The basics of physics to the anesthesiologist.

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Application of Physics in Anesthesiology

- Basic knowledge of physics necessary for a full understanding of the functioning of many anesthetic apparatus.

main topics of the lectures

- pressure and flow of gases and liquids.
- electricity and electrical safety.

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)

BASIC DEFINITIONS

- Fundamental values in the physics of mass, length, and are time.

table of physical quantities

	Quantity	Definition	Formula	Units	Dimensions
Basic Mechanical	**Length or Distance**	*fundamental*	d	m (meter)	*L (Length)*
	Time	*fundamental*	t	s (second)	*T (Time)*
	Mass	*fundamental*	m	kg (kilogram)	*M (Mass)*
	Area	$distance^2$	$A = d^2$	m^2	L^2
	Volume	$distance^3$	$V = d^3$	m^3	L^3
	Density	mass / volume	d = m/V	kg/m^3	M/L^3
	Velocity	distance / time	v = d/t	m/s c (speed of light)	*L/T*
	Acceleration	velocity / time	a = v/t	m/s^2	L/T^2
	Momentum	mass × velocity	p = m·v	kg·m/s	*ML/T*
	Force Weight	mass × acceleration mass × acceleration of gravity	F = m·a W = m·g	N (newton) = $kg \cdot m/s^2$	ML/T^2
	Pressure or Stress	force / area	p = F/A	Pa (pascal) = $N/m^2 = kg/(m \cdot s^2)$	M/LT^2
	Energy or Work Kinetic Energy Potential Energy	force × distance mass × $velocity^2$ / 2 mass × acceleration of gravity × height	E = F·d $KE = m \cdot v^2/2$ PE = m·g·h	J (joule) = N·m = $kg \cdot m^2/s^2$	ML^2/T^2
	Power	energy / time	P = E/t	W (watt) = J/s = $kg \cdot m^2/s^3$	ML^2/T^3
	Impulse	force × time	I = F·t	N·s = kg·m/s	*ML/T*
	Action	energy × time momentum × distance	S = E·t S = p·d	J·s = $kg \cdot m^2/s$ h (quantum of action)	ML^2/T
Rotational Mechanical	**Angle**	*fundamental*	θ	° (degree), rad (radian), rev 360° = 2π rad = 1 rev	*dimensionless*
	Cycles	*fundamental*	n	cyc (cycles)	*dimensionless*
	Frequency	cycles / time	f = n/t	Hz (hertz) = cyc/s = 1/s	*1/T*
	Angular Velocity	angle / time	ω = θ/t	rad/s = 1/s	*1/T*
	Angular Acceleration	angular velocity / time	α = ω/t	$rad/s^2 = 1/s^2$	$1/T^2$
	Moment of Inertia	mass × $radius^2$	$I = m \cdot r^2$	$kg \cdot m^2$	ML^2
	Angular Momentum	radius × momentum moment of inertia × angular velocity	L = r·p L = I·ω	J·s = $kg \cdot m^2/s$ ħ (quantum of angular momentum)	ML^2/T
	Torque or Moment	radius × force moment of inertia × angular acceleration	τ = r·F τ = I·α	N·m = $kg \cdot m^2/s^2$	ML^2/T^2
Thermal	**Temperature**	*fundamental*	T	°C (celsius), K (kelvin)	*K (Temp.)*
	Heat	heat energy	Q	J (joule) = $kg \cdot m^2/s^2$	ML^2/T^2
	Entropy	heat / temperature	S = Q/T	J/K	ML^2/T^2K
Electromagnetic	**Electric Charge +/-**	*fundamental*	q	C (coulomb) e (elementary charge)	*C (Charge)*
	Current	charge / time	i = q/t	A (amp) = C/s	*C/T*
	Voltage or Potential	energy / charge	V = E/q	V (volt) = J/C	ML^2/CT^2
	Resistance	voltage / current	R = V/i	Ω (ohm) = V/A	ML^2/C^2T
	Capacitance	charge / voltage	C = q/V	F (farad) = C/V	C^2T^2/ML^2
	Inductance	voltage / (current / time)	L = V/(i/t)	H (henry) = V·s/A	ML^2/T^2
	Electric Field	voltage / distance force / charge	E = V/d E = F/q	V/m = N/C	ML/CT^2
	Electric Flux	electric field × area	$\Phi_E = E \cdot A$	V·m = $N \cdot m^2/C$	ML^3/CT^2
	Magnetic Field	force / (charge × velocity)	B = F/q·v	T (tesla) = Wb/m^2 = N·s/(C·m)	*M/CT*
	Magnetic Flux	magnetic field × area	$\Phi_M = B \cdot A$	Wb (weber) = V·s = J·s/C	ML^2/CT

Note: Other conventions define different quantities to be fundamental.

Mass, energy, momentum, angular momentum, and charge are conserved, which means the total amount does not change in an isolated system.

basic mechanical

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	Momentum	mass × velocity	$p = m \cdot v$	kg·m/s	ML/T
	Force Weight	mass × acceleration mass × acceleration of gravity	$F = m \cdot a$ $W = m \cdot g$	N (newton) = $kg \cdot m/s^2$	ML/T^2
	Pressure or Stress	force / area	$p = F/A$	Pa (pascal) = N/m^2 = $kg/(m \cdot s^2)$	M/LT^2

electricity

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I x R$	$P = I^2 x R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V x I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{P x R}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

FLUIDS

- Substances may exist in solid, liquid or gaseous form. In solids, molecules oscillate about a fixed point, whereas in liquids the molecules possess higher velocities and move more freely and thus do not bear a constant relationship in space to other molecules.
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FLUIDS

- The molecules of gases also move freely, but to an even greater extent.
  Both gases and liquids are termed fluids.
  Liquids are incompressible and at constant temperature occupy a fixed volume, conforming to the shape o f a container; gases have no fixed volume but expand to occupy the total space o f a container.

FLUIDS

GAS PRESSURES

- There are three important laws which determine the behaviour of gases and which are important to anaesthetists.

GAS PRESSURES

- *Boyle's law* states that, at constant temperature, the volume (*V*) of a given mass of gas varies inversely with its absolute pressure (P):
- $P1*V1 = P2*V2$

GAS PRESSURES

- *Charles' law* states that, at constant pressure, the volume of a given mass o f gas varies directly with its absolute temperature (*T*):
- $V1/T1=V2/T2$
- T_1 = Initial Temperature (*Kelvin - K*)
- V_1 = Initial Volume (*L or mL*)
- T_2 = Final Temperature (*Kelvin - K*)
- V_2 = Final Volume (*L or mL*)

GAS PRESSURES

- The third gas law indicates that at constant volume the absolute pressure on the gas varies directly with the absolute temperature or P / T = constant. Therefore at constant volume a doubling of temperature results in a doubling of pressure.

GAS PRESSURES

- Combining these three gas laws: $P1*V1/T1=P2*V2/T2$

GAS PRESSURES

- The behaviour of a mixture of gases in a container is described by *Dalton's law of partial pressures.*
- This states that, 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.
- Thus, in a cylinder o f compressed air at a pressure of 100 bar, the pressure exerted by nitrogen is equal to 79 bar (as the fractional concentration o f nitrogen is 0.79).

Avogadro’s hypothesis

- Avogadro’s hypothesis states that equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.

Avogadro’s hypothesis

Critical temperature

Critical temperature

Pressure notation in anaesthesia

Pressure notation in anaesthesia