First Year Electricity & Magnetism Classwork 1 Quiz

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5 February 2008

In all questions, choose the *best* answer. Numerical answers need only be accurate to at most 2 significant figures.

Good Luck

1. A vector is something that has

- **(A)** Length
- **(B)** Direction
- **(C)** Neither of the above
- **(D)** Both Length and Direction

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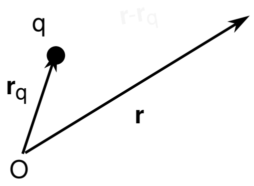
The correct answer is (D). This is essentially the definition of a vector

2. A charge q is located at position $\mathbf{r}_q$ with respect to the origin. An observer is located at position $\mathbf{r}$. The position of $\mathbf{r}$ relative to the position of the charge is

- **(A)** $\mathbf{r}_q - \mathbf{r}$
- **(B)** $r - r_q$
- **(C)** $\mathbf{r} - \mathbf{r}_q$
- **(D)** $|\mathbf{r} - \mathbf{r}_q|$
- **(E)** None of the above



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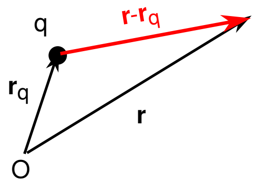

The correct answer is (C). The answer must be a vector. Vector addition gives $\mathbf{r} = \mathbf{r}_q + (\mathbf{r} - \mathbf{r}_q)$ as shown in the diagram. You can also see which way to form the difference by ensuring that for $\mathbf{r}_q \to \mathbf{0}$ the result reduces to $\mathbf{r}$.

3. **A charge Q of 2 C is placed at the origin. A test charge q_1 of +2 C is placed 1 m from the origin, while a second test charge q_2 of -1 C is placed 2 m from the origin. The the forces on the two test charges due to the charge at O**

(A) Have the same magnitude, but the first is repelled while the second is attracted
(B) Have the same magnitude, but the first is attracted while the second is repelled
(C) The magnitude of the force on q_1 is twice that on q_2
(D) The magnitude of the force on q_1 is four times that on q_2
(E) None of the above

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(E) None of the above

The correct answer is (E). The force is $\mathbf{F} = Qq_i/(4\pi\epsilon_o r_i^2)\hat{\mathbf{r}}$ so the magnitude is proportional to q_i/r_i^2. For q_1 this is $2/1^2 = 2$ while for q_2 it is $1/2^2 = 1/4$ so the ratio of the magnitudes is 8. q_1 is repelled, and q_2 is attracted.

4. A charge q moves from rest under the influence of a uniform electric field $\mathbf{E} = E_x\hat{\mathbf{x}} + E_y\hat{\mathbf{y}}$. The resulting motion is

(A) parabolic
(B) circular
(C) uniform acceleration in a straight line
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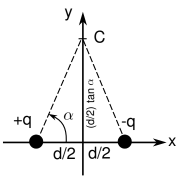
The correct answer is (C). Solve separately the $\hat{\mathbf{x}}$ and $\hat{\mathbf{y}}$ equations of motion $m\frac{dv_x}{dt} = qE_x \Rightarrow x = (qE_x/2m)t^2$ and similarly $y = (qE_y/2m)t^2$ so $y = (E_y/E_x)x$. OR, better, invent a new coordinate system in which one axis is aligned with $\mathbf{E}$ in which case the problem reduces to a 1-D problem along that axis. The answer (motion in a straight line) only holds for $\mathbf{v}(t=0) = \mathbf{0}$ but the trick (?) of using $\mathbf{E}$ to define an axis makes the problem simpler if $\mathbf{v}(t=0) \neq \mathbf{0}$

5. **A dipole is formed along the x-axis by a charge $+q$ at $x = -d/2$ and a charge $-q$ at $x = +d/2$. The electric field at a point $C = (0, y) \equiv (0, \frac{d}{2}\tan\alpha)$ along the y-axis is**

(A) $\frac{2q\cos^3\alpha}{\pi\epsilon_o d^2}\hat{\mathbf{i}}$
(B) $\frac{2q\cos^2\alpha\sin\alpha}{\pi\epsilon_o d^2}\hat{\mathbf{i}}$
(C) $\frac{2q\cos^2\alpha\sin\alpha}{\pi\epsilon_o d^2}\hat{\mathbf{j}}$
(D) 0
(E) None of the above



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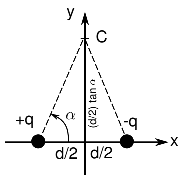

The correct answer is (A). The distance from each charge to C is $(d/2)\sec\alpha$ so

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 = \frac{q}{4\pi\epsilon_o\frac{d^2}{4}\sec^2\alpha}\left[\left(\cos\alpha\,\hat{\mathbf{i}} + \sin\alpha\,\hat{\mathbf{j}}\right) - \left(-\cos\alpha\,\hat{\mathbf{i}} + \sin\alpha\,\hat{\mathbf{j}}\right)\right]$$

That is, the x-components add and the y-components cancel.

6. **A dipole of dipole moment p is free to rotate. In the presence of an electric field, E, we've seen that there is a torque $\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$ on the dipole. For a uniform $\mathbf{E} = E\,\hat{\mathbf{i}}$**

(A) the torque will be zero if **p** is perpendicular to **E**
(B) the dipole has a stable equilibrium with **p** aligned with **E**
(C) the dipole has a stable equilibrium with **p** anti-aligned with **E**
(D) both aligned and anti-aligned orientations are stable
(E) None of the above

6. **A dipole of dipole moment p is free to rotate. In the presence of an electric field, E, we've seen that there is a torque $\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$ on the dipole. For a uniform $\mathbf{E} = E\,\hat{\mathbf{i}}$**

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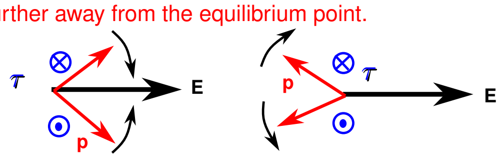
(E) None of the above

The correct answer is (B). For **p** nearly aligned with **E** the torque τ acts to align **p**. Near the anti-alignment position, although $\tau \to \mathbf{0}$ here, τ takes **p** further away from the equilibrium point.



7. A square with sides of length 3 m lies in the $x - y$ plane. A uniform electric field is present such that $\mathbf{E} = (3.0, 0.0, -1.0)$ V/m. Taking $+\hat{\mathbf{k}}$ to be the orientation of the normal to the square, the electric flux Φ_E through the square in Vm is

(A) 9.0
(B) -9.0
(C) 18.0
(D) -9.0 $\hat{\mathbf{k}}$
(E) None of the above

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(B) -9.0
(C) 18.0
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(E) None of the above

The correct answer is (B). Taking $\mathbf{E} \cdot \mathbf{A}$ gives $(3.0, 0, -1.0) \cdot (0, 0, 9) = -9.0$. Note Φ_E is a scalar.

8. **A square with sides of length 3 m lies in the $x - y$ plane, with a corner at the origin and sides aligned with the $x - y$ axes. An electric field is present such that $\mathbf{E} = (3.0z, 0.0, -1.0y)$ V/m. Taking $+\hat{\mathbf{k}}$ to be the orientation of the normal to the square, the electric flux Φ_E through the square in Vm is**

(A) -9.0
(B) -27.0
(C) -13.5
(D) $-9.0y$
(E) None of the above

8. **A square with sides of length 3 m lies in the $x - y$ plane, with a corner at the origin and sides aligned with the $x - y$ axes. An electric field is present such that $\mathbf{E} = (3.0z, 0.0, -1.0y)$ V/m. Taking $+\hat{\mathbf{k}}$ to be the orientation of the normal to the square, the electric flux Φ_E through the square in Vm is**

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(B) -27.0
(C) -13.5
(D) $-9.0y$
(E) None of the above

The correct answer is (C). Taking $\mathbf{E} \cdot \mathbf{dA}$ gives $(3.0z, 0, -1.0y) \cdot dx\,dy\,\hat{\mathbf{k}}$.
So $\Phi_E = \iint_S \mathbf{E} \cdot \mathbf{dA} = \int_{y=0}^{3} \int_{x=0}^{3} -y\,dx\,dy = [-3]\left[y^2/2\right]_0^3 = -13.5$

9. A charge Q is placed at $(0.5, 0.0, 0.0)$ and surrounded by an ellipsoidal surface of the form $x^2 + 2y^2 + z^2 = 1$. The electric flux through the surface is

(A) 0
(B) $Q/(4\pi\epsilon_o)$
(C) $\sqrt{6}Q/(4\pi\epsilon_o)$
(D) None of the above

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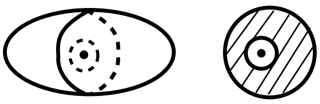
(A) 0
(B) $Q/(4\pi\epsilon_o)$
(C) $\sqrt{6}Q/(4\pi\epsilon_o)$
(D) None of the above

The correct answer is (D). Gauss's Law says $\oiint_S \mathbf{E} \cdot \mathbf{dA} = Q_{encl}/\epsilon_o$ for ANY surface where Q_{encl} is the charge enclosed by that surface. It is easy to verify that in this case Q lies inside the ellipsoid, therefore $\Phi_E = Q_{encl}/\epsilon_o$.

10. A charge Q is placed at $(0.5, 0.0, 0.0)$. A surface is formed by the combination of an ellipsoidal surface of the form $x^2 + 2y^2 + z^2 = 1$ together with a spherical surface of radius 0.1 m that it centred around the charge. The electric flux through this surface is



(A) 0
(B) $2Q/\epsilon_o$
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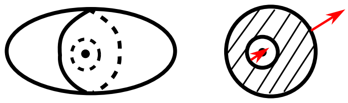

(A) 0
(B) $2Q/\epsilon_o$
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(D) This question is too hard
(E) None of the above

The correct answer is (A). Gauss's Law says $\oiint_S \mathbf{E} \cdot \mathbf{dA} = Q_{encl}/\epsilon_o$ for ANY surface where Q_{encl} is the charge enclosed by that surface. The surface we've formed does not contain any charge. The diagram shows the volume it encloses and the outward normal.