# AP Physics C: Mechanics:: Formula Sheet

<table>
<tr><th>I</th><th>II</th><th>III</th><th>IV</th><th>V</th><th>VI</th></tr>
<tr><td>Uniform fields or nonlinear fields that are drawn.</td><td>Point charge $q$ superposition</td><td>Sphere with charge Q and sphere within a sphere</td><td>Arc with Point P at center of the arc</td><td>Hoop with P offset along an axis passing thru center</td><td>Cylinder</td></tr>
<tr><td rowspan="3">$E$ given (or $V$ is given)<br><br>If $V$ is given instead of $E$<br><br>you can use the equation<br>$E = -\frac{dV}{dr}$<br><br>to solve for E .<br><br>Usually these problems involve uniform fields or when non-uniform they allow you to find average $E$ between two equal potential line values.<br>$E = \frac{V}{d}$</td><td colspan="4">All four of these problems use the same equation derived from Gauss's Law<br>$\oint \vec{B}\cdot\vec{dA} = \frac{Q_{enc}}{\epsilon_0}$ $E(4\pi r^2) = \frac{Q_{enc}}{\epsilon_0}$ $E = \frac{1}{4\pi\epsilon_0}\frac{Q_{enc}}{\epsilon_0}$ $k = \frac{1}{4\pi}\epsilon_0$</td><td rowspan="2">$\oint \vec{B}\cdot\vec{dA} = \frac{Q_{enc}}{\epsilon_0}$<br><br>$E(2\pi rl) = \frac{Q_{enc}}{\epsilon_0}$<br>$E = \frac{Q_{enc}}{2\pi rl\epsilon_0}$<br><br>$\lambda = \frac{Q}{L}$<br>$E = \frac{\lambda}{2\pi r\epsilon_0}$</td></tr>
<tr><td rowspan="2">Use $E = k\frac{Q}{r^2}$ to find All the individual $E_i$, vectors due to each charge $q_i$ acting a point P. Add all the individual<br><br>$E_i$ vectors to find the total electric field $E$.<br><br>If a new charge appears at point P, then you can find the force on the new charge due to the field $E$ .<br><br>$F_E = q_{new}E_{total}$</td><td>Use $E = k\frac{Q_{enc}}{r^2{}_{GS}}$ to find $E$ at various points (inside the sphere $r < R$ , on its surface $r = R$, and outside the sphere $r > R$ ).</td><td rowspan="2">$E = k\frac{Q}{r^2}$<br>$dE = k\frac{dq}{r^2}$<br>$\int dE_x = \int k\frac{dq}{r^2}\cos\theta$<br><br>Density<br>$\lambda = \frac{Q}{L} = \frac{dq}{dl}$<br><br>$E_x = \int \frac{kQ}{r^2L}dl\cos\theta$<br>$r = R$<br>Arc length $dl = Rd\theta$<br><br>$E_x = \int \frac{kQ}{RL}\cos\theta\, d\theta$<br>$E_x = \frac{kQ}{RL}\int_{\theta_0}^{\theta}\cos\theta\, d\theta$<br><br>$E_x = \frac{kQ}{RL}(\sin\theta_b - \sin\theta_a)$</td><td rowspan="2">$E = k\frac{Q}{r^2}$<br>$dE = k\frac{dq}{r^2}$<br><br>$\int dE_x = \int k\frac{dq}{r^2}\cos\theta$<br><br>$E_x = \frac{k}{r^2}\cos\theta\int dq$<br><br>$E_x = \frac{kQ}{r^2}\cos\theta$<br><br>$\cos\theta = \frac{x}{r}$ and $r = \sqrt{R^2 + x^2}$<br><br>$E_x = \frac{kQx}{(R^2 + x^2)^{3/2}}$</td></tr>
<tr><td>$r < R$ in an insulator<br>$\frac{Q_{enc}}{V_{enc}} = \frac{Q_{total}}{V_{total}}$<br><br>$\frac{Q_{enc}}{\left(\frac{4}{3}\right)\pi r^3} = \frac{Q_{total}}{\left(\frac{4}{3}\right)\pi r^3}$</td><td>$r < R$ in an insulator<br><br>$\frac{Q_{enc}}{V_{enc}} = \frac{Q_{total}}{V_{total}}$<br><br>$\frac{Q_{enc}}{\pi r^2 L} = \frac{Q_{total}}{\pi r^2 L}$</td></tr>
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| $E = -\frac{dV}{dr}$<br>$V = -\int E\ dr$<br>Usually these problems involve uniform fields.<br>$V = Ed$ | $V = k\Sigma\frac{q_i}{r_i}$<br>$V_{total} = k\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}+\frac{q_3}{r_3}+..\right)$<br>If a new charge appears at point P, then you can find the energy on the new charge due to the total potential $V$ .<br>$U_E = q_{new}V_{total}$<br>If released the charge is released you can find its speed<br>$q_{new}V_{total} = \frac{1}{2}m_{new}v^2{}_{new}$ | Change in potential moving from point a to b<br>$\Delta V = -\int_a^b E\ \ dr$<br>$\Delta V = -\int_a^b\left(k\frac{Q}{r^2}\right)\ dr$<br>$V = -kQ\int_a^b\left(\frac{1}{r^2}\right)\ dr$<br>$V = k\frac{Q_{enc}}{r}\left\{\begin{matrix}b\\a\end{matrix}\right.$<br>$V = kQ\left(\frac{1}{b}-\frac{1}{a}\right)$<br>(If $a = \infty$ and $b = R$ )<br>$V = k\frac{Q}{R}$ | The arc consists of many charged spheres (protons or electrons) to total.<br>$V = k\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}+\frac{q_3}{r_3}+..\right)$<br>All points are at the same distance $r$ , and $R = r$ .<br>$V = k\frac{Q}{R}$ | The hoop consists of many charged spheres (protons or electrons) to total.<br>$V = k\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}+\frac{q_3}{r_3}+..\right)$<br>$V = k\frac{Q}{R}$<br>All points are at the same distance $r$ , where<br>$r = \sqrt{R^2+x^2}$<br>$V = k\frac{Q}{\sqrt{R^2+x^2}}$ | Change in potential moving from point *a* to *b*<br>$V = -\int_a^b E\ dr$<br>$V = -\int_a^b\left(\frac{\lambda}{2\pi r\epsilon_0}\right)dr$<br>$V = -\frac{\lambda}{2\pi r\epsilon_0}\int_a^b\left(\frac{1}{r}\right)dr$<br>$V = -\frac{\lambda}{2\pi\epsilon_0}(In\ b - In\ a$<br>$V = -\frac{\lambda}{2\pi\epsilon_0}In\frac{b}{a}$ |
| ***2005-1*** | ***2000-2, 2001-1, 2006-1*** | ***1996-1, 1997-2, 1998-1, 1999-1, 2003-1, 2004-1, 2007-2, 2008-1*** | **2002-1** | **1999-3** | **1998-1, 2000-3** |
| **I** | **II** | **III** | **IV** | **V** | **VI** |
| Fixed Magnet | Wires and Superposition | Cylinder with current $I$<br>Cylinder within a cylinder | Arc with Point P at center of the arc | Hoop with P offset along an axis passing thru center | Solenoid |
| | These two problems use Ampere's Law<br>$\oint\vec{B}\cdot\vec{dl} = \mu_0 I_{enc}$<br>$\vec{B}\oint\vec{dl} = \mu_0 I_{enc}$<br>In Ampere's Law $dl$ is the length of the magnetic field which circles the wire, with a sum of $\oint\vec{dl} = 2\pi r$<br>Lower case $r$ is used since we are measuring the to | | These two problems use Biot-Savart<br>$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\hat{r}}{r^2}$<br>$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\vec{dl}}{r^2}\sin\theta$ | | $B_s = \mu_0 nI$<br>$n = \frac{N}{L}$ |

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| $B$ uniform and given<br><br>If a moving charge passes through the fixed field<br>$F_B = qvB$<br><br>If a wire passes through the fixed field<br><br>$F_B = ILB$ | field.<br>$B(2\pi r) = \mu_0 I_{enc}$<br><br>$B = \frac{\mu_0}{2\pi}\frac{I_{enc}}{r_{GS}}$ | | This theta is the angle between $l$ and $r$ and is usually 90°. The sin of 90° is 1, eliminating this theta.<br>$\int \overrightarrow{dB} = \int \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$<br>$B = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$ | | where $N$ is the number of loops in the solenoid and $L$ is the solenoid's length.<br><br>$B_s = \frac{\mu_0 N}{L} I$<br>The trick way to find n is to use only a single loop of whole solenoid.<br><br>*N = 1*<br><br>*L* = diameter of the wirer.<br><br>$B_s = \mu_0 \frac{1}{dia} I$<br><br>$B_s = \frac{\mu_0 I}{dia}$ |
| | Use<br>$B = \frac{\mu_0}{2\pi}\frac{I_{enc}}{r_{GS}}$<br><br>to find all the $B$ vectors due to each wire carrying a current I a distance r from a point P. Add all the $B$ vectors to find the total $B$ . If a moving charge passes through point P<br><br>$F_B = qvB$<br><br>If a wire passes through point P<br><br>$F_B = ILB$ | Use<br>$B = \frac{\mu_0}{2\pi}\frac{I_{enc}}{r_{GS}}$<br><br>to find $B$ at various points<br><br>Point B<br>$\frac{I_{enc}}{V_{enc}} = \frac{I_{total}}{V_{total}}$<br><br>$\frac{I_{enc}}{\pi r^2 L} = \frac{I_{total}}{\pi r^2 L}$ | $B = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int dl$<br><br>In Biot-Savart $dl$ is the length of the wire. This is the arc length<br><br>$\oint dl = R\theta$<br>Use upper case R when working with objects. However, in this problem<br><br>R = r , so<br>$\oint dl = r\theta$<br>$B = \frac{\mu_0}{4\pi}\frac{I}{r^2} r\theta$<br>$B = \frac{\mu_0}{4\pi}\frac{I}{r}\theta$<br><br>Where theta is the angle of the arc measured in radians. Note: this will also solve for an entire hoop where theta is 2π radians. | $x$-components are needed, introducing a second theta. Magnetism's geometry is odd, since it acts at 90°.<br><br>$dB_x = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}\sin\theta$<br>$B_x = \frac{\mu_0}{4\pi}\frac{I}{r^2}\sin\theta \int dl$<br><br>In Biot-Savart $dl$ is the length of the wire. This is the arc length<br>$\oint dl = 2\pi R$<br>Use upper case $R$ when working with objects.<br>$B_x = \frac{\mu_0}{4\pi}\frac{I}{r^2}\sin\theta(2\pi R)$<br><br>$B_x = \frac{\mu_0}{2}\frac{IR}{r^2}\sin\theta$ | |
| | | **2000-3** | | **2008-3** | **1996-3, 2005-3** |