PHYS 1004 MASTER SHEET

Formula	Units	Description / Notes

Week 1: Electrostatics

$F = \frac{\|q_1\|\|q_2\|}{4\pi\varepsilon_o r^2}$	ε_o $(\frac{C^2}{N*m^2})$ $\|q_1\|\|q_2\|$ *are both in Coulombs* [C] *r is distance between 2 point charges (m)*	Coulomb's law describes the magnitude of the force of attraction or repulsion between two point charges.
$\|Q\| = Ne$	e *in Coulombs/electron* [C/e] Q *in Coulombs* [C] N *is an integer*	
$N_{excess} = \frac{Charge\ Density}{e}$	$\frac{C/m^n}{C} = \frac{C}{m^n}$	Excess electrons
$\|N\| = \frac{Qnet}{e}$	*N is number of electrons transferred* *Qnet is magnitude of charge on object (Coulombs)* *e is elementary charge (*1.602 x 10^-19 *Coulombs)*	Number of electrons transferred from or to an object.

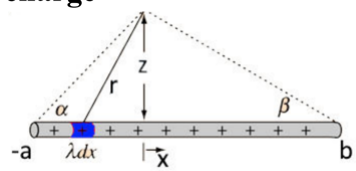
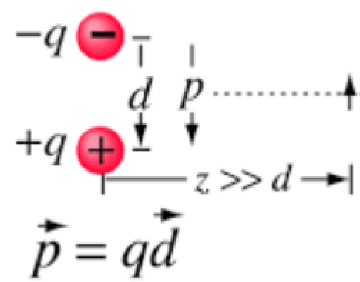
Week 2: Electric Fields

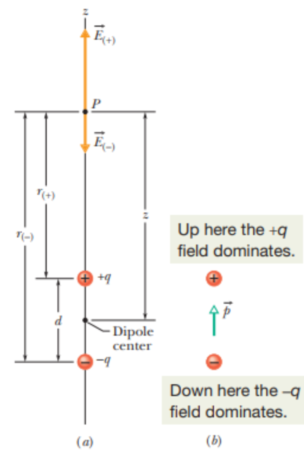
$\vec{E} = \frac{\vec{F}}{q}$ $\vec{F} = q\vec{E}$ $\vec{F} = m_{p/e}a$	F *is in Newtons* E *(electric field) is in* N/C q *is in* C a *is in* m/s^2 m *is in* kg *(prot/elec)*	Force due to an external field
$\vec{a} = \frac{\vec{F}}{m}$ $\vec{a} = \frac{q\vec{E}}{m}$	F *is in Newtons* E *(electric field) is in* N/C q *is in* C a *is in* m/s^2	Acceleration and know that F=qE from above.

	$m\ is\ in\ kg$	
$E = \frac{mv_f}{qt}$	E: magnitude of the electric field [N/C] or [V/m] m: mass [kg] v_f: final velocity [m/s] q: charge [C] t: time [s]	
$\vec{E} = \frac{q}{4\pi\varepsilon_o r^2}\hat{r}$	$E\ is\ in\ N/C$ $q\ is\ in\ C$ $r\ is\ in\ m$	Electric field **due to a point charge**
$\vec{E}_{net} = E_1 + E_2\ \hat{r}$	$E\ is\ in\ N/C$	Net Electric field (vector sum) from multiple charged points along r (i, j, k)
$\vec{E}_{net} = \Sigma\vec{E}_i$	$\vec{E}_i$: sum of electric fields [N/C] or [V/m]	Net electric field is equal to the sum of the electric fields
p = qd	d: distance between dipoles q: charge	Dipole moment

Week 3: Continuous Charge Distribution

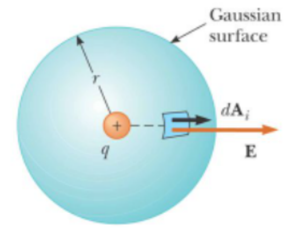
- **Linear** Charge Density: $\lambda = \frac{Qtotal}{Length}; [\frac{C}{m}]$ - **Area** Charge Density: $\sigma = \frac{Qtotal}{Area}; [\frac{C}{m^2}]$ -**Volume** Charge Density: $\rho = \frac{Qtotal}{Volume}; [\frac{C}{m^3}]$	- **Linear** Charge Density: $\lambda = [\frac{C}{m}]$ - **Area** Charge Density: $\sigma = [\frac{C}{m^2}]$ -**Volume** Charge Density: $\rho = [\frac{C}{m^3}]$	Charges are spread out along a line or over an area or in a volume.
$E = \frac{qZ}{4\pi\varepsilon_0(Z^2+R^2)^{\frac{3}{2}}}$ OR $E = \frac{\lambda Z(2\pi R)}{4\pi\varepsilon_0(Z^2+R^2)^{\frac{3}{2}}}$	λ: $Ring\ charge\ density\ \frac{C}{m}$ R: $Radius\ of\ ring\ (m)$ Z: $Height\ of\ point\ (m)$	Electric Field Axial to a **ring** of charge:
$E = \frac{\lambda}{4\pi\varepsilon R}\hat{r}$	λ: linear charge density $[\frac{C}{m}]$	Electric Field near a **line** of charge. Can also be expressed in vector format.

$E_{plane} = \frac{\sigma}{2\varepsilon_0}$ (non conducting) $E_{plane} = \frac{\sigma}{\varepsilon_0}$ (conducting)	σ: $Charge\ density\ \frac{C}{m^2}$	Electric Field due to an **infinite** charged **plane** non conducting infinite sheet
$E_x = \frac{\lambda}{4\pi\varepsilon_0}(\frac{1}{\sqrt{a^2+z^2}} - \frac{1}{\sqrt{b^2+z^2}})$	λ: charged line [C] a: distance at point a [m] b: distance at point b [m] z: vertical distance [m]	Electric Field **parallel to the line of charge** 
$\vec{E}_z = \frac{\lambda}{2\pi\varepsilon_0 z}\hat{r}$	E_z: electric field in the z-direction [N/C] z: distance away from the line [m] λ: charged line [C]	Electric field due to a **infinite** line of charge (in the z-direction; same diagram above). Can also be expressed in vector format.
$\vec{E}_{net} = \frac{\lvert\lambda_2\rvert}{2\pi\varepsilon_0 r_2}\hat{i} - \frac{\lvert\lambda_1\rvert}{2\pi\varepsilon_0 r_1}\hat{i}$	λ: charged line [C] r: distance [m]	Electric field net charge with vectors
$E = -\frac{1}{4\pi\varepsilon_0}\frac{p}{z^3}$(Along ⊥ bisector) [Point P] $E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3}$ (Along axis of dipole) [Point Q] $p = qd$	z: distance of the dipole's midpoint [m] p: magnitude of the electric dipole component [C·m] q: charge [C] d: distance between charges [m]	Electric field due to an electric dipole 

		
$\vec{E}_z = \frac{\sigma}{2\epsilon_0}(1 - \frac{z}{\sqrt{z^2+R^2}})\hat{k}$	R: *Radius of disk* (m) z: *distance from disk* (m) σ: *Charge density* $\frac{C}{m^2}$	Electric Field due to the charge **disk**
$E_x = \frac{\lambda}{2\pi\varepsilon_0 R}$ $E_x = \frac{Q}{2\pi^2\varepsilon_0 R^2}$	λ = Charge Density R = Radius(m) Q = Charge(C)	Electric Field Due to an **Arc**

Week 4: Gauss's Law

$\phi = \|E\|\|A\|cos\theta$ $\phi = \vec{E} \cdot \vec{A}$ $\phi = E_x A_x + E_y A_y + E_z A_z$	ϕ: electric flux $[\frac{N \bullet m^2}{C}]$ E: electric field [N/C] A: area (don't forget that area can be replaced by the area of the shape or object so spheres and such that) [m^2] θ: angle in degrees	
$\phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Qenc}{\epsilon_0}$ (Both are vectors) (Non- uniform electric Field)	Φ_E: electric flux [V . m] or $[\frac{N \bullet m^2}{C}]$ Q_{enc}: charge enclosed [C] E: electric field; note that <u>E in the formula is a constant</u>, so move it in front of the integral [N/C] or [V/m]	**Gauss's Law**: charges enclosed inside a surface are proportional to the flux through the surface. *Note that the <u>contour integral means an enclosed surface</u>; you would replace the [$\oint$ dA] with the surface area of a sphere or cylinder (most likely these two).

		 **dA and E are parallel to each other**. E is everywhere on the Gaussian surface which is why it is a constant and moved to the front. dA is any spot on the Gaussian surface and we know that E is parallel to dA at each point–which is every point of the Gaussian surface. This is why we replace dA with the area of the surface. <u>Surface area formula</u>: $4\pi r^2$ (Sphere) $2\pi rh$ (Cylinder) For a Gaussian cylinder, you can neglect ends and if it says infinitely long, ignore the ends.
$n_V = \frac{\rho}{e}$	n_v: number of charges in a vacuum [$\frac{electrons}{m^3}$] ρ: charge density [$\frac{C}{m^3}$] e: charge of a single electron; elementary charge [C]	

Credit to Spongy from his notes for Gauss's Law.

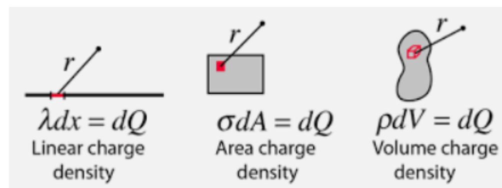
Week 5: Work and Energy

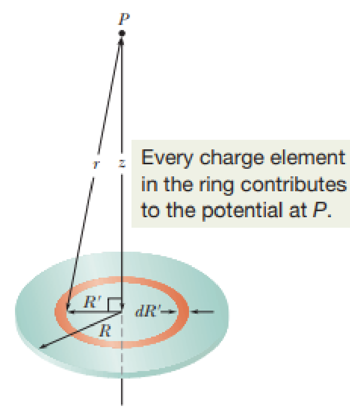
$W = \vec{F} \cdot \vec{\Delta d}$ $W = F\Delta d cos\theta$ ΔE = W Work done by a variable force (also works for electric forces	W: Joules(J)	**Work:** the energy transferred from the force of an object over a distance. θ is the angle between the displacement and the direction of the force.

W = $\int_{x1}^{x2} F(x)\, dx$		
$W_{int} = k\,(\frac{x_f^2}{2} - \frac{x_i^2}{2})$	W: Joules(J) X_i: Initial Position X_f: Final Position	Work done by a spring.
$\Delta U = -W_{int}$ $-W_{int} = W_{ext}$	U: Change in potential energy [J] W_{int}: work done by internal force [J]	Change in potential Energy
ΔU_g= mgh $\Delta U_g = Gm_1m_2(\frac{1}{r_1} - \frac{1}{r_2})$	Joules [J] m: mass g: gravitation acceleration ($9.81 m/s^2$)	Gravitational Potential Energy Gravitational Constant(G) = 6.67×10^{-11}
$\Delta U_e = \frac{1}{2} kx_f^2 - \frac{1}{2} kx_i^2$	Joules(J)	Elastic Potential Energy(the change) **For U_e only use $\frac{1}{2} kx^2$**
$U(r) = \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$	U: electrical potential energy [J] q: charge of particle [C] r: distance between charges [m]	Potential Energy Between Point Charges **Same symbol point charges(+ , + and -,-) produce positive potential energy** **Opposite symbol point charges(+,-) produce negative potential energy** Multiple charges can be added up, considering all possible pairs. $U_{12} + U_{13} + U_{23}$
$P = \frac{E}{t}$ P = **F** * **v**	P: power [W] E: electric field [N/C] or [V/m] t: time [s]	
$E = \frac{F}{e}$	F: force [N] e: elementary charge [C] E: electric field [N/C] or [V/m]	

$\Delta U = K = \frac{1}{2}mv^2$	K: kinetic energy [J] m: mass [kg] v: velocity [m/s]	Kinetic energy
$\Delta U = U_f - U_i$ $\Delta U = \frac{q_1 q_2}{4\pi\varepsilon_0}(\frac{1}{r_f} - \frac{1}{r_i})$	q: charge of particle [C] r_f: final distance r_i: initial distance	The change in energy
$\Delta V = E\,\Delta x = \sigma/2\varepsilon\Delta x$	Δx: distance separated [m]	Electric field due to two uniformly charged thin sheet

Week 6: Electric Potential

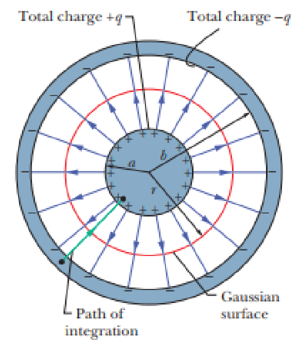
$V = \int \frac{kdq}{r}$ or $\frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$ $dV = \frac{dq}{4\pi\varepsilon_0 r}$	V: Electrical Potential [V] k: coulomb constant r: distance [m]	Potential due to a continuous charge distribution.  Any constants within the integral will be moved to the front. The dq part will then be replaced whatever the surface is above. Look at *week 3* for charge density formulas
$V(r) = \frac{q}{4\pi\varepsilon_0 r}$ $\Sigma V(r) = \Sigma \frac{q}{4\pi\varepsilon_0 r} =$ $\frac{1}{4\pi\varepsilon_0}[\frac{q_n}{r_n} + \frac{q_{n+1}}{r_{n+1}} + ...]$	V: potential Due to Point Charge (V) q_n: the charge of point n [C] r_n: the distance between (it would be very small) [m]	Potential due to a charged particle and the sum of particles.
$U = qV$	U: potential energy [J] q: charge [C] V: voltage [V]	Electric potential energy
$W = -q\Delta V$	q: charge [C] ΔV: change in potential energy/voltage [V]	
$W = -\Delta U_{electrical}$		Work done by the electric force is equal to the negative change in electric

		potential energy
$V = \frac{\lambda}{4\pi\varepsilon_o} ln\left\lvert\frac{L+\sqrt{d^2+L^2}}{d}\right\rvert$	D: potential at a distance [m] L: length of the rod [m] Note that $\lambda = \frac{Q}{Length}$ meaning you would replace λ with $\frac{Q}{L}$. Q: charge [C]	Net potential due to a **uniformly charged rod**; the equation for the whole rod. (Linear charge density)
$V = \frac{\lambda}{4\pi\varepsilon_0}\phi$ $V = \frac{Q}{8\pi^2\varepsilon_0 R}\phi$	ϕ: arc length in radians [rad]	Potential due to **charged arc**. (linear charge density)
$V = \frac{\sigma}{2\varepsilon_o}[\sqrt{z^2+R^2} - z]$ $z^2 = r^2 - R^2$	R: the radius to the outer edge of the disk [m] z: distance to point P [m] σ: area charge density $[\frac{C}{m^2}]$	Potential due to a **charged disk or ring**. (Area charge density) 
$V = \frac{2\pi\lambda R}{4\pi\varepsilon\,(\sqrt{z^2+R^2})}$	R: radius of the charged thin ring. λ: linear charge density z: point above the ring	Potential at a point 'z' above the thin charged ring.
$V(R) = \frac{Q}{4\pi\varepsilon_0 R}$	Q: charge [C] R: radius [m]	Potential at the **surface of a sphere**.
$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$	Q: charge [C] r: radius [m]	Electric field outside the sphere.

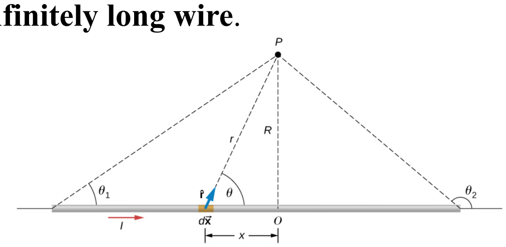
Week 7: Capacitance

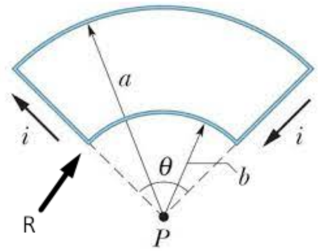
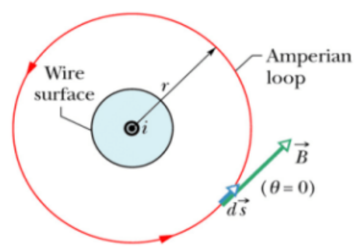
$R = \frac{V}{i} = \frac{P}{i^2} = \frac{V^2}{P} = \frac{\rho L}{A}$	V: voltage [V] i: current [A] P: power [W] ρ: resistivity $[\Omega \cdot m]$ L: length [m] A: cross-sectional area [m^2]	Resistance formulas from Ohm's Law
$\rho = \frac{1}{\sigma} = \frac{E}{J} = R\frac{A}{L}$	ρ: resistivity $[\Omega \cdot m]$ P: power [W] J: current density $[\frac{A}{m^2}]$ E: electric field [N/C] or [V/m] σ: conductivity $[S \cdot m]$ R: resistance [Ω] L: length [m]	
$i = \frac{V}{R} = \frac{P}{V} = \sqrt{\frac{P}{R}}$ $i = \int \vec{J} \cdot d\vec{A} = JA$ $i = \frac{dq}{dt}$`	V: voltage [V] P: power [W] R: resistance [Ω] $\vec{J}$: current density $[\frac{A}{m^2}]$ $\frac{dq}{dt}$: The rate of change of charge over time $[\frac{C}{s}]$ A: cross-sectional area [m^2]	Current formulas from Ohm's Law (do not mistake i for the imaginary number, do not think imaginary numbers are used in PHYS 1004) Move $\vec{J}$ in front of the integral and $\int d\vec{A}$ would then be replaced by the total area such as a cylinder or sphere.
$C = \frac{Q}{\Delta V}$ Q = CV	Q : Columbs (C) ΔV: Change in electric potential (V)	Capacitance
$C_0 = \frac{\varepsilon_o A}{d}$ $C = \frac{\varepsilon_0 \kappa A}{d}$	A: area [m^2] d: distance [m]	Capacitance between two parallel plates and with dielectric.
$C = 2\pi\varepsilon_o \frac{L}{ln(b/a)}$	L: length [m] b: outer length radii [m] a: inner length radii [m]	Cylindrical capacitor capacitance (two long coaxial cylinders)
$\frac{C}{l} = \frac{2\pi\varepsilon_0}{ln(\frac{b}{a})}$ $\frac{C}{l} = \frac{2\pi\varepsilon_0\kappa}{ln(\frac{b}{a})}$	$\frac{C}{l}$: Capacitance per length [F/m] b: outer radius [m] a: inner radius [m] B:outer radius [m]	Capacitance per length and capacitance per length with dielectrics of coaxial cable. With the dielectric, you would just put the κ constant on top or multiply with the capacitance per length formula.

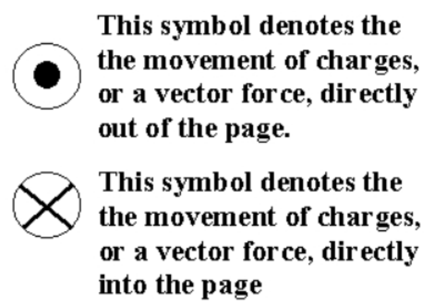
		Don't forget that adding capacitors are opposite than resistors: Parallel just added to each other and series is adding the reciprocal.
$C = \kappa C_0$ $\varepsilon_\kappa = \kappa\varepsilon_0$ $E_{new} = \frac{E_{old}}{\kappa}$	κ: dielectric constant C_o: value of capacitance with vacuum between the conductors	Capacitance of a capacitor with a dielectric.
$E = \frac{1}{4\pi\kappa\varepsilon_0}\frac{q}{r^2}$	κ: dielectric constant q: charge [C] r: distance [m]	Magnitude of the electric field produced by a point of charge inside a dielectric
$E = \frac{\sigma}{\kappa\varepsilon_0}$	κ: dielectric constant σ: area charge density [$\frac{C}{m^2}$]	Electric field outside an isolated conductor immersed in a dielectric
$\oint \kappa\vec{E} \cdot d\vec{A} = \frac{Qenc}{\epsilon_0}$ $q = \kappa\varepsilon_0 EA$	κ: dielectric constant q: charge [C] E: electric field [N/C] or [V/m] A: area [m^2]	<u>Gauss's Law with dielectrics</u>: pretty much the same concept as Gauss's Law but we have a dielectric constant to deal with. To deal with it, simply **move κ to the front of the contour integral.**
C = $\frac{\varepsilon E^2}{2}$	C: capacitance [F] E: electric field (V/m or N/C)	
$\Delta V = \frac{q}{4\pi\varepsilon_0}(\frac{b-a}{ab})$	Q: charge [C] a: inner radius [m] b: outer radius [m]	Potential difference between conductors.
$C = 4\pi\varepsilon_0 R$	R: radius [m]	Capacitance of an isolated sphere (spherical capacitor)
$C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$	a: inner radius [m] b: outer radius [m]	For a spherical capacitor.

		
$\frac{1}{Ceq} = \Sigma \frac{1}{C(1+...+n)}$	C_{eq}= Equivalent Capacitance	Capacitance in **series;** they are the opposite of adding resistors in series
$Ceq = \Sigma C(1 + ... + n)$	C_{eq}= Equivalent Capacitance	Capacitance in **parallel;** they are the opposite of adding resistors in parallel
$U_C = \frac{q^2}{2C} = \frac{1}{2}CV^2$	U: work [J] q: Charge [C] C = Capacitance [F] V: voltage [V]	The electric potential energy done by a charged capacitor. (Sample question: how much work is done to charge up a capacitor)
$u = \frac{U}{Volume}$	u: energy density [$\frac{J}{m^3}$] U: total energy [J]	
$u = \frac{1}{2}\varepsilon_0 E^2$ $E = -\frac{V}{d}$	u: energy density [$\frac{J}{m^3}$] E: electric field [C] V: voltage [V] d: distance [m]	Energy density for parallel plate capacitor
$u_E = \frac{\varepsilon_0 V^2}{2d^2} = \frac{\varepsilon_0 E^2}{2}$	u_E: energy stored in electric field inside the capacitor V: voltage [V] E: electric field [N/C] or [V/m] d: distance [m]	
$U = \frac{C(\Delta V)^2}{2}$	U: Potential Energy [J] ΔV: Potential Difference [V] C: Capacitance [F]	Potential energy of a capacitor
$q = \kappa \varepsilon_0 E A$	q: Charge on the plate [C] k: dielectric constant E: Electric field [V/m] A: Area of the plate [m^2]	enclosed charge

Week 8: Magnetic Fields

$d\vec{B} = \frac{\mu_0 i d\vec{s}(\vec{r})}{4\pi r^2}$	$\vec{B}$ is measured in Teslas i is measured in Amperes (Coulombs per second)	Biot-Savart's law describes the magnetic field due to a small segment of current i.
$\vec{F}_B = q\vec{v} \times \vec{B}$ $F_B = \lvert q\rvert vB\sin\varphi$ $B = \frac{F_B}{\lvert q\rvert v}$	q is measured in Coulombs $\vec{v}$ is measured in metres/seconds $\vec{B}$ is measured in Teslas $\vec{F}_B$ is measured in Newtons φ: angle in degrees	This formula describes the force from a magnetic field on a moving charge. Using the right hand rule (thumb in the direction of the velocity, index in the direction of the magnetic field, and palm in the direction of the magnetic force), it is apparent that the velocity is perpendicular to the field, and thus the cross-product will simply be vBsin90 = vB most of the time.
$r = \frac{mv}{\lvert q\rvert B}$ $f = \frac{\lvert q\rvert B}{2\pi m}$ $\omega = \frac{\lvert q\rvert B}{m}$	r: radius [m] f: frequency [Hz] q: charge [C] B: magnetic field [T] m: mass [kg]	Cyclotron radius and frequency used such as an electron in a magnetic field.
$\vec{\mu} = Ni\vec{A}$ $\vec{\tau} = \vec{\mu}\, x\, \vec{B}$	$\vec{\tau}$: torque i: current [A] $\vec{A}$: area vector [m^2] N: number of turns	Magnetic dipole moment which also follow the right-hand rule 
$B = \frac{\mu_0 i}{2\pi R}$ (r > R) $B = \frac{i_{total}\mu_0}{2\pi R^2} r$ (r < R)	i: current [A] R: distance between the given point P [m] R: Radius of wire r : Radius / distance of measurement	Magnetic field for **long straight wires or around an infinitely long wire**.  Magnetic field **inside** a wire. (r < R)
$B = \frac{\mu_0 i}{4\pi R}$	i: current [A] R: distance [m]	Magnetic field for a **semi-infinite straight wire**

$B = \frac{\mu_0 i}{4\pi R}\phi$	i: current [A] R: distance; if you are finding the magnetic field from length a and b, then use the distance from a or b [m] Φ: angle in radians [rad]	Magnetic field **due to a circular arc of current** 
$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$	$\vec{B}$ is measured in Teslas i_{enc} is measured in Amperes	**Ampere's law** describes the current inside a closed Amperian loop, where the magnetic field generated by the current is integrated over said Amperian loop, keeping in mind the dot product of these two must not equal 0 for the formula to work (pick the same direction on the loop as the field). Just like Gauss's Law, the contour integral means an enclosed surface. The [$\oint$ ds] would be replaced by the perimeter. Unlike Gauss's law where Gaussian surfaces are used such as spheres and cylinders, **Ampere's law is about loops, so like circles. Circumference of a circle but not the area of it.**  B and ds are parallel with each other. The same concept as Gauss's law but with 2D shapes instead of 3D. Loops: $2\pi r$ (Circle loop aka the circumference)
$B = \mu_0 in$ $n = \frac{N}{l}$	B: magnetic field [T] i: current [A] n: turns per length N: number of turns; integer l: length [m]	Magnetic field for an ideal solenoid.

$B = \frac{\mu_0 iN}{2\pi} \frac{1}{r}$	i: current [A] N: total number of turns r: radius [m]	Magnetic field for a toroid.
$\vec{F}_{\mathbf{B}} = i\,\vec{L}\,x\,\vec{B}$ $\lvert fB \rvert = iLBsin\theta$	$\vec{F}_{\mathbf{B}}$: magnetic force on a current carrying wire. i : current charge $\vec{L}$**:** length of the wire. $\vec{B}$**:** magnitude of magnetic field. Θ: angle	The magnitude of the magnetic force acting on a current carrying wire.
$F = \frac{\mu_0 L i_n i_m}{2\pi d}$ $B_n = \frac{\mu_0 i_n}{2\pi d}$	L: length of wires [m] i_n: the current of wires n [A] i_m: the current of wires m [A] d: distance between the two wires n and m [m]	Force between two parallel wires and the magnetic for each wires . **If they are parallel, they attract, if they are non-parallel, they repel.** 
$B_{\parallel} = \frac{\mu_0 iR^2}{2z^3}$ $B_{\parallel} = \frac{\mu_0 iR^2}{2(R^2+z^2)^{\frac{3}{2}}}$	R: radius [m] i: current [A] z: height distance [m]	The top equation is for long distances from the plate, for the loop (Z >>> R or significantly bigger). The bottom equation is for Magnetic field above a current carrying loop.

$\oint \vec{B} \cdot \vec{ds} = \mu_0 i_{enc} + \mu_0 \varepsilon_o \frac{d\Phi_E}{dt}$	Ampere-Maxwell's law relates changing electric flux to the enclosed current and the induced magnetic field. Just like Ampere's Law, [$\oint$ ds] would be replaced by the perimeter of the Amperian Loop.

Week 9: Induction

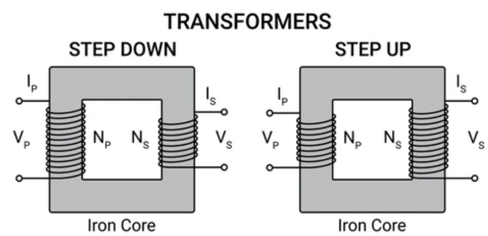
$L = L_1 + L_2 + \ldots$ (Series) $L = [\frac{1}{L_1} + \frac{1}{L_2} + \ldots]^{-1}$(Parallel)	L: inductance [H]	Inductors follow the same as adding resistors

$\Phi_B = \int \vec{B} \cdot d\vec{A}$ (Single Loop) $\Phi_B = N \int \vec{B} \cdot d\vec{A}$ (N Turn Coil) $\Phi_B = BA = \mu_0 n I \frac{\pi d^2}{4}$	Φ_B : Magnetic flux [Wb] B: magnetic field [T] N: number of coils [no units]	
$\phi_B = \frac{1}{N} Li$	Φ_B : Magnetic flux [Wb] N: number of coils/'Turns' [no units] L: inductance [H] i: current [A]	
$\varepsilon = \oint \vec{E} \bullet d\vec{s} = -\frac{d\phi_B}{dt}$ $\varepsilon = -N\frac{d\phi_B}{dt}$ (Coil with N loops) $\frac{d\phi_B}{dt} = \frac{\Delta\phi_B}{\Delta t}$	ε: induced emf [V] N: number of turns	Faraday's Law: if the magnetic flux through an area bounded by a closed conducting loop changes with time, a current and an emf are produced in the loop.
$L = \frac{N\phi_B}{i}$	N: number of coils [no units] Φ_B : Magnetic flux [Wb] i: current [A]	Inductance defined in terms of flux.
$\frac{L}{l} = \mu_0 n^2 A$	$\frac{L}{l}$: inductance per length [H/m] n: number of coils in wire per unit length A: area of coil [m^2]	Inductance per unit length near the middle of a long solenoid.
$U_L = \frac{1}{2} Li^2$	U_L: energy done in inductor [J] L: inductance [H] i: current [A]	Work done in an inductor.
$u_B = \frac{B^2}{2\mu_0}$	u_B: energy density [$\frac{J}{m^3}$] B: magnetic field [T]	Magnetic energy density
EMF = $\varepsilon = L\frac{di}{dt}$	EMF or ε: [V] L: inductance [H] $\frac{di}{dt}$: rate of change of current over time [$\frac{A}{s}$]	

$EMF = \varepsilon = NAB\omega$	A: area of loop [m^2] N: number of coils B: magnetic field [T] w : Angular Freq [rad/s]	Max EMF from rotating loops
$i = \frac{BLv}{R}$	i: current [A] B: magnetic field [T] v: velocity [m/s] R: resistance [Ω]	
$F = \frac{B^2L^2v}{R}$	F: force [N] B: magnetic field [T] v: velocity [m/s] R: resistance [Ω] L: Length of wire [m]	
$P = Fv = \frac{B^2L^2v^2}{R}$	P: power [W] F: force [N] B: magnetic field [T] v: velocity [m/s] R: resistance [Ω] L: Length of wire [m]	Rate of doing work
$P = i^2R = iV = \frac{V^2}{R}$	i: current [A] R: resistance [Ω] V: voltage [V]	General power formula most should know from 1043.

Week 10: Alternating Current (AC)

$\varepsilon(t) = \varepsilon_{max} sin(\omega t)$	ω, the natural frequency [rad/s] ε_{max}: max induced voltage [V]	Forced oscillation of an **RLC** circuit function/differential equation for induced voltage. Where t is the time in seconds.
$i(t) = I_{max} sin(\omega t - \phi)$	ω, the natural frequency [rad/s] I_{max}: max induced current [A] ϕ: Phase angle in radians [rad]	Forced oscillation of an **RLC** circuit function/differential equation of the current driven. Where t is the time in seconds.carleton
$q(t) = q_0 cos(\omega t + \phi)$	q_0: the charged amplitude [C]	Differential equation of an **LC** circuit oscillation.

	ω: the natural frequency [rad/s] ϕ: Phase angle in radians [rad]	
$q(t) = q_0 e^{-\frac{Rt}{2L}} cos(\omega' t + \phi)$ $\omega' = \sqrt{\omega^2 - (\frac{R}{2L})^2}$	q_0: the charged amplitude [C] ω: the natural frequency [rad/s] ϕ: Phase angle in radians [rad] R: resistance [Ω]	Damped oscillation differential equation of an RLC circuit. Charge Decay
$\frac{I_S}{I_P} = \frac{N_P}{N_S}$	N_S: number of loops on the secondary coil; integer N_P: number of loops on the primary coil; integer I_S: secondary current [A] I_P: primary current [A]	This ratio relates the number of coils in the primary and secondary loops of a transformer to their respective currents. 
$\frac{V_p}{V_s} = \frac{N_P}{N_S}$	N_S: number of loops on the secondary coil N_P: number of loops on the primary coil V_S: secondary voltage [V] V_P: primary voltage [V]	This **ratio** relates the **number** of **coils** in the primary and secondary loops of a transformer to their respective **voltages**.
$I_{rms} = \frac{I_{max}}{\sqrt{2}}$ $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ $\varepsilon_{rms} = \frac{\varepsilon_{max}}{\sqrt{2}}$	I_{rms}: root mean square of current [A] V_{rms}: root mean square of voltage [V] ε_{rms}: root mean square of induced voltage [V]	Root mean square (RMS) values and formulas.
$\omega = \frac{1}{\sqrt{LC}} = 2\pi f$ $T = 1/f = 2\pi/\omega$	L, the inductance, is measured in henries (H) C, the capacitance, is measured in Farads (F) ω, the natural frequency [rad/s]	The natural frequency (resonance) of an **LC** circuit is given by this equation.

$\chi_C = \frac{1}{\omega C}$	C, the capacitance [F] ω, the natural frequency [rad/s] χ, the reactance [Ω]	Reactance of a capacitor
$V_c = I_{max}\chi_C$	I_{max}: the maximum current [A] χ_C: the reactance of capacitor [Ω]	Voltage of capacitor
$\chi_L = \omega L$	ω: angular frequency [rad/s] L: inductance [H] χ, the reactance [Ω]	Reactance of an inductor
$V_L = I_{max}\chi_L$	I_{max}: the maximum current [A] χ_L: the reactance of inductor [Ω]	Voltage of inductor
$I_{max} = \frac{V_{max}}{\chi} = \frac{\varepsilon}{R}$	χ: the reactance [Ω] V_{max}: the maximum voltage, is given in Volts (Joules/Coulomb) [V] I_{max}: the maximum current [A] ε: induced voltage (emf) [V] R: resistance [Ω]	
$q_{max} = C\varepsilon$	q_{max}: max charge [C] C: the capacitance [F] ε: induced voltage (emf) [V]	
$Z = \sqrt{(L\omega - \frac{1}{C\omega})^2 + R^2}$ $Z = \sqrt{(\chi_L - \chi_C)^2 + R^2}$	Z: impedance [Ω] L:inductance [L] C: capacitance [F] R: resistance [Ω] ω: angular frequency [rad/s]	General impedance formula of an RLC circuit
$\omega = \frac{R}{2L}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} = \frac{R}{2L}\sqrt{\frac{4L}{R^2C} - 1}$	ω: angular frequency [rad/s]	Angular frequency of an LRC circuit

	L:inductance [L] C: capacitance [F] R: resistance [Ω]	
$T = \frac{2\pi}{\omega}$	T: period of oscillation [s] ω: angular frequency [rad/s]	
$\tau = \frac{L}{R} = RC$	τ: time constant [s] L: inductance [H] R: resistance [Ω] C: capacitance [F]	Time constant for LR and RC circuits.
$tan\phi = \frac{\chi_L - \chi_C}{R}$	χ_C: the reactance of capacitor [Ω] χ_L: the reactance of inductor [Ω] R: resistance [Ω]	Phase angle
$cos\phi = \frac{R}{Z}$	R: resistance [Ω] Z: impedance [Ω]	Power factor
$E = U_C + U_L$	E: total energy [J] U_c: Work done in capacitor [J] U_L: work done in inductor	Total energy done in an LC circuit; just add the energy done of the capacitor and inductor. Energy done in a capacitor is in *week 7* and the energy of an inductor formula is in *week 9*.
$V_f = V_i\sqrt{\frac{u}{U}}$	V_f: final voltage [V] V_i: initial voltage [V] u: final energy [J] U: initial energy [J]	
$V = \frac{Q}{C}$	V: voltage [V] Q: charge [C] C: capacitance [F]	
$\frac{di}{dt} = \frac{V}{L}$	$\frac{di}{dt}$: rate of change of current over time [$\frac{A}{s}$] V: voltage [V] L: inductance [H]	

$u = Ue^{(-2 \times \frac{R}{2L} \times NT)}$	u: energy decay [J] U: work [J] R: resistance L: inductance [H] N: number of cycles T: period of oscillation [s]	

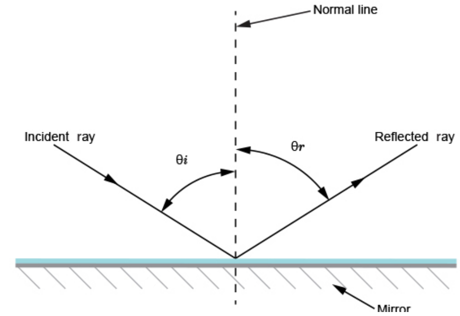
Week 11: Maxwell's Equations (Laws with Contour Integrals from above)

$i_D = \varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt} = C\frac{dV}{dt}$	i_D: displacement current [A] $\frac{d\phi_E}{dt}$: rate of change of the electric flux over time [$\frac{V \cdot m}{s}$] C: capacitance [F]	Displacement current
$i_D = \frac{r^2}{R^2} i$	r: distance from center of plate [m] R: plate radius [m]	Displacement current
$i_D = \frac{A}{d^2} i$	A: area of plate [m^2] d: side length of plate [m] i: current [A]	Displacement current of capacitor with square plates
$\frac{dE}{dt} = \frac{4k}{r^2} i_D$	$\frac{dE}{dt}$: rate of change of electric field over time [$\frac{V}{m \cdot s}$] i_D: displacement current [A] r: radius [m]	
$B = (\frac{\mu_0 i_d}{2\pi R^2})r$ (r > R) & $B = \frac{\mu_0 i_d}{2\pi r}$ (r < R)	i_D: displacement current [A] r: inner radius [m] R: outer radius [m]	Induced B (inside a charging circular capacitor) Induced B (outside a charging circular capacitor)
$B = \frac{r}{2c^2}\frac{dE}{dt}$	$\frac{dE}{dt}$: rate of change of electric field over time [$\frac{V}{m \cdot s}$] r: radius [m]	Magnitude of the magnetic field when a cylindrical region contains a uniform electric field parallel to the axis changing over time.
$c = \frac{E}{B} = \sqrt{\frac{1}{\mu_0 * \varepsilon_0}}$	E: electric field [N/C] or [V/m] B: magnetic field [T]	Speed of light (roughly)

$\oint \vec{E}.d\vec{A} = \frac{Q}{\epsilon_0}$		Electric field of point charge

Week 12: Electromagnetic Waves

$n_1 sin(\theta_1) = n_2 sin(\theta_2)$	n (refraction index)	Snell's law
$\vec{S} = \frac{1}{u_0} \vec{E} \times \vec{B}$	$S(\frac{Power}{Area} = \frac{\frac{Energy}{Time}}{Area})$ $[\frac{W}{m^2}]$	Poynting vector; **instantaneous** intensity.
$S = \frac{EB}{u_0} = \frac{1}{cu_0}E^2 = \frac{cE^2}{4\pi k} = c\varepsilon_0 E^2$	E: electric field [N/C] or [V/m] B: magnetic field [T] c: speed of light constant [m/s] k: coulomb constant	Instantaneous rate of energy flow
$I = \frac{P}{4\pi r^2} = \frac{P}{A}$	$I\,(\frac{Power}{Area})$ $r:\ distance\ or\ radius\ (m)$	General Intensity
$I = S_{avg} = \frac{1}{c\mu_0} E_{rms}^{\ 2} = \frac{cE^2}{4\pi k}$	E_{rms}: root mean squared of electric field [N/C] or [V/m] E: electric field [N/C] or [V/m]	The average instantaneous intensity is equal to just intensity. **I = S**
$Q = SA\Delta t$	Q: energy absorbed [J] S: instantaneous energy flow rate $[\frac{W}{m^2}]$ A: area [m^2] Δt: change in time [s]	Energy absorbed
$E_{rms} = \sqrt{\frac{P}{4\pi r^2 c\varepsilon_0}}$ $E_{rms} = cB_{rms}$ $E_{rms} = \frac{E_m}{\sqrt{2}}$	P: power [W] B_{rms}: root mean square of magnetic field [T]	
$p = \frac{\|F\|}{A}$	p: pressure [Pa] |F|: force magnitude [N] A: area [m^2]	

$p_r = \frac{I}{c}$ (Total Absorption) $p_{ref} = \frac{2I}{c}$ (Total reflection back along path)	p_r: radiation pressure [Pa] p_{ref}: radiation pressure reflected [Pa] I: intensity $[\frac{W}{m^2}]$	
$I = \frac{1}{2}I_0$ (One-Half rule) $I = I_0 cos^2\phi$ (Cosine squared rule) $\frac{I}{I_o} = \frac{cos^2\phi}{2}$	I_0: intensity of the original light $[\frac{W}{m^2}]$	
$I_1 \propto \frac{1}{r_1^2}$ $I_2 \propto \frac{1}{r_2^2}$ $I_1 r_1^2 \propto 1$ $I_2 r_2^2 \propto 1$ $I_1 r_1^2 = I_2 r_2^2$	I_1: light intensity at distance 1 $[\frac{W}{m^2}]$ I_2: light intensity at distance 2 $[\frac{W}{m^2}]$ r_1: distance 1 from light source [m] r_2: distance 2 from light source [m]	Intensity relation between **two** distances from a single point source.
$\lambda = \frac{c}{f}$	λ: wavelength [m] f: frequency [Hz]	Wavelength of the electromagnetic wave
$k = \frac{2\pi}{\lambda}$	k: wavenumber [Hz]	
$v = f\lambda = \frac{\omega}{k}$	v: velocity [m/s] f: frequency [Hz] λ: wavelength [m] ω: angular frequency [rad/s]	Speed of propagation of the wave
$I = \frac{cB^2}{2u_0} = \frac{E_{rms}^{\ 2}}{cu_0} = c\varepsilon_0 E_{rms}^{\ \ 2}$	$c\ (\frac{m}{s})\ (\vec{v}\ light)$	Intensity when a magnetic or electric field is in the wave
$\theta_{critical} = sin^{-1}(\frac{n_t}{n_i})$	n_t (Transmitted)(Refracted) n_i (Incident)(Original)	Total internal reflection Only occurs from n(high) → n(low)

$\theta_{critical} = sin^{-1}(\frac{1}{n_i})$		
$\theta_B = tan^{-1}(\frac{n_t}{n_i})$	θ_B: Brewster angle in degrees n_t (Transmitted)(Refracted) n_i (Incident)(Original)	Polarization by reflection (Brewster's angle)

Constants

k (Coulomb Constant)	$8.99 * 10^9 \frac{N*m^2}{C^2}$
c (Speed of Light in Vacuum)	$3.00 * 10^8 \frac{m}{s}$
ε_o (permittivity of space)	$8.85*10^{-12} \frac{C^2}{N*m^2}$
μ_0 (Permeability of Space)	$4\pi * 10^{-7} \frac{T*m}{A}$
h (Planck's Constant)	$6.626*10^{-34} J * s$
N_A (Avagadro's Constant)	$6.022 * 10^{23} \frac{1}{mol}$
e (Elementary Charge)	$1.602 * 10^{-19} C$
m_e (Mass of Electron)	$9.11 * 10^{-31} kg$
M_p (Mass of Proton)	$1.673 * 10^{-27} kg$
M_n (Mass of Neutron)	$1.675 * 10^{-27} kg$
G (Gravitational Constant)	$6.67 \times 10^{-11} \frac{m^3}{kg*s^2}$

Surface Areas (Left) and **Perimeters** (Right) needed for Maxwell Equations

$6a^2$ (Cube) $4\pi r^2$ (Sphere) $2\pi rh$ (Cylinder w/o the ends) $2\pi r(r + h)$ (Cylinder) $\pi r^2 + \pi rs$ (Cone) $2(wl + hl + hw)$ (Rectangular Prism)	4s (Square) 2a + 2b (Rectangle) $2\pi r$ (Circle)

$\pi r^2 \phi$ (Sector)	

Indexes of Refraction

Medium	Index	Medium	Index
Vacuum	Exactly 1	Typical crown glass	1.52
Air (STP)[b]	1.00029	Sodium chloride	1.54
Water (20°C)	1.33	Polystyrene	1.55
Acetone	1.36	Carbon disulfide	1.63
Ethyl alcohol	1.36	Heavy flint glass	1.65
Sugar solution (30%)	1.38	Sapphire	1.77
Fused quartz	1.46	Heaviest flint glass	1.89
Sugar solution (80%)	1.49	Diamond	2.42

SI prefixes

Prefix	Symbol	Value	Prefix	Symbol	Value
peta	P	10^{15}	femto	f	10^{-15}
tera	T	10^{12}	pico	p	10^{-12}
giga	G	10^{9}	nano	n	10^{-9}
mega	M	10^{6}	micro	µ	10^{-6}
kilo	k	10^{3}	milli	m	10^{-3}
			centi	c	10^{-2}

SI units

Unit	Symbol	Quantity	Base
Ohm	Ω	resistance, impedance	[V/A]
Joule	J	energy, work	[N m]
Ampere	A	current	
Tesla	T	magnetic field	[N/(A m)]
Volt	V	potential, EMF, voltage	[J/C]
Newton	N	force	[(kg m)/s^2]
Coulomb	C	charge	[A s]
Farad	F	capacitance	[C/V]
Watt	W	power	[J/s]
Webber	Wb	magnetic flux	[T m^2]
Henry	H	inductance	[Wb/A]
Hertz	Hz	frequency	[s^{-1}]
Radian	rad	angle	

How to deal with unit conversions: (6.9420×10^4) nC = (6.9420×10^4) x 10^{-9} = (6.9420×10^{-5}) C

Or if you know the exponents law $(a^x)\ x\ (a^y) = a^{x+y}$ and $\frac{a^x}{a^y} = a^{x-y}$

Standard symbols

Name	Symbol	SI unit
Angle	θ	rad
Angular frequency	ω	rad/s
Capacitance	C	F
Charge	q, Q	C
Conductivity	σ	$\Omega^{-1}\,\mathrm{m}^{-1}$
Current	i, I	A
Current density	$\vec{J}$	$\mathrm{A/m^2}$
Electric field	$\vec{E}$	N/C or V/m
Electric flux	Φ_E	V$\cdot$ m
Electric potential	V	V
Energy	E	J (or eV)
1 eV $= 1.6 \times 10^{-19}$ J		
Potential	U	
Kinetic	K	
EMF	$\mathcal{E}$	V
Force	$\vec{F}$	N
Frequency	f	Hz
Inductance	L, M	H
Intensity	I	$\mathrm{W/m^2}$
Mass	M, m	kg
Magnetic field	$\vec{B}$	T
Magnetic flux	Φ_B	Wb
Period	T	s
Power	P	W
Resistance	R	Ω
Resistivity	ρ	$\Omega\,\mathrm{m}$
Time	t	s
Voltage	$V, \Delta V$	V
Wavelength	λ	m or nm
Work	W	J

Common integrals

$$\int x^a \, \mathrm{d}x = \frac{x^{a+1}}{a+1} \quad (\text{for } a \neq -1)$$

$$\int (ax+b)^n \, \mathrm{d}x = \frac{(ax+b)^{n+1}}{a(n+1)} \quad (\text{for } n \neq -1)$$

$$\int \frac{1}{x} \, \mathrm{d}x = \ln|x|$$

$$\int \frac{c}{ax+b} \, \mathrm{d}x = \frac{c}{a} \ln|ax+b|$$

$$\int e^{ax} \, \mathrm{d}x = \frac{1}{a} e^{ax}$$

$$\int \sin ax \, \mathrm{d}x = -\frac{1}{a} \cos ax$$

$$\int \cos ax \, \mathrm{d}x = \frac{1}{a} \sin ax$$

$$\int \frac{a}{a^2+x^2} \, \mathrm{d}x = \tan^{-1} \frac{x}{a}$$

$$\int \frac{1}{\sqrt{x^2 \pm a^2}} \, \mathrm{d}x = \ln\left|x + \sqrt{x^2 \pm a^2}\right|$$

$$\int \frac{x}{\sqrt{x^2 \pm a^2}} \, \mathrm{d}x = \sqrt{x^2 \pm a^2}$$

$$\int \frac{\mathrm{d}x}{(a^2+x^2)^{3/2}} = \frac{x}{a^2\sqrt{a^2+x^2}}$$

$$\int \frac{x}{(a^2+x^2)^{3/2}} \, \mathrm{d}x = -\frac{1}{\sqrt{a^2+x^2}}$$

Conversions:

Conversions:

Unit we're working with	From meter to unit	From unit to meter
Peta (P)	Divide by 1e+15	Multiply by 1e+15
Tera (T)	Divide by 1e+12	Multiply by 1e+12
Giga (G)	Divide by 1e+9	Multiply by 1e+9
Mega (M)	Divide by 1e+6	Multiply by 1e+6
Kilo (k)	Divide by 1e+3	Multiply by 1e+3
Meter	Divide by 1	Multiply by 1
Centi (c)	Multiply by 1e+2	Divide by 1e+2
Milli (m)	Multiply by 1e+3	Divide by 1e+3
Micro (u)	Multiply by 1e+6	Divide by 1e+6
Nano (n)	Multiply by 1e+9	Divide by 1e+9
Pico (p)	Multiply by 1e+12	Divide by 1e+12
Femto (f)	Multiply by 1e+15	Divide by 1e+15

Area conversions:

Unit we're working with	From meter to unit	From unit to meter
m^2	Multiply by 1	Divide by 1
cm^2	Multiply by 10000	Divide by 10000
mm^2	Multiply by 1e+6	Divide by 1e+6
um^2	Multiply by 1e+12	Divide by 1e+12