PHY111 END GAME BY ENG SEGUN
ALL FORMULAS

CHAPTER 1

SOME QUANTITIES	DIMENSIONS
Mass	M
Length	L
Time	T
Current	I
Speed/velocity	LT^{-1}
Acceleration	LT^{-2}

Most conversions can be done with your casio calculator.

CHAPTER 2

VECTORS

Unit vector notation

if

$$A = a_x + a_y + a_z$$

$$\boxed{|A| = \sqrt{a_x^2 + a_y^2 + a_z^2}}$$

Where

$|A|$ = magnitude of A

If

$$A = a_x i + a_y j + a_z k$$

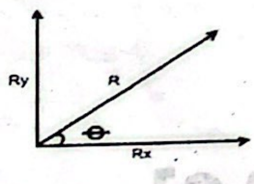
$$B = b_x i + b_y j + b_z k$$

Then,

$$A + B = (a_x + b_x)i + (a_y + b_y)j + (a_z + b_z)$$

$$\boxed{|A + B| = \sqrt{(a_x + b_x)^2 + (a_y + b_y)^2 + (a_z + b_z)^2}}$$

Resolution of vectors



Horizontal - component

$$R_x = R\cos\theta$$

Vertical - component

$$R_y = R\sin\theta$$

- **Vectors inclined at an angle of Θ to each other.**

$$\boxed{R^2 = A^2 + B^2 + 2AB\cos\theta}$$

$$\boxed{\phi = \tan^{-1}\left(\frac{A\sin 0 + B\sin\theta}{A\cos 0 + B\cos\theta}\right)}$$

R = magnitude of resultant vector; ϕ = direction

Resultant of more than two vectors

$$\boxed{R = \sqrt{\left(\sum x\right)^2 + \left(\sum y\right)^2}}$$

$$\boxed{\theta = \tan^{-1}\left(\frac{\sum y}{\sum x}\right)}$$

Σy = summation of all the y - component.
Σx = summation of all the x – component.

CHAPTER 3

Equation of motion

$$v = u \pm at$$

$$s = ut \pm \frac{1}{2}at^2$$

$$v^2 = u^2 \pm 2as$$

$$s = \left(\frac{v + u}{2}\right)t$$

Instantaneous velocity and acceleration

$$\boxed{v = \frac{ds}{dt}}$$

$$\boxed{a = \frac{dv}{dt} = \frac{d^2s}{dt^2}}$$

Vertical motion

Equation of vertical motion

$$v = u \pm gt$$

$$h = ut \pm \frac{1}{2}gt^2$$

$$v^2 = u^2 \pm 2gh$$

Note: if a body is dropped from a certain height above the ground,
$u = 0$

Complex Cases of Vertical Motion

- **If an object is falling from a certain height H so that it fell the last height h in the last time t, then the total time T it took the ball to fall is given by**

$$\boxed{T = \frac{gt^2 + 2h}{2gt}}$$

$$\boxed{H = \frac{1}{2}gT^2}$$

- **For objects thrown vertically upward from the top of an elevated platform.**

$$\boxed{h_f - h_i = uT - \frac{1}{2}gT^2}$$

h_f = final height above the ground

h_i = initial height above the ground

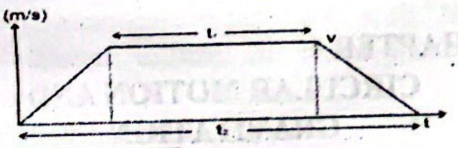
T = time of flight

at the ground level, $h_f = 0$

Similarly,

$$\boxed{v^2 = u^2 - 2g(h_f - h_i)}$$

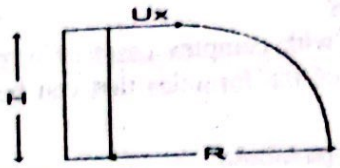
Typical velocity time graph



$$\boxed{S = \frac{1}{2}(t_1 + t_2)v}$$

CHAPTER 4
PROJECTILE MOTION

Case 1 (body thrown horizontally from a certain height).



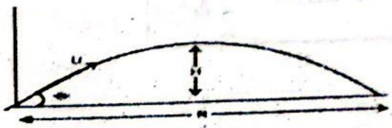
$$\boxed{T = \sqrt{\frac{2H}{g}}}$$

$$\boxed{R = u_x T}$$

Where,
T = time taken to reach the ground
H = height of tower, building, cliff etc.
U_x = horizontal velocity of projection

$$\boxed{v = \sqrt{u_x^2 + (2gH)}}$$

Case 2 (body thrown at an angle to the horizontal from a level plane)



horizontal component of the velocity
$u_x = u\cos\theta$
initial vertical component of the velocity
$u_y = u\sin\theta$

$$\boxed{T = \frac{2u\sin\theta}{g}; \quad H = \frac{u^2\sin^2\theta}{2g} \qquad R = \frac{u^2\sin 2\theta}{g} \quad or \quad R = UT\cos\theta}$$

Where,
T = time of flight; H = maximum weight
R = horizontal range; Θ = angle of projection
Note: R is maximum at Θ = 45°

u_x is constant throughout the motion

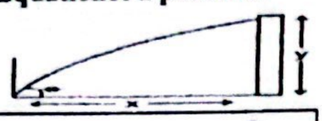
the velocity of the projectile at any time t in the motion is given by

$$\boxed{v = \sqrt{(u\cos\theta)^2 + (u\sin\theta - gt)^2}}$$

where v = resultant velocity

Complex cases
When dealing with complex cases of projectile motion, some of the formulas that can be very useful include:

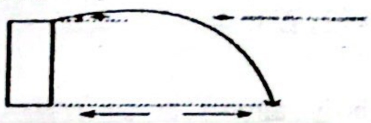
- **Equationof a parabola**



$$\boxed{y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}}$$

y = vertical distance; x = horizontal distance
u = velocity of projection; θ = angle to the horizon

Case 3



$$\boxed{h_f - h_i = uT\sin\theta - \frac{1}{2}gT^2}$$

Note :if the angle is below the horizontal then

$$\boxed{h_f - h_i = -uT\sin\theta - \frac{1}{2}gT^2}$$

CHAPTER 5 (DYNAMICS)

$$\boxed{F = \frac{m(v-u)}{t}}$$

$$\boxed{Ft = \Delta P}$$

Since
$I = Ft$

Then

$$\boxed{I = \Delta P}$$

I = impulse
P = momentum

- **Body on an elevator**
  i. Elevator stationary or moving up or down with constant speed.
  $$\boxed{R = mg}$$
  ii. Elevator accelerating upwards:
  $$\boxed{R = m(g+a)}$$
  iii. Elevator accelerating downwards
  $$\boxed{R = m(g-a)}$$

R = reaction or apparent weight
g = acceleration due to gravity
a = acceleration of elevator

MOTION OF CONNECTED PARTICLES
General formula

$$\boxed{T = \frac{m_1 m_2(\sin\theta_2 + \sin\theta_1)g}{m_1 + m_2}}$$

$$\boxed{a = \left(\frac{m_2\sin\theta_2 - m_1\sin\theta_1}{m_1 + m_2}\right)g}$$

Where $m_2\sin\theta_2 > m_1\sin\theta_1$

Note
If the string is horizontal
$\theta = 0$
If the string is vertical
$\theta = 90^0$

CHAPTER 6
CIRCULAR MOTION AND GRAVITATION

- $s = \theta r$
- $\omega = \frac{\theta}{t}$; $\omega = 2\pi f$
- $v = \omega r$
- $\alpha = \frac{\omega}{t}$
- $a_t = \alpha r$

where,
s = linear distance
θ = angular displacement
ω = angular velocity

a_t = tangential acceleration

α = angular acceleration

Note

$360^\circ \equiv 2\pi$ radian

Centripetal acceleration and centripetal force

$$\boxed{a_c = \frac{v^2}{r}}$$

$$F_c = ma_c$$

$$\therefore \boxed{F_c = \frac{mv^2}{r} = m\omega r^2}$$

Where,

a_c = centripetal acceleration

F_c = centripetal force

r = radius of circular path

Banking Angle

$$\boxed{\tan\theta = \frac{v^2}{gr}}$$

θ = banking angle

v = maximum velocity without skidding

Newton's Law of Universal Gravitation

$$\boxed{F = \frac{Gm_1m_2}{r^2}}$$

Where,

G = gravitational constant = $6.67 \times 10^{-11} Nm^2kg^2$

r = distance between the center points of the masses

Relationship between g an G

$$\boxed{g = \frac{GM}{r^2}}$$

Note

$$\boxed{r = h + R}$$

Where,

g = acceleration due to gravity; M = mass of planet

R = radius of planet H = altitude above the planet surface

Gravitational Potential

$$V = -\frac{GM}{r}$$

$$V = -\frac{u}{m}$$

Where,

U = gravitational work done/energy

$$U = -\frac{GMm}{r}$$

Escape Velocity

$$\boxed{v_{esc} = \sqrt{2gh}}$$

Or

$$\boxed{v_{esc} = \sqrt{\frac{2GM}{R}}}$$

m = mass of planet

- For circular orbit

$$\boxed{v = \sqrt{\frac{GM}{r}}} \boxed{T = 2\pi\sqrt{\frac{r^2}{GM}}}$$

Where,

V = velocityT= periodr = radius of orbit

CHAPTER 7

Work energy and power

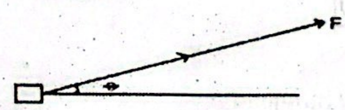
$$\boxed{w = F \times d}$$

Where,

w = work done

F = force

d = distance



$$\boxed{W = Fd\cos\theta}$$

Work done on a swinging pendulum

The work done to swing a pendulum through an angle is given by

$$w = mgl(1 - \cos\theta)$$

Types of mechanical energy

- $PE = mgh$
- $KE = \frac{1}{2}mv^2$

Power

$P = \frac{w}{t}$ or $P = FV$

V = uniform velocity
F = constant force

Gravitational Potential Energy

$$U = \frac{GmM_e}{r}$$

The difference in potential energy from r_1 to r_2 is given by

$$U = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Where $r_1 < r_2$
G = gravitational constant
U = gravitational potential energy
r = distance

CHAPTER 8
MOMENTUM

$$\boxed{P = mv}$$

Where
P = momentum
V = velocity

$$\boxed{I = Ft}$$

$I = \Delta P$

$$\boxed{I = m(v - u)}$$

I = impulse
ΔP = change in momentum

Conservation of linear momentum

$M_A U_A + M_B U_B = M_A V_A + M_B V_B$

Recoil velocity of a gun

$$\boxed{m_g v_g = m_b v_b}$$

Where
M_g = mass of gun
V_g = recoil velocity of gun
M_b = mass of bullet
V_b = velocity of bullet

Rocket propulsion

$$\boxed{v_f - v_i = v_e \ln\left(\frac{m_i}{m_f}\right)}$$

v_f = final velocity of rocket

v_i = initial velocity of rocket

V_e = exhaust velocity of rocket

Thrust on the rocket

$$\boxed{F = -v_e \frac{dm}{dt}}$$

$$a = \frac{F}{M} = \frac{F}{M_i + M_f}$$

$$\boxed{a = \frac{-v_e}{(m_i + m_f)} \times \frac{dm}{dt}}$$

Coefficient of restitution

$$\boxed{e = \frac{v_1 - v_2}{u_1 - u_2}}$$

when,
e = 1 (perfectly elastic collision)
e = 0 (perfectly inelastic collision)
0 < e < 1 (in between)

CHAPTER 9
ROTATIONAL MOTION

$$\boxed{s = \theta r} \boxed{v = \omega r} \boxed{a_t = \alpha r}$$

$$\boxed{\omega = \frac{\theta}{t}} \boxed{\omega = 2\pi f} \boxed{\alpha = \frac{\Delta\omega}{t}}$$

where,
θ = angular displacement
s = arc length
Note

2π radian = 360°
ω = angular velocity
f = frequency
α = angular acceleration
a_t = tangential acceleration

Centripetal acceleration

$$\boxed{a_c = \frac{v^2}{r}}$$

Note: Tangential acceleration and centripetal acceleration are at right angle to each other. Hence the resultant linear acceleration is given by:

$$\boxed{a = \sqrt{a_t^2 + a_c^2}}$$

More Equation of rotational motion

$$\boxed{\omega_f = \omega_i + \alpha t; \quad \theta = \omega_i t + \frac{1}{2}\alpha t^2 \quad \omega_f^2 = \omega_i^2 + 2\alpha\theta}$$

$$\boxed{\tau = I\alpha}$$

Where
τ = torque
I = moment of inertia

$$\boxed{I = \sum mr^2}$$

Also,

$$\boxed{I = mK^2}$$

K = radius of gyration

Commonly asked Moment of inertia of some solids

1. **Cylindrical hoop, shell or ring**
$$\boxed{I = MR^2}$$
2. **Fly wheel, solid cylinder or disc**
$$\boxed{I = \frac{1}{2}MR^2}$$
3. **Solid sphere**
$$\boxed{I = \frac{2}{5}MR^2}$$
4. **Thin spherical shell**
$$\boxed{I = \frac{2}{3}MR^2}$$

Rotational work energy and power

$$\boxed{W = \tau\theta}$$

τ= torque
Θ = angular displacement
W= rotational work done

$$\text{K.E} = \frac{1}{2}I\omega^2$$

$$\text{K.E}_t = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$$

Rotational power

$$\boxed{P = \frac{\text{rotational work}}{\text{time}} = \frac{W}{t} = \frac{\tau\theta}{t} = \tau\omega}$$

Angular momentum

$$\boxed{\begin{aligned} L &= I\omega \\ L &= 2\pi f I \end{aligned}}$$

Conservation of angular momentum

$$\boxed{I\omega_i = I\omega_f}$$

CHAPTER 10

THERMOMETERY

Temperature scales	Upper fixed point	Lower fixed point
Celsius	100°c	0°c
Fahrenheit	212	32
Kelvin	373.16	273.16
Rankin	672	492

Liquid in glass thermometers

$$\boxed{\frac{T}{100} = \frac{L_t - L_0}{L_{100} - L_0}}$$

L_{100} = length at 100°c
L_0 = length at 0°
T = temperature to be measured
L_T = length at temperature T

Gas thermometer

$$\boxed{\frac{T}{100} = \frac{P - P_0}{P_{100} - P_0} = \frac{h - h_0}{h_{100} - h_0}}$$

h_{100} = height h at steam point
h_0 = is the height h at ice point
h = height at the desired temperature

Resistance thermometer

$$\boxed{\frac{T}{100} = \frac{R - R_0}{R_{100} - R_0}}$$

Thermodynamic temperature scale

$$\boxed{T = \frac{X_t}{X_{tr}} \times 273.16K}$$

CHAPTER 11
HEAT CAPACITY

- $C = \dfrac{Q}{\Delta\theta}$

$$\boxed{Q = C\Delta\theta}\ \boxed{Q = mc\Delta\theta}$$

$\Delta\theta = \theta_2 - \theta_1$ (change in temperature)
C = heat capacity
c = specific heat capacity

$$\boxed{l_f = \frac{Q}{m}}$$

Q = ml
Where,
L = specific latent heat
Q = quantity of heat
m = mass of substances

CHAPTER 12
THERMAL EXPANSION

Linear expansivity

$$\boxed{\alpha = \frac{\Delta L}{L_1 \Delta\theta}}$$

$\Delta L = L_2 - L_1$

$\Delta L = L_2 - L_1$

L_1 = original length
∝ = linear expansivity

$$\boxed{L_2 = L_1(1 + \alpha\Delta\theta)}$$

$$\boxed{F = AE\alpha\Delta\theta}$$

$$\boxed{W = EA\Delta L\alpha\Delta\theta}$$

where
F= force
W= work done
E = young's modulus
ΔL = change in length
ΔΘ = change in temperature

Area Expansivity

$$\boxed{\begin{array}{l}\beta = \dfrac{\Delta A}{A_1\Delta\theta} \\ A_2 = A_1(1 + \beta\Delta\theta)\end{array}}$$

Note: $\beta = 2\alpha$
$\Delta A = A_2 - A_1$ = change in area
β= area expansivity

Cubic Expansivity

$$\boxed{\begin{array}{l}\gamma = \dfrac{\Delta V}{V_1\Delta\theta} \\ V_2 = V_1(1 + \gamma\Delta\theta)\end{array}}$$

$\Delta V = V_2 - V_1$ = change in volume

γ = cubic expansivity
ΔΘ = change in temperature

$$\boxed{\rho_1 = \rho_2(1 + \gamma\Delta\theta)}$$

Where,
ρ_1 and ρ_2 = initial and final density respectively.

$\gamma = 3\alpha$; $\gamma = \frac{3}{2}\beta$

Cubic expansivity of liquids

$\gamma_{real} = \gamma_{apparent} + \gamma_{vessel}$

$\gamma_{apparent} = \frac{apparent\ increase\ in\ volume}{original\ volume \times \Delta\theta}$

CHAPTER 13
KINETIC THEORY AND THERMODYNAMICS

Charles law

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

At constant pressure

BOYLES LAW

$$\boxed{P_1V_1 = P_2V_2}$$

at constant temperature

PRESSURE LAW

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$

At constant volume

IDEAL GAS EQUATION

$$\boxed{PV = nRT}$$

Where
P = pressure; V = volume; n = number of moles
R = molar gas constant; T = absolute temperature

$$\boxed{PV = NK_bT} \quad \boxed{K_b = \frac{R}{N_A}}$$

Where
K_b = Boltzmann's constant; N_A = Avogadro's number

Equation of kinetic theory of gases

$$\boxed{V_{R.M.S} = \sqrt{\frac{3K_bT}{m}}}$$

$$\boxed{V_{R.M.S} = \sqrt{\frac{3RT}{M}}} \quad \boxed{V_{R.M.S} = \sqrt{\frac{3P}{\rho}}}$$

V_{RMS} = root mean square velocity

$\boxed{U = \frac{3}{2}nRT}$ ----------monoatomic gas

$\boxed{U = \frac{5}{2}nRT}$ ----------diatomic gas

U = total internal energy

Average translational kinetic energy

$$\boxed{\overline{KE} = \frac{3}{2}k_bT}$$

- **First law of thermodynamics:**

$$\boxed{dQ = du + dW}$$

But $dW = PdV$

$$\therefore \boxed{dQ = du + PdV}$$

Where
dQ = amount of heat supplied to the system.
du = changed in internal energy of the system
dW = work done by the system.

Mayer's formula

$$\boxed{R = C_P - C_v}$$

$$c_v = \frac{3}{2}R$$

$$c_p = \frac{5}{2}R$$

C_v = molar specific heat at constant volume
C_P = molar specific heat at constant pressure

Application of second law

- **Heat Engine**

$$\eta = \frac{work\ done}{heat\ taken\ from\ source}$$

$$\boxed{\eta = \left(\frac{Q_1 - Q_2}{Q_1}\right)\times 100 = \left(1 - \frac{Q_2}{Q_1}\right)\times 100 = \left(1 - \frac{T_2}{T_1}\right)\times 100}$$

Carnot cycle

$$\boxed{\mu = \left(1 - \frac{T_L}{T_H}\right) \times 100}$$

Where

μ = efficiency of carnot engine

Relative efficiency

$$\boxed{\eta_{rel} = \left(\frac{\eta}{\mu}\right)}$$

η_{rel} = relative efficiency η = efficiency of heat engine

μ = Carnot efficiency

- **Refrigerator, Air Conditional and Heat Pump**

$$\boxed{COP = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}}$$

Q_L = Heat removed from the law temperature region

Q_H = heat deposited at the high temperature region

For heat pump

$$\boxed{COP = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}}$$

Thermodynamic processes

- **Isothermal process:** in this process temperature is constant hence $du = 0$

Since

$$dQ = du + dW$$

$$\therefore \boxed{dQ = dW}$$

Work done in isothermal process is given by.

$$\boxed{w = RT \ln\left(\frac{V_2}{V_1}\right)}$$

- **Adiabatic process**

$$dQ = 0$$

Since; $dQ = du + dW$

$$0 = du + dW$$

$$\boxed{du = -dW}$$

Note

$$\boxed{P_1V_1^{\gamma} = P_2V_2^{\gamma}} \boxed{T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}}$$

$$\boxed{\frac{P_1^{1-\frac{1}{\gamma}}}{T_1} = \frac{P_2^{1-\frac{1}{\gamma}}}{T_2}}$$

$$\boxed{\gamma = \frac{C_P}{C_V}}$$

Work done in adiabatic process

$$\boxed{w = nC_V(T_1 - T_2) \text{ or } w = \frac{1}{\gamma - 1}(P_1V_1 - P_2V_2)}$$

- **Isobaric process:**

$$\boxed{w = P(V_2 - V_1)}$$

- **ISOCHORIC PROCESS:**

Volume is constant

$$dQ = du + PdV$$

$$\therefore dQ = du + 0$$

$$dQ = du$$

ENTROPY

$$\boxed{\Delta s = \frac{Q}{T}}$$

Where

Δs = entropy change; Q=quantity of heat supplied

T = temperature

Chapter 14

Heat transfer

1. **Conduction**

$$\boxed{H = KA\frac{T_H - T_C}{L}}$$

Where

K = thermal conductivity

H =heat current

2. **Convection**

$$\boxed{H = hA_s(T_s - T_f)}$$

h =convection coefficient; A_s = surface area of solid

T_s = temperature of solid; T_f = temperature of fluid

3. **Radiation:**

$$\boxed{H = \sigma A e T^4}$$

the above equation is known as Stefan-Boltzmann's law

σ = Stefan-Boltzmann's constants

= $5.07051 \times 10^{-8} w/m^2k^4$

e =emissivity of the surface. the value of e ranges from 0 to 1. Dark surfaces have larger emissivity than light surface

Bodies absorbing radiant energy from surrounding

$$\boxed{H = \sigma A e T_S^{\ 4}}$$

where

T_S = temperature of the surroundings.

Therefore the net rate of radiation from the a body to a surrounding of temperature T_S is given by

$$\boxed{H_{net} = \sigma A e\left(T^4 - T_S^4\right)}$$

If H_{net} = +ve heat flows out of the body

If H_{net} = -ve heat flows into the body

Thermal resistivity R is given by the equation

$$\boxed{R = \frac{L}{K} = \frac{1}{U}}$$

Where

K= thermal conductivity

U= rate of energy flow per unit area of the material per unit temperature difference

Chapter 15

Mechanics of solid liquid and gas

Stress and strain

$$\boxed{stress = \frac{force}{area}}$$

- Strain is defined as the ratio of the change in dimension to the original dimension of the body.

Hooks law

$$\boxed{F = ke}$$

MODULI OF ELASTICITY

$$youngs\ \text{mod}\,ulus = \frac{tensile\ stress}{tensile\ strain}$$

$$= \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

BULK MODULUS (B)

$$\text{Bulk modulus} = \frac{\text{bulk stress}}{\text{bulk strain}}$$

$$bulk\ strain = \frac{-\Delta volume}{original\ volume} = -\frac{\Delta V}{V}$$

$$\therefore \boxed{B = \frac{-PV}{\Delta V}} \boxed{compressivity = \frac{1}{B}}$$

SHEAR MODULUS

$$\text{shear modulus} = \frac{\text{shear stress}}{\text{shear strain}}$$

$$\text{shear strain} = \frac{\text{displacement}}{transferes\ \text{dim}\,ension}$$

FLUID MECHANICS

$$\boxed{\rho = \frac{m}{V}} \boxed{\rho_r = \frac{\rho_s}{\rho_w}}$$

ρ = density ρ_s =density of object

ρ_w = density of water

ρ_r = relative gravity or specific gravity

Pressure in fluid

Generally pressure is given by

$$\boxed{P = \frac{F}{A}}$$

For an enclosed liquid the pressure is given by

$$\boxed{P = \rho g h}$$

For liquid exposed to the atmosphere,

$$\boxed{P = \rho g h + P_{atm}}$$

Pascal's principle

$$\boxed{\frac{F_1}{A_1} = \frac{F_2}{A_2}}$$

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Buoyant force (upthrust)

$$\boxed{U = \rho V g}$$

U = buoyant force
V = volume of liquid displaced

Viscosity

$$\boxed{F = \eta \frac{Av}{d}}$$

Where
η = coefficient of viscosity

Reynolds Number

This is the type of flow of a liquid.
$R < 2000$ (streamline flow)
$R > 3000$ (the flow is turbulent)
$2000 \leq R \leq 3000$ (the flow fluctuates between streamline or turbulent.

The Reynolds number R can be calculated as

$$\boxed{R = \frac{2\rho r v_C}{\eta}}$$

Where
ρ = density
r = radius of tube
v_C = velocity of the fluid
η =viscosity

Stokes laws

$$\boxed{R = 6\pi\eta r v}$$

Note: the law above holds true for a spherical small mass
r = radius of sphere
η =viscosity
V = velocity of sphere.

Terminal velocity

$$\boxed{v = \frac{2}{9}\frac{r^3(\rho_s - \rho_L)}{\eta} g}$$

POISEUILLES EQUATION

$$\boxed{Q = \frac{\Delta P \pi R^4}{8\eta L}}$$

Where
Q= rate of flow of the fluid in pipe
ΔP = difference in pressure between the ends of the pipes
L= length of pipe
R= radius of pipe

Surface tension and capillarity

$$\boxed{\gamma = \frac{F}{L}}$$