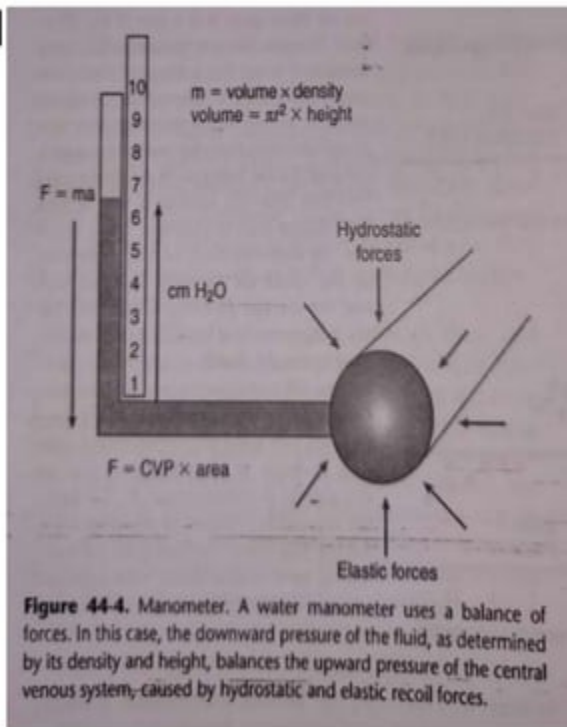


Figure 44.5. Wheatstone bridge. A Wheatstone bridge is an electrical circuit consisting of four resistors arranged in a diamond shape, with a voltage source (EMF) connected across the top and bottom nodes, and a galvanometer (V) connected across the left and right nodes.

# CVP MEASUREMENT

- Hydrostatic forces are used in a liquid manometer.
- It simply uses the weight of measured vertical column of liquid to balance pressure exerted against the bottom of the column.
- Depends on height of column, density of liquid and independent of cross-section area of tube.

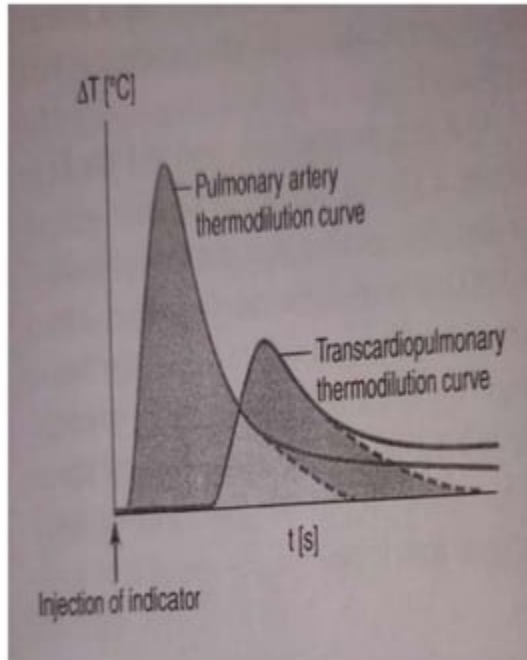


# CARDIAC OUTPUT

- $CO = \text{stroke volume} \times \text{heart rate}$ 
  - Ficks principle – thermodilution and dye dilution
  - PiCCO – pulse induced contour CO
  - Oxygen consumption method
  - Doppler – TOE or TTE
  - Electrical impedance
  - Mobile Application - Capstesia®

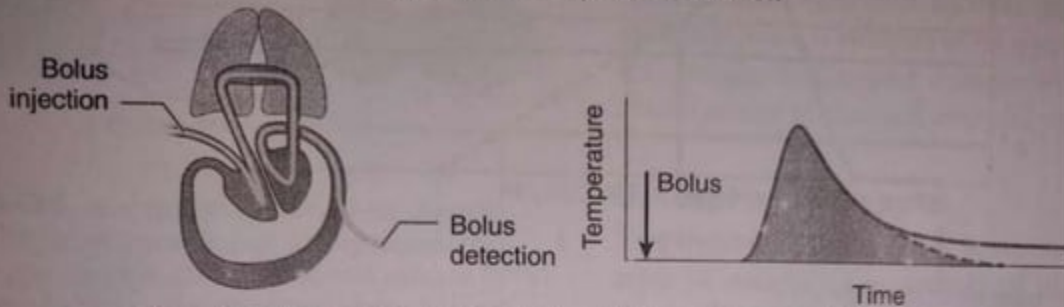
# DYE/THERMO DILUTION

- **Dye Dilution** - If some measurable indicator is injected into a flow and its concentration is measured as a function of time in downstream, then volume flow can be calculated.
- **Thermo Dilution** - Pulmonary Artery thermodilution method. – can measure blood flow aswell.



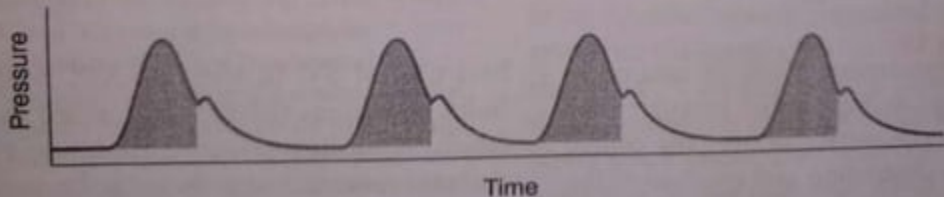
- PiCCO – measured at peripheral artery. Cool saline is injected via central line
- **Fick's Law** - Rate of diffusion of substance across unit area is directly proportional to the concentration gradient / partial pressure across a membrane.
- O<sub>2</sub> elimination - The O<sub>2</sub> consumption divided by A-V difference in CO<sub>2</sub>.
- $CO = VO_2 / (cVo_2 - CaO_2)$
- $A = B + C$
- Capstesia®

## transpulmonary thermodilution



- The cold indicator passes through the right heart, lungs and left heart.
- The indicator is detected in a central artery.
- Precise cardiac output measurement based on Stewart-Hamilton algorithm.
- Breathing cycle independent.
- Passage through the heart and lungs allow determination of preload volumes and lung water.

## Pulse contour analysis



- Stroke volume is reflected by the area under the systolic part of the pressure curve (red area) of one heart beat.
- Cardiac output is calculated beat-by-beat: stroke volume  $\times$  heart rate

# MEASUREMENTS USING ELECTRICAL ENERGY

- **PASSIVE ELECTRICAL EXAMINATION:** ECG, EEG
- Source of EMF are heart and brain respectively.
- ECG potentials on skin are 1mV and EEG potentials are near 0.1 mV.
- Voltage Divider Network. The capacitance of skin attenuate the low frequency components.
- Data Processing or Bispectral Density for analysing raw EEG.
- EEG power spectrum – hemisphere asymmetry and frequency changes.
- Burst Suppression ratio – time during which amplitude is <5microvolt

- **ACTIVE ELECTRICAL EXAMINATION -**
- Neuromuscular Block Monitor – muscle twitch can be elicited by generating a 0.2 to 0.3 msec pulse of current to depolarise a motor nerve.
- Coupling of electrode to patient is important.
- Most common ulnar nerve - adductor pollices
- Functioning of monitor - Positive control and negative control.

- Evoked Response Potentials – can determine status of multiple parts of the sensory nervous system by measuring CNS response to discrete sensory stimulus.
- Stimulus can be auditory, optical or peripheral somatosensory.
- Signal enhancement technique called Ensemble Averaging.
- Averaging process reinforces the signal from evoked response.

# PRINCIPLE OF TEMPERATURE

- Kinetic energy of molecules and atoms defines the temperature.
- When all these movements cease temperature is at Absolute Zero.  $-273^{\circ}\text{C}$  or  $0^{\circ}$  Kelvin.
- Amount of heat required to raise temperature of 1gm of substance by  $1^{\circ}\text{C}$  is specific heat of that substance.
- Calorie is amount of heat required to raise temperature of 1gm of water from  $14.5^{\circ}\text{C}$  to  $15.5^{\circ}\text{C}$ . equivalent to 4.184 J.

# TEMPERATURE MONITORS

- 1. Based on expansion of material as its temperature increases.
- 2. Based on changes in electrical properties.
- 3. Based on optical properties of material.
- **Thermometers** – Based on expansion liquid  
Based on expansion gas –  
Bourdon tube – used in thermostats.

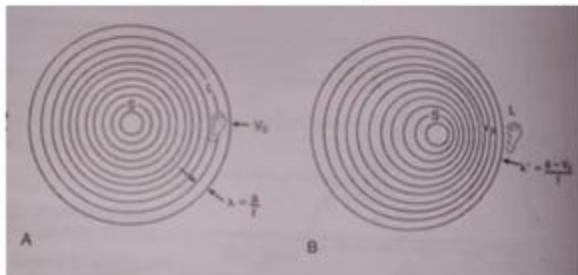
- **Electrical Techniques –**
  - Resistance Thermometers
  - Thermistors
  - Thermocouples
- Resistance thermometers – increase in temperature increases resistance. Platinum thermometers are used.
- Thermistors – semiconductors. Increase in temperature decreases resistance.
- Thermocouples – generate voltage in response to temperature gradient.

- **Optical properties –**

- Thermopile – measures infrared black-body emission of an object. Produces electrical signal.
- Liquid crystal matrix – optical change in colour can be seen with change in temperature. Polarisation .

# DOPPLER EFFECT

- In 1842, Christian Johann Doppler described change in pitch of a sound that occurs when either source of the sound or listener is moving.
- **Doppler Effect** – when listener is moving toward a stationary sound source, frequency increases. When sound source is moving to stationary listener, wavefronts stack up causing increased frequency.



# ECHO / DOPPLER

- Sound waves of frequency ranging from 2 to 10 MHz are transmitted in bursts or pulses.
- After each pulse, transducer passively listens to reflected echoes from various tissues
- This effect is used in echocardiography, oesophageal transducers.
- Doppler – converts doppler shift of sound waves reflected from erythrocytes into colour display. Valvular regurge, aortic blood velocity, flow can be determined.

- **FIBREOPTICS** – use of bundles of very thin glass fibre or plastic fibre which act as a transmission medium for light by total internal refraction and reflection from the boundaries.
  - Fibreoptic scopes, laryngoscopes.
- **LASER DOPPLER** – Laser with doppler is being used to determine skin blood flow.

# REFERENCES

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**THANK YOU!!!**