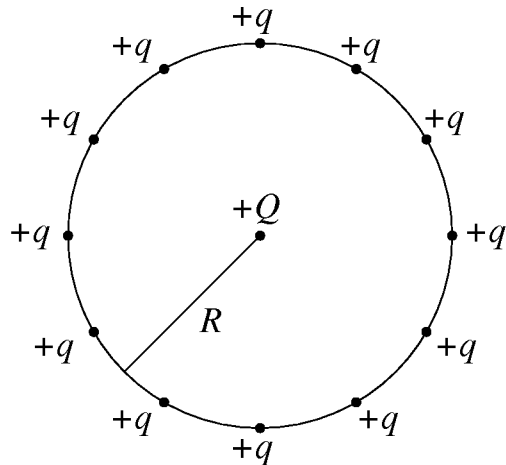


Problem 1 (5 points)

Twelve equal charges $+q$ are situated in a circle with radius R , and they are equally spaced (see the figure).



a. (2) What is the net force (magnitude and direction) on a charge $+Q$ at the center of the circle?

We remove **only** the $+q$ charge which is located at “3-o’clock.”

b. (3) What now is the force (magnitude and direction) on the charge $+Q$ at the center of the circle?

MIT 8.02 Spring 2002 Final Exam Solutions

Problem 1

(a) The force on $+Q$ due to any particular charge $+q$ on the ring is exactly balanced by the force due to the charge $+q$ diametrically opposite. So the net force on $+Q$ is zero.

(b) With the 3:00 charge removed, the 9:00 charge is now unbalanced, and $+Q$ thus experiences a force $\frac{1}{4\pi\epsilon_0}(qQ/R^2)$ to the right. (We may also obtain the same result by considering the effectively equivalent process of placing a charge $-q$ at 3:00 instead of removing the charge $+q$ from there.)

Problem 2

~~The now familiar application of Ampère's law gives~~

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{piercing surface}} \implies B = \frac{\mu_0 I_{\text{p.s.}}}{2\pi r} .$$

~~For definiteness, consider a cross-section where the inner cylinder current flows into the page and the outer cylinder current flows out of the page. Take currents out of the page to be positive, so that positive B corresponds to a counterclockwise magnetic field (by right-handed convention) and negative B corresponds to a clockwise field.~~

$$\text{Region (i):} \quad I_{\text{p.s.}} = 0 \implies B = 0$$

$$\text{Region (ii):} \quad I_{\text{p.s.}} = -I \implies B = -\frac{\mu_0 I}{2\pi r}$$

$$\text{Region (iii):} \quad I_{\text{p.s.}} = 3I - I = 2I \implies B = \frac{\mu_0 I}{\pi r}$$

~~(One's own choices of sign convention and system orientation may differ from those made here.)~~

Problem 3

~~If no current flows through the meter A , then one current (call it I_1) flows through both R_3 and R_x and another current (call it I_2) flows through both R_1 and R_2 . Applying Kirchhoff's loop rule to a simple loop through all four resistors gives $I_1(R_3 + R_x) = I_2(R_1 + R_2)$. Taking another loop through R_3 , R_1 , and A , we get $I_1 R_3 = I_2 R_1$. Dividing the first equation by the second eliminates both I_1 and I_2 , and solves to give $R_x = R_3 R_2 / R_1$.~~