# Formulae sheet 1 PEC152

**Net Torque** 1.1 $\Sigma\tau = I a_a$

**AvgAcceleration** $a_{avg} \equiv \frac{v_f - v_i}{t_f - t_i} = \frac{\Delta v_x}{\Delta t}$ or $a \equiv \frac{F_{net}}{m}$

**Position** $x_f - x_i = \frac{1}{2}(v_i + v_f)t$

**Velocity** $v_f = \sqrt{v_i^2 + 2a(x_f - x_i)}$

8.10 $v_f = v_i + at$

8.1: $a = \frac{v_f - v_i}{t}$

8.2 $t = \frac{v_f - v_i}{a}$

8.3: $v_i = v_f - at$

**Momentum** 8.3.2 $p = mv \quad kg \cdot m/s$

**Projectile**

$y_f = h = \frac{v_i^2 \sin^2\theta_i}{2g}$ or

$x_f = R = \frac{v_i^2 \sin 2\theta_i}{g}$

**Atwood Machine** 8.3.5 $\Delta F = (m_1 + m_2)a$

$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$ or $T = \left(\frac{2m_1m_2}{m_1 + m_2}\right)g$

**Radian** $(\theta \approx 57^\circ)$

8.5 $\theta = 180^\circ \div \pi$

8.6 $\theta = \frac{s}{r}$ where $s$ = arc length

**Radial Accel** 9.0: $a_r = \frac{v^2}{r}$

**Angular Accel** $\alpha_a = \frac{a_T}{r} = \frac{d\omega}{dt}$ in $rad/s^2$

Where $a_T$ = Linear Tangential acceleration

9.0.2 $a_T = a_a r$

Period of rotation 9.1 $t = \frac{2\pi r}{v}$

Velocity of rotation 9.2 $v = \frac{2\pi r}{t}$

**Angular Velocity** 9.2.1 $\omega =$ Angular Velocity *rad/s*

9.2.2 $\omega = \frac{\Delta\theta}{\Delta t}$

**Tangential Velocity** 9.2.3 $v = r\omega$

**Angular Momentum** $L = r \times p$

Where $p$ = Linear Momentum $L = I\omega$

**Moment of Inertia** $kg \cdot m^2$ $I = \sum m_i r_i^2$

Continuous 2D $I = \int r^2 dm$

Continuous 3D $I = \int \rho r^2 dV$

**KE of rotat rigid object** $KE_R = \frac{1}{2} I\omega^2$

**Torque** $N \cdot m$ 9.5 $\tau = r \times F$

9.6 $\tau = \frac{dL}{dt}$

9.7 $\Sigma\tau = I a_a$

**Work – KE for rotation** 9.8 $W = \Delta K_R$

**Power – Rotationa** $P = \frac{dW}{dt} = \tau\frac{d\theta}{dt} = \tau\omega$

**KE of Rolling mass** $KE_{Rol} = \frac{1}{2} I_{CM}\omega^2 + \frac{1}{2} M v_{CM}^2$

**Falling object if acceleration at height known**

$y_f = y_i + y_{yi}t - \frac{1}{2}gt^2$

$t = \sqrt{\frac{y_f - y_i - y_{yi}t}{-\frac{1}{2}g}}$

$y_{yi}t =$ the initial position at the initial time

$mgh = \frac{1}{2}mv^2$

Force due to a friction Coefficient $F_s = \mu_s N$

where n = magnitude of normal force against the surface. Ie N = mg

**Resistance Due to air** $R = \frac{1}{2} D\rho A v^2$

$a = g - \left(\frac{D\rho A}{2m}\right)v^2$

$g = \left(\frac{D\rho A}{2m}\right)v_T^2$

$v_T = \sqrt{\frac{2mg}{D\rho A}}$

**DE for finding time taken to reach 90% of Terminal V**

(1) Find coefficient b $b = \frac{mg}{v_T}$

(2). Find Time constant Tau $\tau = \frac{m}{b}$

(3) Sub (1) & (2) into (3) $v = v_T\left(1 - e^{-t/\tau}\right)$

The scalar product of 2 vectors $\vec{A} \cdot \vec{B} \equiv AB\cos\theta$

**Work Done** 1Nm = 1Joule $W \equiv F\Delta r\cos\theta$

15.1 *W=FD*

**Work KE theorem** 15.3 $W_{net} = E_{Kf} - E_{Ki}$

15.4 $W = \Delta KE$

**Impulse** 17.0 $\text{Im}\,pulse = FT$

but F is really the change in MOMENTUM

$I = \left(mv_f - mv_i\right)/t$

17.1 $Ft = \Delta mv$

**Power** 18.0 $P = \frac{Work}{Time}$

18.1 $1W(watt) = 1\frac{J}{s}$

**Potential Energy** 19.0 $PE = U_P = mgh$

**Kinetic Energy** 20.0 $KE = \frac{1}{2}mv^2$

20.1 $KE = F \times D$

Rotating body 20.2 $KE_K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

**Equilibrium of a rigid body** $\sum\tau = 0$ & $\sum F = 0$

**SHM** $x(t) = A\cos(\omega t + \phi)$

$\phi =$ phase constant

$\omega =$ angular frequency

**Springs** 22.0 $F = kx$

From pg 375 $\omega^2 = k/m$

$m\omega^2 = k$

k = spring constant in Nm

x = compression of spring

**Energy of a simple harmonic oscillator** - 381

$W = \frac{1}{2}kx^2$ or $E = \frac{1}{2}kA^2$

If there is no displacement at time t = 0

**Phase Constant** $\phi = \pi/2$

If displacement $y = A\sin\phi$

which rearranges to $\phi = \sin^{-1} y/A$

Angular wave number $k = 2\pi/\lambda$

**Wave function (sin)** $y = A\sin(kx - \omega t + \phi)$

**Amplitude** $A = \sqrt{x_i^2 + \left(\frac{v_i}{\omega}\right)^2}$

**Period of 1 complete oscillation**

$T = \frac{2\pi}{\omega}$ $T = 2\pi\sqrt{(L/g)}$ $g = \frac{L}{\left(\frac{T}{2\pi}\right)^2}$

**Maximum Transverse wave speed and acceleration**

22.1.2.1 $v_{y\max} = \omega A$

22.1.2.2 $a_{y\max} = \omega^2 A$

**angular frequency (Hz)** $\omega = 2\pi f = \frac{2\pi}{T}$

**Frequency** $f = \frac{1}{T} = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

**Position and Acceleration of a particle in Simple Harmonic Motion** pg – 377

$v = \frac{dx}{dt} = -\omega A\sin(\omega t + \phi)$

$v = \frac{d^2x}{dt^2} = -\omega^2 A\cos(\omega t + \phi)$

$v = \sqrt{\frac{k}{m}\left(A^2 - x^2\right)}$

Position $x = A\cos(\omega t + \phi)$

Velocity $v = -\omega A\sin(\omega t + \phi)$

Acceleration $a = -\omega^2 A\cos(\omega t + \phi)$

**PE of a spring** $PE = U = \frac{1}{2}kx^2$

Find the speed (v) of something after being released from the spring

$(ElasticPEinSpring)PE_{initial} = KE_{final}(ofMass)$

$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

rearrange to $V = \sqrt{\frac{\frac{1}{2}kx^2}{\frac{1}{2}m}}$

to allow for friction $V = \sqrt{\frac{\frac{1}{2}kx^2 - F_x d}{\frac{1}{2}m}}$

K = sum of all kinetic energies in a system

U = Total potential energy in a system

**Pendulums** $\omega = \sqrt{\frac{g}{L}}$ and $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}}$

**To find the force in a system from the KE and distance**

23.0 $F_x = -\frac{dU}{dx}$

**Inelastic Collision** $m_1V_1 + m_2V_2 = (m_1 + m_2)V_f$

**Elastic Collisions** -If both masses are the same their angles after collision will be at $90°$

$U_{1i} + U_{2i} = U_{1f} + U_{2f}$

**Power –** $P = \frac{dE}{dt}$

*Energy = Power x Time*

Measured in Watts

$U_g = graviationalPE = E_P = mgh$

$U_{mech} = E_{KE} + E_{PE} = K + U_g$

$KE_{before} + PE_{before} = KE_{after} + PE_{after}$

$mgh = \frac{1}{2}mv^2$

rearranges to $V_f = \sqrt{2gh}$

**Pressure** $P = F/A$

**Pressure** $P = P_0 + \rho gh$ where $\rho = density$

or $\rho = \frac{m}{V} = \frac{mass}{Volume}$

$1Pa = 1N/m^2 = 1atm$

**Centre o Mass** $x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$

**Static Friction** $f_s = \mu_s n$

where $n =$ Opposing force to $mg$

$\mu_s =$ Coefficient of Static friction

**Buoyancy** The weight of the liquid displaced is equivalent to the weight of the object

$B = P_{bot}A - P_{top}A = \Delta PA = \rho_f ghA$

where $V = hA$ & $M = \rho_f V$

$B = \rho_f gV$

**Inertial Moments**

Cylindrical Shell $I = MR^2$

Hollow Cylinder $I = 1/2M(R_1^2 + R_2^2)$

Solid Cylinder $I = 1/2MR^2$

Rectangular Plate $I = 1/12M(a^2 + b^2)$

Long rod centre axis $I = 1/12ML^2$

Long rod end axis $I = 1/3ML^2$

Solid Sphere $I = 2/5MR^2$

Thin spherical shell $I = 2/3MR^2$

**Universal Gravity** $F_g = G\frac{m_1m_2}{r^2} = m\frac{v^2}{r}$

**Velocity of Satellite of Earth** 35.1 $v = \sqrt{\frac{GM_E}{r}}$

**Grav Constant** $G = 6.673 \times 10^{-11} N \cdot m^2/kg^2$

**Gravitational Field** pg-339 37.0 $g = G\frac{F_g}{m}$

**Kepler's 3rd Law** $T^2 = \left(\frac{4\pi^2}{GM_s}\right)a^3 = K_s a^3$

**ME of planet Star system** 39.0 $E = -\frac{GMm}{2a}$

Where a = is the radius or the semi major axis

**Escape Speed** $v_{esc} = \sqrt{\frac{2GM}{R}}$ where R=Radius

**Acceleration in an ElecField** $a = \frac{qE}{m}$

**Elec Field due to a finite # of point charges** $E = k\sum\frac{q_1}{r^2}\hat{\mathbf{r}}$

**Elec Field of a continuous charge distribution** $E = k\int\frac{dq_1}{r^2}\hat{\mathbf{r}}$

**Resistors in Parallel** $R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

**Change in PE for a Charge Field System** $\Delta U = U_B - U_A = -q_0\int_A^B E \cdot ds$

Where 's' = displacement.

**Electric Potential** $V = \frac{U}{q_0}$

**Potential Difference between 2 points In an electricfield** $V = \frac{U}{q_0} = -\int_A^B E \cdot ds$

**Potential Difference** p645 $\Delta V = -E\Delta d$

**PE Difference** $\Delta U = q\Delta V = W$

**Equipotential Surfaces** $V = k\frac{q}{r}$

**Capacitance** p-657 $C = \frac{Q}{\Delta V}$ in Farrads *1F=1C/V*

**Charge per unit area** $\sigma = \frac{Q}{A}$ Where $Q$ = charge

**E between Capacitor plates** $E = \frac{V_B - V_A}{d}$

**V Between Plates** $V = Ed$

**Capacitor** p-671 $C = k\frac{\epsilon_0 A}{d}$

**Electric potential energy of a pair of point charges** p673

53.0 $U = k\frac{q_1q_2}{r_{12}}$

**Energy stored in a charged capacitor** p665 $U = k\frac{Q^2}{2C} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$

**C in Parallel** $C_{eq} = C_1 + C_2 + C_3 + ...$

**Capacitance Series** $C_{eq} = \frac{C_1C_2}{C_1 + C_2}$

**Capacitance with a dielectric** 54.3 $C = kC$

**Charging a C** $\tau = RC$

$q(t) = Q_{\max}\left(1 - e^{-t/RC}\right)$

$I(t) = I_{initial}e^{-t/RC} = \frac{\varepsilon}{R}e^{-t/RC}$

**Discharging a C** $q(t) = Q_{\max}e^{-t/RC}$

$I(t) = -I_{initial}e^{-t/RC}$

**Fluid Continuity** $A_1v_1 = A_2v_2$

**Bernoulli's theorem**

$P_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2$

**Coulomb's Law** p608 $F = k\frac{q_1q_2}{r^2}$

- p634 vector form $F_{12} = k\frac{q_1q_2}{r^2}\hat{\mathbf{r}}_{12}$

**Definition of elec field** $E = F/q$ unit N/C

**Elec Field due to point charge** $E = k\frac{q_1}{r^2}\hat{\mathbf{r}}$

*E* = Electrical field

$q_1$ = charge

**Electric Current** $I = \frac{dQ}{dt} = nA\Delta xq$

*1A = 1C/s*

Where $\Delta x$ = drift Velocity

Wave length pg - 424 $\lambda = \frac{v}{f} = vT = \frac{2\pi}{k}$

Mass per unit length $\mu = m/\ell$

**EMF** pg 699 54.5 $\Delta V = \varepsilon - Ir$

54.6 $IR = \varepsilon - Ir$

**Power -** P35 55.3 $P = i^2R$

55.4 $P = v^2/R$

55.5 $P = Vi$

**Components in a circuit will add to zero** $P_1 + P_2 + P_3 = 0$

**Resistivity** 56.5 $R = \frac{\rho L}{A}$

Variation with temp $R = R_0\left[1 + \alpha\left(T - T_0\right)\right]$

**Magnetic Fields**

B = Magnetic Force in Teslas (**T**)

$F = qvB\sin\theta$

**Radius of path of electron or proton n a magnetic field**

Pg 733 56.9 $r = \frac{mv}{qB}$

**Angular Particle speed** (cyclotron frequency)

57.0 $\omega = \frac{v}{r} = \frac{qB}{m}$

**Particle Period** $T = \frac{2\pi r}{v} = \frac{2\pi}{\omega} = \frac{2\pi \cdot m}{qB}$

**Lorentz Force** – particle acted on by magnetic and elec forces – p735 $F = qE + qv \times B$

**Mass to charge ratio used in Mass Spectrometer**

57.3 $\frac{m}{q} = \frac{rB_0 B}{E}$

**Doppler Effect** p – 419 $f' = f\left(\frac{v + v_o}{v + v_s}\right)$

**Fundamental Frequency of a stretched string** – pg 441

58.0 $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

**Pulse Velocity on a string** 58.1 $v = \sqrt{\frac{T}{\mu}}$

**Fundamental Frequency in a closed end tube** pg444

59.0 $f = \frac{nv}{4L}$ where n is the odd harmonic

v = velocity of air L = Tube length F = is the harmonic freq

Rearranged to $L = \frac{nv}{f4}$

**Gravitational Force** 60.0 $F = G\frac{m_1 m_2}{d^2}$

**Radius of a geostationary satellite** $r = \frac{d^2 v^2}{Gm_2}$

**Beat Frequency** $f_b = [f_1 - f_2]$

**Average Frequency** $f_{avg} = [f_1 - f_2]/2$

| | | |
|---|---|---|
| Gig | **G** | $10^9$ |
| Mega | **M** | $10^6$ |
| Kilo | **k** | $10^3$ |
| Milli | **m** | $10^{-3}$ |
| Micro | **μ** | $10^{-6}$ |
| Nano | **n** | $10^{-9}$ |
| Pico | **p** | $10^{-12}$ |
| Femto | **f** | $10^{-15}$ |

Volume Charge Density $\rho = \frac{Q}{V}$ C/m$^3$

Surface Charge Density $\sigma = \frac{Q}{A}$ C/m$^2$

Linear Charge Density $\lambda = \frac{Q}{\ell}$ C/m

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| Relation | Resistor (R) | Capacitor (C) | Inductor (L) |
|---|---|---|---|
| v-i: | $v = iR$ | $v = \frac{1}{C}\int_{t_0}^{t} i\,dt + v(t_0)$ | $v = L\frac{di}{dt}$ |
| i-v: | $i = v/R$ | $i = C\frac{dv}{dt}$ | $i = \frac{1}{L}\int_{t_0}^{t} v\,dt + i(t_0)$ |
| p or w: | $p = i^2R = \frac{v^2}{R}$ | $w = \frac{1}{2}Cv^2$ | $w = \frac{1}{2}Li^2$ |
| Series: | $R_{eq} = R_1 + R_2$ | $C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$ | $L_{eq} = L_1 + L_2$ |
| Parallel: | $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ | $C_{eq} = C_1 + C_2$ | $L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$ |
| At dc: | Same | Open circuit | Short circuit |
| Circuit var. that cannot change | n/a | v | 42 |

**General Figures**

mass of an electron pg - 7 $9.11 \times 10^{-31}$

mass of proton pg609 $1.67262 \times 10^{-27}$

charge / mass electron, proton neutron pg 609

Electron or Proton Charge

$1.6021765 \times 10^{-19}$

$-1.6021765 \times 10^{-19}$

*1Volt = 1 J/C*

Gravitational Constant

$6.67 \times 10^{-11}\ N \cdot m^2/kg^2$

| | | |
|---|---|---|
| 1 litre | = | 0.001 cubic meters |
| 1 cubic meter | = | 1 000 litres |
| 1 square centimetre | = | 0.000 1 square meters |
| 1 square meter | = | 10 000 square centimetres |

**CoulombsConstant**

$k = 8.99 \times 10^9\ N \cdot m^2/C^2$ $k = \frac{1}{4\pi\varepsilon_0}$

**Permittivity**

**F.S.**

$\varepsilon_0 = 8.8542 \times 10^{-12}\ C^2/N \cdot m^2$

**Speed of electron in a TV tube** is 8.0 x $10^6$m/s. Coil of wire around tube creates a magnetic field of 0.025T at an angle of 60degrees to the x-axis as shown. What is

**a)The force on the electron**

F = qvBsinθ

F = (1.60x$10^{-19}$)(8.0 x $10^6$x0.025sin $60^0$)

F=2.8 x $10^{-14}$N down

**b)The acceleration of the electron**

F=ma

a=2.8x$10^{-14}$/9.1x$10^{-31}$

a=3.1x$10^{16}$ m/s$^2$