1. (2 pts) Two identical conducting spheres, one that has an initial charge $+Q$, the other initially uncharged, are brought into contact. What is the new charge on each sphere?
   a. $-Q$
   b. $-Q/2$
   c. zero
   d. $+Q/2$
   e. $+Q$
   Answer: zero

2. (2 pts) What is the direction of the magnetic force on a positive charge that moves as shown in the diagram?
   a. left
   b. right
   c. up
   d. down
   Answer: (b) into the page

3. (10 pts) Determine the force (in $E\hat{r}$ notation) on an aluminum rod with a 2.7 $\mu$C charge that passes between the poles of a (1.5T) T permanent magnet at a speed of $(21 - 3\hat{j} + 4\hat{k})$ m/s.

\[ F = q(E \times \hat{B}) = 2.7 \times 10^{-6} C \left(21 \times 1.55 + 4 \times 1.55 \right) \times (1.5) \]

-2 wrong $\hat{i}$, $\hat{k}$ in answer

-2 Forget to multiply by $q$

-2 wrong cross product

\[ F = 2.7 \times 10^{-6} (-62 + 3\hat{k}) \]

\[ F = (-16.2\hat{j} + 8.1k) \times 10^{-6} N \]

**MAKE-UP EXAM SOLUTION:**

\[ F = (2.7 \times 10^{-6})(3.7 \times 1.55 + 8.1 \hat{k}) \]

\[ F = 1.83 \times 10^{-5} N \]

4. (14 pts) Point charges $q_1 = +2 e$, $q_2 = +3 e$, and $q_3 = 4 e$ are arranged as shown. Determine the magnitude of the net force on charge $q_1$.

\[ F = k \frac{|q_1 q_2|}{r^2} \]

-2 wrong (For $F_2$)

-2 didn't use $k$

\[ F_1 = q_1 \frac{k |q_2|}{r^2} \]

\[ F_1 = 2.16 \times 10^{-5} N \]

\[ F_2 = q_1 \frac{k |q_3|}{r^2} \]

\[ F_2 = 1.125 \times 10^{-5} N \]

\[ F_3 = q_1 \frac{k |q_3|}{r^2} \]

\[ F_3 = 1.832 \times 10^{-5} N \]

5. (14 pts) Point charges $q_1 = 14 \mu C$, $q_2 = -4 \mu C$, and $q_3 = 6 \mu C$ are placed along the x-axis as shown. Determine the magnitude and direction (left or right) of the net electric field at point P.

\[ E = \frac{k q}{r^2} \]

\[ E = \frac{7355}{10^6} \text{ N/C} \]

\[ E_x \text{ at } P = \frac{k q}{r^2} \]

\[ E_x = 7355 \text{ N/C} \]

\[ E_{max} = 7355 \text{ N/C} \]

**MAKE-UP:**

\[ E_2 = -3540 \text{ N/C} \]

Negative means field pointing into P, so $q$ must be positive.

\[ \theta = 6.29 \text{ m} C \]
6. (14 pts) Two stationary point charges of -3.4nC and -2.2nC are separated by a distance of 0.6 m. A proton is released from rest at a point midway between the two charges and moves linearly between the two charges. What is the speed of the proton when it is 0.1 m from the -3.4nC charge? 

Hint: Acceleration is not constant.

\[ v = \sqrt{\frac{1}{2} \cdot \frac{k}{m} \cdot \frac{q_1 q_2}{r^2 + \Delta r^2}} \]

\[ 184,000 \text{ m/s} \]

\[ \Delta r = 0.5 \text{ m} \]

\[ \text{cons of energy \#2} \]

\[ V_1 + V_2 = V \]

\[ V = -168 \text{ V} \]

\[ V_2 = -2.3 \times 10^{-19} \text{ F} \]

\[ V = 2.945 \times 10^{-17} \text{ J} \]

\[ v = (184,000 \text{ m/s}) \]

\[ \Delta V = 177.6 \text{ V} \]

\[ \text{MADE-UP EXAM.} \]

\[ \text{REVIEW - DEBT (or Forward - Charge energy)} \]

\[ 6.73 \text{ A} \]

\[ \text{voltage not across twin series.} \]

\[ \text{r1, r2, r3} = 15 \text{ ohms} \]

\[ \text{only solved I}_{\text{total}} \]

\[ I_{\text{total}} = 75 \text{ A} \]

\[ 7. (14 pts) \] For the circuit shown, determine the current through the 15 \Omega resistor.

\[ 8. (14 pts) \] Determine the energy stored in the circuit shown.

\[ 9. (16 pts) \] Determine the unknown voltage, \( E \).

\[ 11.25 \text{ V} \]