Equations Sheet- Physics 152

Nicholas Pittman

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Constants, Charges, and Masses

- Free fall acceleration: $g = 9.81 m/s^2$
- Mass of proton (and neutron): $m_p = 1.67 \cdot 10^{-27}$ kg
- Mass of electron: $m_e = 9.11 \cdot 10^{-31}$ kg
- Charge of proton AND electron: $q_p \equiv e \equiv |q_e| = 1.6 \cdot 10^{-19} C$ (when people (our book is one of them) write " e " they usually mean the number $1.6 \cdot 10^{-19}$, not the negative number. So the charge of the electron is $-e$.)
- Coulomb's constant: $k_{(\text{Coul})} = 9 \cdot 10^9 \frac{N \cdot m^2}{C}$ (equivalent units: $m \cdot F^{-1}$)
- "Vacuum permittivity" /Permittivity of Free Space/Epsilon naught: $\epsilon_0 = 8.85 \cdot 10^{-12} \frac{C^2}{N \cdot m^2}$ (equivalent units on Google: $F \cdot m^{-1}$)
- Relation between k and $\epsilon_0 : k = \frac{1}{4\pi\epsilon_0}$, which equivalently means $\epsilon_0 = \frac{1}{4\pi k}$
- Electron-Volt, a unit of ENERGY: $1 eV = 1.6 \cdot 10^{-19}$ Joules

Physics 1 Stuff :(

$$F_{net} = ma$$

$$x_F = x_i + v_0 t + \frac{1}{2} a t^2$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$Ft = m\Delta v \equiv J_{impulse}$$

Electric Field and Force

$$\vec{\mathbf{F}}_{\text{pt charge on pt charge only}} = \frac{kq_1q_2}{r^2}\hat{r}$$

$$\vec{\mathbf{E}}_{\text{created by pt charge only}} = \frac{kq_{source}}{r^2}\hat{r}$$

$$\vec{\mathbf{F}}_{\text{on experiencer}} = q_{\text{experiencer}}\vec{\mathbf{E}}_{\text{at location of experiencer}}$$

Electric Field near Common Objects

Infinite line of charge density λ. r is the distance of the observation point away from the wire. $\hat{r}$ points radially away from the wire.

$$\vec{\mathbf{E}}_{line} = \frac{\lambda}{2\pi\epsilon_0}\frac{1}{r}\hat{r}$$

Near ANY cylindrically-shaped system, such as a fat wire, or a wire inside of another cylinder.

$$\vec{\mathbf{E}}_{\text{general cylinder}} = \frac{\lambda_{enc}}{2\pi\epsilon_0}\frac{1}{r}\hat{r}$$

Thin ring of charge Q and radius a, at distance z away from the center from the disk looking down the barrel. $\hat{z}$ points away from the disk down the barrel.

$$\vec{\mathbf{E}}_{ring} = \frac{kQz}{(a^2+z^2)^{3/2}}\hat{z}$$

Solid disk of charge density η (I often use σ instead), radius a, and at distance z away from the center from the disk looking down the barrel. $\hat{z}$ points away from the disk down the barrel.

$$\vec{\mathbf{E}}_{disk} = \frac{\eta}{2\epsilon_0}\left(1 - \frac{z}{\sqrt{a^2+z^2}}\right)\hat{z}$$

Outside a spherical shell surface of total charge Q.

$$\vec{\mathbf{E}}_{\text{outside shell}} = \frac{kQ}{r^2_{\text{obs point to CENTER}}}\hat{r}, \quad r > r_{shell}. \qquad E = 0 \text{ inside shell}$$

ANY spherically shaped system, such as a charged ball:

$$\vec{\mathbf{E}} = \frac{kQ_{enc}}{r^2_{\text{obs point to CENTER}}}\hat{r}$$

Near infinite *insulating* plane of surface charge density η

$$E_{\text{insulating plane}} = \frac{\eta}{2\epsilon_0}$$

Near infinite *conducting* plane of surface charge density η

$$E_{\text{conducting plane}} = \frac{\eta}{\epsilon_0}$$

Within parallel plate capacitor of two plates with surface charge densities $\pm\eta$.

$$E_{\text{par. plate capacitor}} = \frac{\eta}{\epsilon_0}$$

Charge density conversions (σ and η interchangeably used)

$$\text{1D: } Q = \lambda L \quad \lambda = \frac{Q}{L} \quad Q = \int \lambda dx$$

$$\text{2D: } Q = \eta L \quad \eta = \frac{Q}{\text{Area}} \quad Q = \int \eta dA$$

$$\text{3D: } Q = \rho L \quad \rho = \frac{Q}{\text{Volume}} \quad Q = \int \rho dV$$

Electric Flux and Gauss' Law

Electric flux due to an electric field through an area.

$$\Phi_E = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}}_{normal} = EA\cos\theta_{\text{b/t E and surface } \textit{perpendicular}}$$

Gauss' Law, original form.

$$\Phi = \frac{Q_{enc}}{\epsilon_0}$$

Gauss' Law, alternate form when considering a Gaussian surface

$$EA = \frac{Q_{enc}}{\epsilon_0}$$

Differential Volume Elements

Mostly for derivations or extra credit problems

$$\text{Sphere: } V = \frac{4}{3}\pi r^3 \implies dV = 4\pi r^2 dr$$

$$\text{Cylinder: } V = \pi r^2 L \implies dV = 2\pi r L dr$$

$$\text{Box: } V = A_{\text{cross sectional}} z \implies dV = A dz$$

$$\text{Circle: } A = \pi r^2 \implies dA = 2\pi r dr$$

Surface areas

$$SA_{sphere} = 4\pi r^2$$

$$SA_{cylinder} = 2\pi r L \ \ (+2 \cdot \pi r^2 \text{ if you need the caps too})$$

Voltage

$$\Delta U = q_{\text{experiencer}} \Delta V$$

$$U = q_{\text{experiencer}} V$$

$$V_{\text{point charge or spherical source}} = \frac{kq_{source}}{r}$$

PE of a point charge near another point charge

$$U = \frac{kq_1 q_2}{r}$$

Conservation of energy

$$KE_i + U_i = KE_f + U_f$$

careful to not confuse v and V in your handwriting in these kinds of problems.
Alternative where you put minus signs in by hand

$$KE_f = KE_i \pm |W_{doneonobject}|$$

Work to ASSEMBLE a charge distribution of point charges q_i, q_j.

$$W_{assembly} = \sum_{Pairs\ i<j} \frac{kq_i q_j}{r}$$

Connection between Voltage and Electric Field

Non-calc versions

$$\Delta V = -\vec{\mathbf{E}} \cdot \Delta \vec{\mathbf{x}} \quad E = -\frac{\Delta V}{\Delta x}$$

Calculus versions

$$\Delta V = -\int_{x_i}^{x_f} E \, \mathrm{d}x \,, \quad E = -\frac{dV}{dx} \quad \text{(Multivar versions: } \Delta V = -\int \vec{\mathbf{E}} \cdot d\vec{\mathbf{x}},\ \vec{\mathbf{E}} = -\vec{\nabla} V)$$