1. [1pt] A force, $F$, applied to a 16.1 kg crate at an angle, $\theta$, of 31.0° makes the crate move horizontally with a constant acceleration of 1.81 m/s². The coefficient of kinetic friction between the crate and the surface is $\mu_k = 0.27$. Calculate the magnitude of $F$.

2. [1pt] Calculate the volume of a spherical balloon which has a surface area of 0.0457 m².

3. [1pt] (This is a tough one! Read the hint which appears after you submit one wrong answer.) The graph below represents the function

$$F(x) = ax^b$$

Make a careful determination of the value of $b$. You have to get within 10% of the correct answer to get credit.

4. [1pt] Find the slope of the function at $x = 1.5$ for the curve above.

5. [1pt] Evaluate the definite integral

$$\int_{1.90}^{3.89} (x^2 + 5x)dx$$

6. [1pt] $X$ and $Y$ are dimensionally different. (They have different units.) Select ALL the physically meaningful operations (i.e., $AE$, $BCD$, ...).

- A) $X^{1/3}$ or $Y^{1/3}$
- B) $\frac{X}{Y}$ or $X \cdot Y$
- C) $e^{XY}$ or $e^{X+Y}$
- D) $X^2 + Y^2$
- E) $X + Y$ or $X - Y$
- F) $X^2$ or $Y^2$

7. [1pt] The speed of a vehicle is 3.56 meters per second. Select from the list below all of the answers which express that speed using metric units AND which are formatted so that CAPA can judge the answer. [* means multiply, ^ means raise to a power, / means divide] (Entering the NUMERICAL VALUE and the UNIT of a quantity: The numerical value is entered with NO blank spaces. Then put in a space. Then enter the desired unit. Give ALL correct answers, i.e., B, AC, BCD...)

- A) 3.56 m/s^-1
- B) 3.56E-3 km/s
- C) 3.56 m/s^-1
- D) 3.56 m/s
- E) 3.56E2 cm/s^-1
- F) 3.56 m/s

8. [1pt] Vectors operations: Select the correct statements. (Give ALL correct answers in alphabetical order, i.e., B, AC, BCD...)

- A) If $\mathbf{B} \perp \mathbf{A}$, then $\mathbf{A} \cdot \mathbf{B} = 0$
- B) The scalar (or dot) product of two vectors can be $(+)(-)$, or zero.
- C) The magnitude of a vector can be positive or negative.
- D) $\mathbf{A} \times \mathbf{C} = \mathbf{C} \times \mathbf{A}$
- E) If $\mathbf{A} = \mathbf{B} \times \mathbf{C}$ and $\mathbf{C} = 10\mathbf{j}$, then $A_y = 0$
- F) The x-component of a vector can be $(+)(-)$, or zero

9. [1pt] Two particles of masses 5.6 kg and 9.6 kg and charges 1.6 C and -9.5 C respectively are separated by a distance 58 cm. Find the ratio of the magnitudes of the Electric to Gravitational forces between them. That is, what is $F_{elec}/F_{grav}$?

10. [1pt] Two small spheres with charges 4.5 C and -1 C are held 8 m apart. Find the magnitude of the force between them.

11. [1pt] If you complete the survey at this link in your browser, you will receive credit for one capa problem.
1. [1pt] Three charges are arranged on a line as shown above. (For each statement select T True, F False). For instance if the first statement is true and the rest are false, enter TFFTF.

A) If \( Q_1 \) is positive, \( Q_2 \) is negative and \( Q_3 \) is positive, then \( Q_2 \) MUST feel a net force to the right.
B) If \( Q_1 \) is positive, \( Q_2 \) is negative and \( Q_3 \) is negative, then \( Q_2 \) MUST feel a net force to the right.
C) If \( Q_1 \) is negative, \( Q_2 \) is negative and \( Q_3 \) is positive, then \( Q_2 \) MUST feel a net force to the right.
D) If \( Q_1 \) is positive, \( Q_2 \) is negative and \( Q_3 \) is positive, then \( Q_2 \) MIGHT feel a net force to the right.

2. [1pt]  

As shown in the figure above, a ball of mass 0.660 grams and positive charge, \( q = 40.9 \, \mu C \), is suspended on a string of negligible mass in a uniform electric field. We observe that the ball hangs at an angle of \( \theta = 15.0^\circ \) from the vertical. What is the magnitude of the electric field?

3. [1pt] Two charges, \( +q \) and \( -q \), are located in the x-y plane at points \((0,+d/2)\) and \((0,-d/2)\), respectively. Calculate the magnitude of the electric field at point \( P \) with the superposition principle.

Data: \( q = 39.0 \, nC \), \( d = 2.40 \, mm \) and \( P \) at \( x = 48.0 \, mm \).

4. [1pt] A uniform circular ring of charge \( Q = 6.20 \, \mu C \) and radius \( R = 1.30 \, cm \) is located in the x-y plane, centered on the origin as shown in the figure.

What is the magnitude of the electric field, \( |\vec{E}| \) at point \( P \) located at \( z = 4.60 \, cm \)?

5. [1pt] Consider other locations along the positive z-axis. At what value of \( z \) does \( |\vec{E}| \) have its maximum value?

6. [1pt] What is the maximum value of \( |\vec{E}| \) on the z-axis?

7. [1pt] If \( z \ll R \) then \( |\vec{E}| \propto z \). (You should verify this by taking the limit of your expression for \( |\vec{E}| \) for \( z \ll R \).) If you place an electron on the z-axis near the origin it experiences a force \( F_z = -kz \), where \( k \) is a constant. Obtain a numerical value for \( k \).

8. [1pt] Two point-like particles are placed 22.5 cm apart and are given equal and opposite charge. The first particle, of mass 41.0 g, has an initial acceleration of 5.75 m/s\(^2\) towards the second particle. What is the mass of the second particle if its initial acceleration towards the first is 3.00 m/s\(^2\)?

9. [1pt] What is the magnitude of the charge on each particle?
Four charges $A_q, B_q, C_q,$ and $D_q$ ($q = 5.00 \times 10^{-7} \text{C}$) sit in a plane at the corners of a square whose sides have length $d = 37.0 \text{ cm}$, as shown in the diagram below. A charge, $E_q$, is placed at the origin at the center of the square.

**DATA:** $A = 2$, $B = 4$, $C = 1$, $D = 4$, $E = -3$. Consider the charge at the center of the square. What is the x-component of the net force on this charge?

A charge $Q = 4.50 \times 10^{-4} \text{ C}$ is distributed uniformly along a rod of length $2L$, extending from $y = -28.3 \text{ cm}$ to $y = +28.3 \text{ cm}$, as shown in the diagram above. A charge $q = 1.15 \times 10^{-6} \text{ C}$, and the same sign as $Q$, is placed at $(D,0)$, where $D = 47.0 \text{ cm}$. Consider the situation as described above and the following statements. If the statement is true, answer 'T', if it is false, answer 'F', and if the answer cannot be determined from the information provided, answer 'C'. For example if 'B' and 'C' are true and there is not enough information to answer 'D' and the rest are false, then answer 'FTTCF'.

A) The magnitude of the force on charge $q$ due to the small segment $dy$ is $dF = (kqQ/2Lr^2)dy$
B) The net force on $q$ in the y-direction does not equal zero.
C) The net force on $q$ in the x-direction does not equal zero.
D) The total force on $q$ is generally in the $\rightarrow$ direction.
E) The charge on a segment of the rod of infinitesimal length $dy$ is given by $dQ = (Q/L^2)dy$
1. [1pt] Three identical metal spheres, x, y, and z, are placed at the corners of an equilateral triangle, as shown below. Sphere z has a constant positive charge. Which vector could represent the force on z, when x is positive and y is negative, with the magnitude of the charge on x less than that on y? WARNING! You have 4 tries only for this problem.

![Diagram](image)

2. [1pt] A cork ball of mass 3.50 g is placed between two very large horizontal planes of charge. The bottom plane has a uniform charge density of +0.82 μC/m², whereas the upper plane has a uniform charge density of -0.24 μC/m². The cork ball, which carries an unknown charge, is placed between the planes and is observed to float motionlessly. What is the charge on the ball?

3. [1pt] The diagram below shows a dipole centered at the origin and along the x-axis. Determine an expression for the total electric field at a point A (r₀ = 2.6L, 0) in terms of q and L. Calculate the magnitude of the total electric field at A, when q = 7.45 × 10⁻⁷ C and L = 44.6 cm.

![Diagram](image)

4. [1pt] Consider the situation as described in the diagram (in the previous problem), and the following statements. If the statement is true, answer ‘T’, if it is false, answer ‘F’, and if the answer cannot be determined from the information provided, answer ‘C’. For example if ‘A’ and ‘E’ are true and there is not enough information to answer ‘C’ and the rest are false, then answer ‘TFCTFT’.

   A) The magnitude of the net electric field at point A is greater than the magnitude of the net electric field at the origin.
   B) The direction of the net electric field at a point on the negative y-axis is ←
   C) The direction of the net electric field at the point (−r₀, 0) is ←
   D) The direction of the net electric field at a point on the positive y-axis is ↗
   E) The direction of the net electric field at A is ←
   F) The direction of the net electric field at the origin is →

A thin infinite nonconducting sheet with uniform surface charge density σ = +8.0 μC/m² lies in the y-z plane. A charge Q = +6.0 μC is located on the x-axis at a distance x = 30 cm from the sheet as shown.

5. [1pt] Find the magnitude of the electric field at a point P with the coordinates x = y = 30 cm, z = 0.

6. [1pt] The figure shows the E-field in the plane of two point charges. (Give ALL correct answers, i.e., B, AC, BCD... in alphabetical order.)

   A) A – charge placed at ‘a’ would move left.
   B) The magnitude of E is the same at ‘a’ and ‘b’.
   C) Q₁ is positive.
   D) A + charge at ‘a’ would move left.
   E) |Q₁| is larger than |Q₂|
   F) Q₁ and Q₂ have the same sign.
7. [1pt] Consider two charged parallel planes of infinite extent as shown above. The magnitudes of the charge densities on the two planes are equal. (For each statement select T True, F False). Enter answer in the format TFF, for example. WARNING! You have 4 tries only for this problem.

A) If both plates are negatively charged, the electric field at a points towards the top of the page.
B) If both plates are positively charged, there is no electric field at b
C) If the plates are oppositely charged, there is no electric field at c

8. [1pt] Consider a spherical CONDUCTING shell with NO NET CHARGE, with a point charge, +q, placed at its center. (For each statement select T True, F False). Enter answer in the format TFF, for example.

A) The inner surface of the shell carries a charge -q.
B) The electric field at a is zero.
C) The electric field at c is zero.
D) The electric field at e is zero.

9. [1pt] A cubic cardboard box of side a = 0.320 m is placed so that its edges are parallel to the coordinate axes, as shown in the figure. There is NO net electric charge inside the box, but the space in and around the box is filled with a nonuniform electric field of the following form: \( \vec{E}(x, y, z) = Kz \hat{j} + Ky \hat{k} \), where \( K = 3.60 \text{ N/C} \cdot \text{m} \) is a constant.

What is the electric flux through the top face of the box? (The top face of the box is the face where \( z = a \). Remember that we define positive flux pointing out of the box.)

10. [1pt] What is the total electric flux through the five other faces of the box? (Again, outward flux is positive.)

11. [1pt] An electric flux of 142 Nm²/C passes through a flat horizontal surface that has an area of 0.87 m². The flux is due to a uniform electric field. What is the magnitude of the electric field if the field points 15° above the horizontal?

12. [1pt] A point charge +q is at the origin. A spherical Gaussian surface centred at the origin encloses +q. So does a cubical surface centered at the origin and with edges parallel to the axes. Select T-True, F-False, If the first is T and the rest F, enter TFFF.

A) By symmetry, the E-Field at all points on the cubical surface is zero.
B) The Electric Flux through the spherical surface is greater than that through the cubical surface.
C) Now q is moved from the origin but is still within both the surfaces. The total flux through both surfaces remains unchanged.
D) If the radius of the spherical Gaussian Surface is varied, the flux through it also varies.
E) The area vector and the E-Field vector point in the same direction for all points on the cubical surface.

13. [1pt] Consider a sphere of radius \( R = 7.5 \text{ m} \) where a charge \( Q = 10.0 \mu C \) is uniformly distributed through the volume of the sphere. What is the magnitude of the electric field at a point half way between the center of the sphere and the surface?
1. [1pt] A small conducting spherical shell with inner radius $a$ and outer radius $b$ is concentric with a larger conducting spherical shell with inner radius $c$ and outer radius $d$. The inner shell has a total charge $-2q$ and the outer shell has a total charge $+4q$.

Which of the following statements are true: (Give ALL correct answers, i.e., B, AC, BCD...)

- A) The radial component of the electric field in the region $r < a$ is given by $+2q/(4\pi \varepsilon_0 r^2)$.
- B) The total charge on the inner surface of the large shell is $+2q$.
- C) The radial component of the electric field in the region $r > d$ is given by $+2q/(4\pi \varepsilon_0 r^2)$.
- D) The total charge on the inner surface of the small shell is $-6q$.
- E) The radial component of the electric field in the region $c < r < d$ is given by $+4q/(4\pi \varepsilon_0 r^2)$.
- F) The total charge on the outer surface of the large shell is $+2q$.
- G) The total charge on the outer surface of the small shell is zero.

2. [1pt] Consider two separate systems, each with four charges of magnitude $q$ arranged in a square of length $L$ as shown above. Points $a$ and $c$ are in the center of their squares while points $b$ and $d$ are half way between the lower two charges. (Give ALL correct answers, i.e., B, AC, BCD...)

- A) The electric potential at $c$ is zero.
- B) The electric field at $a$ is zero.
- C) The electric field at $b$ is zero.
- D) The electric potential at $a$ is zero.
- E) The electric field at $d$ is zero.
- F) The electric potential at $d$ is zero.
- G) The electric field at $c$ is zero.
- H) The electric potential at $b$ is zero.

3. [1pt] Using the diagram in the previous problem, find the magnitude of the electric field at point $d$. DATA: $q = 0.750 \mu C$, $L = 0.40 m$.

4. [1pt] The figure below shows two points in an E-field: Point 1 is at $(X_1, Y_1) = (3,4)$ in $m$, and Point 2 is at $(X_2, Y_2) = (12,9)$ in $m$.

The Electric Field is constant, with a magnitude of 65 V/m, and is directed parallel to the +X-axis. The potential at point 1 is 1200 V. Calculate the potential at point 2.

5. [1pt] Calculate the work required to move a negative charge of $Q = -493 \mu C$ from point 1 to point 2.

6. [1pt] In the picture below, the 3 charges $Q_1$, $Q_2$, and $Q_3$ are located at positions $(-a,0)$, $(a,0)$ and $(0,d)$ respectively. (The origin is the point halfway between $Q_1$ and $Q_2$.)

Consider the special case where $Q_1, Q_3 > 0$, and $Q_2 = -Q_1$. Assume that the zero of potential is at infinity, as is normal for point charges. Which of the following statements are true? (Choose all correct answers e.g. ABD, CDFG).

- A) The electric potential at any point along the y-axis is positive.
- B) The force on $Q_3$ due to the other two charges is zero.
- C) If $Q_3$ is released from rest, it will initially accelerate to the right.
- D) The electric potential at the origin equals $Q_3/(4\pi \varepsilon_0 d)$.
- E) The work required to move $Q_3$ from its present position to the origin is zero.
- F) The external work done to bring these charges to this configuration (from infinity) was positive.
- G) The electric field at the origin points in the positive y direction, away from $Q_3$.

7. [1pt] In the previous problem, let $Q_1 = 1.40 \mu C$, $Q_2 = 2.80 \mu C$, and $Q_3 = 4.10 \mu C$. (Note that $Q_1$ and $Q_2$ are different now.) The distances are $a = 1.20\ cm$ and $d = 2.80\ cm$. Calculate the total electrostatic potential energy of the charge configuration.
8. [1pt] The diagram below depicts a section of an infinitely long cylinder of radius $R$ that carries a uniform (volume) charge density $\rho$. Develop an expression for the electric field anywhere inside the cylinder. To check your result, what is the magnitude of the electric field at $r = 3.35 \text{ cm}$, where $R = 9.25 \text{ cm}$ and $\rho = 4.65 \mu \text{C/m}^3$? (Note: $r$ is measured radially from the center axis of the cylinder.)

9. [1pt] A thin plastic rod is bent so that it has a shape of a semicircle of radius $R = 1.60 \text{ m}$. An amount of charge $Q = 94.00 \text{ C}$ is distributed along the rod. What is the magnitude of the electric field at the center of the circle (point $P$)?
1. [1pt] What is the electric field at the point $x = 6.5\, m$? Positive E-fields point to the right.

2. [1pt] The lines show the equipotential contours in the plane of three point charges, $Q_1$, $Q_2$, and $Q_3$. The values of the potentials are in kilovolts as indicated for the +5, 0, and -5 kV contours. The positions of the charges are indicated by the dots. (Give ALL correct answers, i.e., B, AC, BCD...)

3. [1pt] Calculate the work performed by an external agent to move a charge of $-0.51\times10^{-12}\, C$ from 'i' to 'b'.

4. [1pt] Calculate the magnitude of the electric field at 'k'.

5. [1pt] Calculate the magnitude of the force on a charge of $8.00\times10^{-19}\, C$ at 'g'.

6. [1pt] Calculate the magnitude of $Q_3$. The magnitudes of the three charges are in the exact ratios of 1 to 2 to 3.

7. [1pt] The large figure shows the equipotential surfaces for a long corner-shaped conductor and a long round conductor, both in a square metal enclosure.

The enclosure is at ground potential (0 volts), the corner is at $+4,000$ volts, and the cylinder is at $-4,000$ volts. The intermediate voltage contours are 1000 volts apart. The labels are in kV.

8. [1pt] Calculate the work required to move a charge of $-0.35\times10^{-13}\, C$ from 'g' to 'a'.

9. [1pt] Calculate the magnitude of the electric field at 'e'.

10. [1pt] A positive charge of $Q = 4.70\, \mu C$ is fixed in place. From a distance of $r_i = 3.00\, \text{cm}$ a particle of mass $m = 5.00\, g$ and charge $q = +4.00\, \mu C$ is fired with an initial speed of $v = 68.0\, \text{m/s}$ directly toward the fixed charge. What is the minimum distance $r_f$ between the two charges?
11. [1pt] Four charges are arranged at the corners of a square as shown in the figure. $Q_1$ is at $(-L/2,L/2)$, $Q_2$ is at $(L/2,L/2)$, point $a$ is at the origin and $Q_1 = Q_2 = -Q_3 = -Q_4$. Which of the following statements correctly describe the electric field $\vec{E}$ and the potential at points $a,b$ and $c$? Enter the letters of true statements in alphabetical order; e.g. "ACF"

A) The magnitude of the $E$ field at $b$ is greater than at $c$.  
B) The $E$ field at $a$ is zero.  
C) The $E$ field at $c$ is perpendicular to the $x$ axis.  
D) The potential at $b$ is zero.  
E) The $E$ field at $c$ points towards $b$.  
F) $a, b,$ and $c$ each lie on a different equipotential surface.  
G) The potential at $c$ is greater (more positive) than the potential at $b$.

12. [1pt] A capacitor consists of two closely spaced metal conductors of large area, separated by a thin insulating foil. It has an electrical capacity of 3200 $\mu$F and is charged to a potential difference of 72.0 V. Calculate the amount of energy stored in the capacitor.

13. [1pt] Calculate the charge on this capacitor when the electrical energy stored in the capacitor is 6.35 $J$. 
Three capacitors having capacitance $C_1 = 1.50 \mu F$, $C_2 = 5.50 \mu F$ and $C_3 = 12.0 \mu F$ are connected to a 34.0 V battery as shown.

1. [1pt] Calculate the charge on $C_3$.

2. [1pt] A parallel plate capacitor with adjustable plate separation $d$ and adjustable area $A$ is connected to a battery. The capacitor is fully charged to $Q$ Coulombs and a voltage of $V$ Volts. $C$ is the capacitance and $U$ is the stored energy.) Give all correct answers concerning a parallel-plate capacitor charged by a battery (e.g. $B$, $AC$, $CDF$).

A) After being disconnected from the battery, increasing the area $A$ will increase $U$.
B) With the capacitor connected to the battery, increasing the area $A$ will increase $Q$.
C) With the capacitor connected to the battery, decreasing $d$ increases $C$.
D) With the capacitor connected to the battery, increasing the area $A$ will increase $C$.
E) With the capacitor connected to the battery, decreasing $d$ decreases $Q$.
F) With the capacitor connected to the battery, decreasing $d$ increases $U$.

3. [1pt] Charges are distributed with uniform charge density $\lambda = 4.95 \mu C/m$ along a semicircle of radius $R=23.0 \text{ cm}$, centered at the origin of a coordinate system (as shown in the diagram below.) What is the potential at the origin?

4. [1pt] An isolated metal sphere of radius 30.5 cm is at a potential of 1750 V. What is the charge on the sphere?

5. [1pt] Determine the energy density of the electric field outside the sphere and integrate this throughout all space in order to calculate the total energy in the electric field.

6. [1pt] A number 16 copper wire has a diameter of 1.291 mm. Calculate the resistance of a 37 m long piece of that wire. Use $\rho = 1.72 \times 10^{-8} \Omega \cdot m$ for the resistivity of copper. Use "Ohm" as your units, i.e. if the answer is 5 ohms, enter "5 Ohm".

7. [1pt] The graph represents the Voltage-Current characteristic for an unknown resistor. Determine the value of the resistor from the graph. Use "Ohm" as your units, i.e. if the answer is 5 ohms, enter "5 Ohm".

8. [1pt] An underground telephone cable, consisting of a pair of wires, has suffered a short somewhere along its length (at point P in the Figure). The telephone cable is 6.00 km long, and in order to determine where the short is, a technician first measures the resistance between terminals $AB$; then he measures the resistance across the terminals $CD$. The first measurement yields 25.00 $\Omega$; the second 110.00 $\Omega$. Where is the short? Give your answer as a distance from point C.

9. [1pt] Calculate the magnitude of the electric field at one corner of a square 1.04 m on a side if the other three corners are occupied by $2.80 \times 10^{-6} C$ charges.

10. [1pt] An electron (mass m = $9.11 \times 10^{-31} kg$) is accelerated in the uniform field $E$ ($E = 1.65 \times 10^4 N/C$) between two parallel charged plates. The separation of the plates is 1.18 cm. The electron is accelerated from rest near the negative plate and passes through a tiny hole in the positive plate, as seen in the figure below.

With what speed does it leave the hole?

11. [1pt] An electron starts from rest 62.8cm from a fixed point charge with $Q = -0.159 \mu C$. How fast will the electron be moving when it is very far away?
12. [1pt] A cardiac defibrillator is used to shock a heart that is beating erratically. A capacitor in this device is charged to 6080V and stores 199J of energy. What is its capacitance?

13. [1pt] An electron starting from rest acquires 6.51keV of kinetic energy in moving from point A to point B. How much kinetic energy would a proton acquire, starting from rest at B and moving to point A?

14. [1pt] Determine the ratio of their speeds (speed of electron/speed of proton) at the end of their respective trajectories.

15. [1pt] Assume that silver has one electron per atom to carry charge. Given that the mass density of silver is 10.5×10³ kg/m³ and that its molecular weight is 107.9 g/mol, calculate the drift speed of the electrons in a silver wire that carries 3.35 A and has a circular cross section 0.90 mm in radius.
1. [1pt] Consider the behavior of the circuit, when various values increase or decrease.

A) If the voltage V increases, the total current from the battery
B) If R1 decreases, the current through R6
C) If R3 decreases, the current from the battery
D) If R6 increases, the power output from the battery
E) If R3 increases, the current through R5
F) If R1 increases, the current through R3

2. [1pt] A 2.98 g copper penny has a positive charge of 38.6 μC. What fraction of its electrons has it lost?

3. [1pt] The picture shows a battery connected to two cylindrical resistors in parallel. Both resistors are made of the same material and are of the same length, but the diameter of resistor A is twice the diameter of resistor B. (For each statement select T True, F False).

A) The current through the battery is five times larger than the current through wire B.
B) The power dissipated in wire A is 16 times the power dissipated in wire B.
C) The voltage drop across wire B is larger than the voltage drop across wire A.
D) The resistance of wire B is twice as large as the resistance of wire A.
E) The resistance of wire B is four times as large as the resistance of wire A.

4. [1pt] Consider the three circuits shown above. All the resistors and all the batteries are identical. (For each statement select T True, F False).

A) The current through a resistor is the same in circuits A and C.
B) The power dissipated in circuit A is twice the power dissipated in circuit B.
C) The total power dissipated in circuit C is twice the total power dissipated in circuit B.
D) The voltage across a single resistor in circuit C is twice the voltage across a single resistor in circuit B.
E) The current through a resistor is the same in circuits A and B.

5. [1pt] Consider the sections of two circuits illustrated above. All resistances shown have a finite, non-zero, resistance. (Give ALL correct answers, i.e. B, AC, BCD...) WARNING: You have only 8 tries for this problem.

A) $R_{ad}$ is always less than $R_5$.
B) After connecting a and b to a battery, the voltage across $R_3$ always equals the voltage across $R_2$.
C) $R_{ab}$ is always less than $R_1$.
D) After connecting c and d to a battery, the current through $R_3$ always equals the current through $R_4$.

6. [1pt] In the section of circuit below, $R_1 = 21.78 \Omega$, $R_2 = 1.44 \Omega$ and the voltage difference $V_a - V_b = 2.900 V$. The current $i = 0.130 \text{amps}$. Find the value of $R_6$. Use "Ohm" as your units.

7. [1pt] What is the current through $R_9$?

8. [1pt] A typical household circuit is capable of carrying 15.0 A of current at 120 V before the circuit breaker will trip. How many 1500 W hair dryers can run off one such circuit? (Give your answer as a unitless integer.)

9. [1pt] In the rush to get ready for lecture, a physics professor leaves the hairdryer described in the previous problem running and does not turn it off until he gets home 7.2 hr later. How much will this add, in dollars, to his next electric bill (assume electricity costs $0.078 per kW\text{hr}$)? Enter the number of dollars without units; i.e. if the answer is 50 cents, enter "0.50".
10. [1pt] A 12 V lead-acid car battery, engineered for 'up to 500 or more charge/discharge cycles', has a rating of 225.0 A \cdot \text{hr}. (It sells for $180.00.) Calculate the total amount of charge that moves through the battery before it needs to be recharged.

11. [1pt] What is the total electrical energy that the battery can deliver before it needs to be recharged?
1. [1pt] Two insulated balls of mass 0.1 g hang from the same support point by massless insulating threads of length l (as shown in the diagram below.) A total positive charge of $5.95 \times 10^{-7}$ C is added to the system. Half this charge is taken up by each ball, distributed uniformly, and the balls spread apart to a new equilibrium position.

Assuming that the balls hang essentially vertical before the charge is added, what is the tension in each thread before the charge is added?

2. [1pt] If $\theta=29.5^\circ$, what is the length, l, of each string?

3. [1pt] An electron and a proton attract each other with a $1/r^2$ electric force, just like the gravitational force. Suppose that an electron moves in a circular orbit about a proton with a period of the circular motion of 1.51 hr. What is the radius of the orbit? (Note, this is an unrealistic situation!)

4. [1pt] Calculate the current $i_5$ in the following configuration:

\[ i_1 = 4A \]
\[ i_2 = 5A \]
\[ i_3 = 6A \]
\[ i_4 = 5A \]

5. [1pt] A solid truncated cone is made of a material of resistivity 4.70 $\Omega$-m. The cone has a height $h = 1.01$ m, and radii $a = 0.38$ m and $b = 0.84$ m. Assuming that the direction of current is parallel to the axis of the cylinder, what is the total resistance for this cone? (Use "Ohm" as your units.)

6. [1pt] Consider the following diagram. (Give ALL correct answers in alphabetical order, i.e., B, AC, BCD...)

\[ i_1 + i_2 = i_3 \]
\[ E_1 - E_2 = i_1 R_1 + i_2 R_2 \]
\[ E_1 - E_3 = i_1 R_1 - i_3 R_3 \]
\[ E_3 - E_1 = -i_3 R_3 - i_1 R_1 \]
\[ E_2 - E_3 = i_3 R_3 - i_2 R_2 \]
\[ E_2 - E_1 = i_1 R_1 - i_2 R_2 \]
\[ i_1 = i_2 + i_3 \]

7. [1pt] What is the magnitude of the current through $R_1$? DATA: $R_1 = R_2 = R_3 = 20.0\Omega$. $V_1 = 8.0$ Volts. $V_2 = 2V_1$.

8. [1pt] Consider the circuit shown below:

\[ R_1 = 630\Omega \]
\[ R_2 = 870\Omega \]
\[ R_3 = 800\Omega \]
\[ R_4 = 190\Omega \]
\[ \epsilon = 1.5V \]

Calculate the potential difference across $R_4$. 

9. [1pt] Consider the following circuit configuration.
9. [1pt] The circuit which was at position a for a long time is suddenly switched to position b at time $t = 0$. (For each statement select T True, F False).
   A) The current through the resistor equals the current through the capacitor at all times.
   B) In the instant after the switch is thrown the voltage across the resistor is zero.
   C) In the instant after the switch is thrown the current through the capacitor is zero.
   D) In the instant after the switch is thrown, the voltage across the capacitor is zero.

10. [1pt] Referring to the circuit of the previous problem, what is $V_c$ at time $t = 2.0 \, ms$? DATA: $R = 435 \, \Omega$, $C = 4.0 \, \mu F$, $V_0 = 2.35 \, V$.

11. [1pt] Referring to the previous problem, what is the energy dissipated in the resistor after time $t = 0$ (that is, for all time after $t = 0$, meaning the during the time period from $t = 0$ to infinity.)
1. [1pt] A charged particle is moving perpendicularly to a magnetic field \( B \). Fill in the blank indicating the direction for the quantity missing in the table.

<table>
<thead>
<tr>
<th>Charge</th>
<th>Velocity</th>
<th>B Field</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+y</td>
<td>-z</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-z</td>
<td>-z</td>
<td></td>
</tr>
</tbody>
</table>

(If your three answers from top to bottom are +z, -x, -y, then enter: +z-x-y in the computer). Use the diagram on the upper left for the directions of the various axes.

2. [1pt] The rectangular loop shown below is located in a uniform magnetic field of 0.20 \( T \) pointing in the positive y direction.

![Diagram of a rectangular loop](image)

DATA:
- \( h = 4.5 \text{ cm} \)
- \( w = 5.5 \text{ cm} \)
- \( \theta = 32.5^\circ \)
- \( I = 6.0 \text{ A} \)

What is the magnitude of the magnetic dipole moment of the loop?

3. [1pt] Calculate the magnitude of the torque about the \( z \)-axis on the loop.

4. [1pt] A proton, that is accelerated from rest through a potential of 8.0 kV enters the velocity filter, consisting of a parallel-plate capacitor and a magnetic field, shown below.

![Diagram of a proton in a filter](image)

The E-field between the parallel capacitor plates is \( 5.5 \times 10^5 \) \( \text{N/C} \). What \( B \)-field is required so that the protons are not deflected? (Ignore relativistic effects for high velocities.)

A mass spectrometer, sketched below, is a device used to separate different ions. Such ions with a well-defined velocity \( v_0 \) enter through a slit into a region of uniform magnetic field \( B \), where they follow a semicircular path until they strike the detector slit \( D \). The distance between the entry and the detector slits is \( d = 1.80 \text{ m} \).
11. [1pt] A 2 kg particle carrying a charge of 61 μC enters a uniform 3 T magnetic field at a speed of 26 m/s and with an angle of 31° with respect to the field lines, as shown in the figure. Answer the following questions: (Select T-True, F-False, If the first is T and the rest F, enter TFFFF).

A) The x-component of the particle's velocity is unchanged as it passes through the B-Field.
B) The force on the particle is in the +x direction.
C) The work done by the field on the particle is zero since the force is normal to the displacement.
D) The path of the particle is a closed circle since the force is normal to the velocity.
E) The particle's speed varies as it passes through the B-Field.

12. [1pt] Decide from the following list of possibilities what is the appropriate direction of the force on the wire for each of the diagrams 1 through 4:

A ↑
B ↓
C ←
D →
E ⊗
F ○
G None of these
H No force

Input the answers for diagrams 1-4 as they are posed - no spaces, no commas. For example if the force on diagram 3 is ⊗ and there is no force on any of the other wires then input 'HHEH'.
1. [1pt] Assume that a lightning bolt can be represented by a long straight line of current. If 15.0 C of charge passes by in a time of \( 1.5 \times 10^{-3} \) s, what is the magnitude of the magnetic field at a distance of 22.0 m from the bolt?

2. [1pt] A small diameter, 53 cm long solenoid has 203 turns and is connected in series with a resistor and battery. The size of the magnetic field inside the solenoid is \( 2.508 \times 10^{-4} \) T when a voltage of 62.0 V is applied to the circuit. Calculate the resistance of the circuit. Use units of "Ohm".

3. [1pt] What is the current in the top wire?

4. [1pt] Given that the wires are separated by \( 2a \), where \( a = 0.041 \) m, what is the magnitude of the magnetic field at point \( p_2 \)?

5. [1pt] In the figure below, a long straight wire carries a current of \( I_w = 5.0 \) A. A square loop of edge length 0.25 m is placed a distance 0.10 m away from the wire. The square loop carries a current \( I_L = 2.6 \) A.

Find the magnitude of the net force on the square loop.

6. [1pt] A single-coil loop of radius \( r = 6.90 \) mm, shown below, is formed in the middle of an infinitely long, thin, insulated straight wire carrying the current \( i = 27.0 \) mA.

What is the magnitude of the magnetic field at the center of the loop?

7. [1pt] Calculate the \( y \) component of the magnetic field at the center of the square.

8. [1pt] In the picture below, the two wires carry current \( i_1 \) and \( i_2 \) respectively, with positive current to the right. The charge \( q \), midway between the wires, is positive and has velocity \( v \) to the right. North is up, East is to the right, etc.

Which of the following statements for magnetism are true? (Give ALL correct answers in alphabetical order, i.e., B, AC, BCD...)

A) If \( i_2 = 0 \) and \( i_1 > 0 \), then the force on \( q \) points into the page.
B) If \( i_1 = -i_2 \), then the wires repel each other.
C) If \( i_1 = -i_2 \), then the force on \( q \) is zero.
D) If \( v = 0 \), then the force on \( q \) is zero.
E) If \( i_2 = 0 \) and \( i_1 > 0 \), then the force on \( q \) is north.
F) If \( i_1 = 0 \) and \( i_2 > 0 \), then the magnetic field near charge \( q \) points into the page.
G) If \( i_1 < i_2 \), then the force on \( q \) is south.

9. [1pt] Two very long solenoids have the same length, but solenoid A has 13 times the number of turns, \( 1/7 \) the radius, and 4 times the current of solenoid B. Calculate the ratio of the magnetic field inside of A to that inside B.

10. [1pt] A long hairpin is formed by bending an infinitely long wire, as shown. If a current of 2.8 A is set up in the wire, what is the magnitude of the magnetic field at the point \( a \)? Assume \( R = 5.5 \) cm.
A 1000-turn loop (radius = 0.031 m) of wire is connected to a (15 Ω) resistor as shown in the figure. A magnetic field is directed perpendicular to the plane of the loop. The field points into the paper and has a magnitude that varies in time as $B = gt$, where $g = 0.25 \ T/s$. Neglect the resistance of the wire.

11. [1pt] What is the magnitude of the potential difference between points $a$ and $b$?

12. [1pt] What is the electrical energy dissipated in the resistor in 35 s?
1. [1pt] A solid rod of radius \( R \) carries a uniformly distributed current \( i_0 = 1.50A \) into the page. A wire lies a distance \( 2R \) away from the surface of the rod.

What is the magnitude and direction (into(+) or out of (-) the page) of the current in the wire so that the magnetic field, \( \mathbf{B} \), at a point \( P \), half-way between the two, equals the field at the center of the rod? (The two fields must be equal in magnitude and direction.)

2. [1pt] The figure shows a hollow cylindrical conductor with radii \( a = 1.7 \text{ cm} \) and \( b = 4.9 \text{ cm} \) which carries a current 2.5 \( A \) uniformly spread over its cross-section. Find the magnitude of the magnetic field at a distance of 2.9 \( cm \) from the axis.

The next four questions refer to this situation: A conducting rod is pulled horizontally with constant force \( F = 4.60 \text{ N} \) along a set of rails separated by \( d = 0.320 \text{ m} \). A uniform magnetic field \( B = 0.800T \) is directed into the page. There is no friction between the rod and the rails, and the rod moves with constant velocity \( v = 4.20 \text{ m/s} \).

3. [1pt] Using Faraday's Law, calculate the induced emf around the loop in the figure that is caused by the changing flux. Assign clockwise to be the positive direction for emf.

4. [1pt] The emf around the loop causes a current to flow. How large is that current? (Again, use a positive value for clockwise direction.)

5. [1pt] From your previous results, what must be the electrical resistance of the loop? (The resistance of the rails is negligible compared to the resistance of the rod, so the resistance of the loop is constant.) Use units of Ohm.

6. [1pt] The rate at which the external force does mechanical work must be equal to the rate at which energy is dissipated in the circuit. What is that rate of energy dissipation (power dissipated)?

7. [1pt] The figures below show two different situations where a current may be induced in a loop according to Faraday's Law, with the direction given by Lenz's Law. The magnetic field is shown by the x's in Fig. 2. Select ALL correct answers (i.e. B, AC, BCD) for the current in the loop. (The compass directions are defined in the usual way.)

A) Fig 1: Magnet moving East, induced current 'a'.
B) Fig 1: Magnet moving West, induced current 'a'.
C) Fig 1: Loop moving West, induced current 'a'.
D) Fig 2: Loop moving South, no induced current.
E) Fig 2: Loop moving North, induced current 'b'.
F) Fig 2: Loop moving East, induced current 'b'.

The next two questions refer to this situation: A rectangular loop with sides of length \( a = 2.00 \text{ cm} \) and \( b = 3.30 \text{ cm} \) is placed near a wire that carries a current that varies as a function of time:

\[ i(t) = 3.60 + 1.30t^2, \]

where the current is in Amperes and the time is in seconds. The distance from the straight wire to the closest side of the loop is \( d = 0.510 \text{ cm} \).

8. [1pt] What is the magnetic flux through the loop at time \( t = 1.20 \text{ seconds} \)? (Define positive flux into the page.)

9. [1pt] What is the induced e.m.f. in the loop at time \( t = 1.20 \text{ seconds} \)? (Note that positive emf is clockwise.)
The next four questions refer to this situation: A thin square coil has 33 turns of conducting wire. It is rotating with constant angular velocity in a uniform magnetic field $B$ of 0.360 T. At times there is NO magnetic flux through the coil, and at other times, there is the maximum possible flux. The graph below shows the magnetic flux $\Phi$ through one turn of the coil as a function of time.

10. [1pt] What is the length of a side of the coil?

11. [1pt] Calculate the angular velocity of the coil. Use units of rad/s.

12. [1pt] Evaluate the magnitude of the induced voltage in the coil, $V_{emf}$, at time $t = 2.60$ seconds.

13. [1pt] A very long solenoid of circular cross section with radius $a = 3.90 \text{ cm}$ has $n = 62.0$ turns/cm of wire. An electron is sitting outside the solenoid, at a distance $r = 4.40 \text{ cm}$ from the solenoid axis. What is the magnitude of the force on the electron while the current in the solenoid is ramped up at a rate of 30.0 $\text{Amps/s}$?
1. A 34.6 cm diameter coil consists of 16 turns of circular copper wire 2.90 mm in diameter. The resistivity of copper is $1.68 \times 10^{-8} \, \Omega \, \text{m}$. A uniform magnetic field, perpendicular to the plane of the coil, changes at a rate of $8.60 \times 10^{-3} \, \text{T/s}$. Determine the current in the loop.

2. In the previous problem, determine the rate (energy/time) at which thermal energy is produced.

3. What is the inductance of a coil if it produces an emf of 8.74 V when the current in it changes from -27.2 mA to +33.1 mA in 48.1 ms?

4. A square loop of wire with a small resistance is moved with constant speed from a field free region into a region of uniform $B$ field ($B$ is constant in time) and then back into a field free region to the right. The self inductance of the loop is negligible.

Select all correct answers:

A) Upon entering the field, a counterclockwise current flows in the loop.
B) While the loop is entirely in the field, the emf in the loop is zero.
C) When entering the field the coil experiences a magnetic force to the right.
D) When leaving the field the coil experiences a magnetic force to the left.
E) Upon leaving the field, a counterclockwise current flows in the loop.

DATA: $V_b = 9.0 \, \text{V}$, $R = 155 \, \Omega$, $L = 8.200 \times 10^{-2} \, \text{H}$.

5. In the diagram above, what is the voltage across the inductor in the instant just after the switch is closed?

6. After the switch is closed for a long time, what is the energy stored in the inductor?

7. The switch in the above diagram is closed after being open a long time. The initial charge on the capacitor is zero. (For each statement select T True, F False).

A) A long time after the switch is closed, the voltage across the capacitor equals the voltage across the battery.
B) A long time after the switch is closed, the current through the resistor is zero.
C) In the instant after the switch is closed, the voltage across the capacitor equals the voltage across the battery.
D) In the instant after the switch is closed, the voltage across the inductor equals the voltage across the battery.

An ideal step-down transformer has a primary coil of 330 turns and a secondary coil of 22 turns. It is plugged into an outlet with 110 V (AC) from which it draws a current of 0.29 A.

8. What is the voltage in the secondary coil?

9. Calculate the rms current in the secondary coil.

10. Assuming that the transformer secondary is driving a resistive load, calculate the average power dissipated in the resistor.

The figure below shows the time variation of the current through an electrical heater when it is plugged into a 110 V, 60 Hz outlet.

11. What is the peak voltage?

12. A power supply that provides a voltage of $22.0 - \sin(200t) \, \text{V}$ is connected across a resistor $R = 170 \, \Omega$. Calculate the average power dissipated in the resistor.

13. The sketches below show a circular coil and a permanent magnet; the arrows indicate both the magnitude and the direction of the velocities of the magnet and coil. In which situations will the induced voltage (and hence the current) in the loop be zero? (Enter your answer in alphabetical order.)

[Diagram with options A through G]
A transverse mechanical wave is traveling along a string lying along the x-axis. The displacement of the string as a function of position and time, \( y(x,t) \), is described by the following equation:

\[
y(x,t) = 0.0350 \times \sin(3.00x - 124t)
\]

where \( x \) and \( y \) are in meters and the time is in seconds.

1. [1pt] What is the wavelength of the wave?

2. [1pt] What is the velocity of the wave? (Define positive velocity along the positive x-axis.)

3. [1pt] Identify the following waves as T-Transverse, or L-Longitudinal. (If the first is T and the rest L, enter TLLL).
   A) Waves on the surface of a bass drum.
   B) The 'WAVE' made by fans at sports events.
   C) Wave on a slinky toy, snugly confined in a long narrow tube.
   D) Waves in a guitar string that is plucked.
   E) Music in an auditorium.

4. [1pt] The transverse displacement of a stretched string from equilibrium as a function of time and position is given by:

\[
y = 0.13 \cos(9x + 99t)
\]

\( x \) and \( y \) are in m; \( t \) is in s.

(Select T-True, F-False, G-Greater than, L-Less than, E-Equal to, If the first is T and the rest F, enter TFFF).

   A) The period is ..... 0.1 seconds
   B) The wavelength is ..... 1 m
   C) The speed of the wave is ..... 12 m/s
   D) The wave travels in the negative x direction

5. [1pt] What is the wavelength of a \( 2.29 \times 10^{10} \) Hz radar signal?

6. [1pt] What is the frequency of a microwave whose wavelength is 1.72 cm?

7. [1pt] How long will it take for an instruction from Earth to reach an interplanetary probe near Pluto; assume Pluto is at its closest approach to Earth (4.20 \times 10^7 km)?

8. [1pt] The switch in the following circuit has been open for a long time. The switch is then closed. The current through the battery immediately after the switch is closed is \( I(t=0) \) and the value at very large \( t \) is \( I(t=\infty) \). Calculate the ratio \( I(t=0)/I(t=\infty) \).

9. [1pt] A circular coil with one turn is in a perpendicular (time dependent) magnetic field given by \( B = 0.400 - 0.0600t \) Tesla, where time \( t \) is in seconds. The induced voltage in the loop is 1.82 V. Calculate the radius of the coil.

10. [1pt] A 170 turn conducting coil with a radius of 15.1 cm rotates at a frequency of \( f = 35.0 \) Hz in a magnetic field \( B = 0.180 T \). Calculate the generated rms emf. The rms (root-mean-square) value of a sinusoidal quantity is the amplitude divided by root of 2.

11. [1pt] The average intensity of solar radiation incident on Earth is 1390 W/m². What is the total power radiated by the sun? DATA: The mean distance between Earth and the sun is \( 1.5 \times 10^{11} \) m.

12. [1pt] The electric field of an electromagnetic wave is given by;

\[
E=1.30 \times 10^3 \sin(2.30 \times 10^6 \pi(x-3.0 \times 10^8 t))
\]

where everything is in SI units. What is the wave's frequency?

13. [1pt] In the previous problem, what is the amplitude of the magnetic field associated with this TEM (transverse electromagnetic) wave?

14. [1pt] A super nova releases \( 1.4 \times 10^{45} \) J of energy. It is 1630 ly from earth. If you were facing the star in question, and your face was a circle 7 cm in radius, how much energy would reach your face?
A linearly polarized electromagnetic wave has an average intensity of 425 W/m². This wave is directed towards two ideal polarizers (in real polarizers, transmission is also affected by reflection and absorption). Polarizer A is oriented with its transmission axis at an angle of θ₁ = 30.0° with the incident electric field. Polarizer B has its axis at an angle of θ₂ = 69.5° with the incident electric field, as in the figure below.

1. [1pt] What is the average intensity of the wave after it passes through polarizer A?

2. [1pt] What is the average intensity of the wave after it passes through polarizer B?

3. [1pt] Suppose that the two polarizers A and B are interchanged. What would the average intensity be after passing through both polarizers?

4. [1pt] An image of the moon is focused onto a screen using a converging lens of focal length (f = 34.3 cm). The diameter of the moon is 3.48 x 10⁶ m, and its mean distance from the earth is 3.85 x 10⁸ m. What is the diameter of the moon’s image?

5. [1pt] Starting with a real object, which of the following statements are TRUE about the image formed by a single lens? (Enter all correct choices in alphabetical order, e.g. B, CD, or ABE).
   
   A) For a converging lens an object has to be placed between the focal length and the lens in order to form a virtual image.
   
   B) A diverging lens can produce a real, inverted, reduced image.
   
   C) A converging lens can produce a virtual, upright, enlarged image.
   
   D) A converging lens cannot produce a real, inverted reduced image.
   
   E) A converging lens can never produce a virtual, upright, reduced image.
   
   F) A diverging lens always produces a virtual, upright, reduced image.

6. [1pt] A point source of light is located 2.98 m below the surface of a large lake of clear toxic fluid (Lake Ontario, where n = 1.42). Find the area of the largest circle on the pool’s surface through which light coming directly from the source can emerge.

7. [1pt] A laser beam enters a 15.5 cm thick glass window at an angle of 60° (from the normal). The index of refraction of the glass is 1.47. At what angle from the normal does the beam travel through the glass? Use units of “deg”.

8. [1pt] How long does it take the beam to pass through the plate?

9. [1pt] Light in air enters a stack of three parallel plates with indices of refraction 1.34, 1.64 and 2.04, respectively. The incident beam makes a 26.0° angle with the normal to the plate surface. At what angle with respect to the stack normal does the beam emerge into the air after passing through the stack? Use units of “deg”. (If you do a lot of calculations for this one, you will kick yourself when you realize the answer.)

10. [1pt] A woman stands between a vertical mirror 0.45 m tall and a distant tree whose height is H. She is 1.60 m from the mirror, and the tree is 11.2 m from the mirror. The height of the mirror relative to the woman’s eye is adjusted so that she sees the reflection of the tree exactly fill the mirror. How tall is the tree?

11. [1pt] A light ray strikes the surface between two transparent materials as shown. Each angle is labeled with a letter. Give the letters for the angle of incidence, angle of refraction and angle of reflection, in that order. (e.g. ddb.)

12. [1pt] Note: We suggest you use ray diagrams to qualitatively understand these questions. A candle 8.20 cm high is placed in front of a thin converging lens of focal length 39.0 cm. What is the image distance i when the object is placed 99.5 cm in front of the same lens?

13. [1pt] What is the size of the image? (Note: an inverted image will have a ‘negative’ size.)

14. [1pt] Is the image real(R) or virtual(V); upright(U) or inverted(I); larger(L) or smaller(S) or unchanged(UC); in front of the lens(F) or behind the lens(B)? Answer these questions in the order that they are posed. (For example, if the image is real, inverted, larger and behind the lens then enter ‘RILB’. )
1. [1pt] What is the linear size of the smallest feature on the moon you could resolve with a telescope that has an objective lens with a diameter of 65.0 mm? Assume that the resolution would be diffraction limited and that the moon is 380,000 km away. Take the wavelength of light as 550 nm, which is near the peak of our sensitivity.

2. [1pt] The left figure shows seven charges. Determine the direction of the total force on the charge at the origin due to all the other charges. Into which quadrant does the total force vector point? Use the right diagram to draw the individual forces (Choose A, B, C or D). WARNING: You have only 3 tries for this problem!

3. [1pt] Consider a sphere of radius \( R = 9.5 \) m where a charge \( Q = 4.0 \) \( \mu \)C is uniformly distributed through the volume of the sphere. What is the magnitude of the electric field at a point half way between the center of the sphere and the surface?

4. [1pt] A \( 3.3 \mu \)C point charge is placed at the center of a cube with a volume of \( 4.3 m^3 \). Calculate the electric flux through one side of the cube.

5. [1pt] Consider the following configuration:

\[
\begin{align*}
A & \quad R_1 & \quad B \\
\varepsilon_1 &= 3 \text{V} & \varepsilon_2 &= 1.5 \text{V} & R_1 &= 800 \Omega \\
\varepsilon_2 & \quad i_1 & \quad \varepsilon_2 & \quad i_2 \\
0 \text{V} & \quad R_2 & \quad 400 \Omega \\
\end{align*}
\]

What is the potential (Voltage) at point B?

6. [1pt] Calculate the current \( i_3 \).

7. [1pt] Which of the following statements are correct for the RC circuit shown? (Give ALL correct answers, i.e., B, AC, BCD...)

A) If \( S \) is in the position \( a \) for a long time, the current through \( R \) approaches \( \mathcal{E}/R \).
B) If \( S \) is in the position \( a \) for a long time, the current through \( R \) approaches zero.
C) Right after \( S \) is moved to the position \( b \), following a long time in the position \( a \), the current through \( R \) is \( \mathcal{E}/R \).
D) If \( S \) is in the position \( a \) for a long time, the charge on \( C \) approaches zero.
E) After \( S \) is moved to \( b \), it takes a time \( \tau = RC \), for the charge on \( C \) to drop to \( 1/e \) of its initial value.
F) If \( S \) is in the position \( b \) for a long time, the current through \( R \) approaches \( \mathcal{E}/R \).
G) Right after \( S \) is moved to the position \( b \), following a long time in the position \( a \), the potential across \( C \) is nearly zero.

8. [1pt] A long wire lying along the x-axis carries a current of 1.80 A in the +x direction. There is a uniform magnetic field present, given by \( \mathbf{B} = 0.003 \hat{i} + 0.004 \hat{j} + 0.002 \hat{k} \) in units of Tesla. Calculate the y-component of the magnetic force acting on a segment of wire of length \( L = 12.5 \text{cm} \).

9. [1pt] Consider two parallel conducting wires along the direction of the x axis as shown below. Wire 1 crosses the x-axis at \( x = -1.90 \text{cm} \) and carries a current of 1.50 A out of the xy-plane of the page. Wire 2 (right) crosses the x-axis at \( x = 1.90 \text{cm} \) and carries a current of 7.80 A into the xy plane.

At which value of \( x \) is the magnetic field zero? (Hint: Careful with sign)

10. [1pt] The toroid shown in the figure has a wire carrying a current \( I = 1.90 \) A wrapped around it \( N = 760 \) times. The inner radius is \( R_1 = 10.0 \) cm and outer radius \( R_2 = 12.0 \) cm.

What is the magnitude of the magnetic field along a circle that is halfway between the inner and outer edges of the toroid?
11. [1pt] A generator is constructed by rotating a coil of \(N\) turns in a magnetic field \(B\) at a frequency \(f\). The internal resistance of the coil is \(R\) and the cross sectional area of the coil is \(A\). Which of the following statements are true? (Give ALL correct answers, i.e., B, AC, BCD...) 

A) As the coil turns at a steady rate, the maximum induced EMF occurs when the plane of the coil is perpendicular to the magnetic field direction. 
B) The maximum induced EMF occurs when the coil is rotated about an axis parallel to the magnetic field lines. 
C) The average induced EMF doubles if the resistance \(R\) is doubled. 
D) The average induced EMF doubles if the magnetic field \(B\) is doubled. 
E) The average induced EMF doubles if the area \(A\) is doubled. 
F) The average induced EMF doubles if the frequency \(f\) is doubled. 

A very long solenoid with a circular cross section and radius \(r_1 = 2.30\, \text{cm}\) with \(n_s = 150\, \text{turns/cm}\) lies inside a short coil of radius \(r_2 = 3.80\, \text{cm}\) and \(N_c = 29\, \text{turns.}\)

12. [1pt] If the current in the solenoid is ramped at a constant rate from zero to \(I_s = 3.00\, \text{A}\) over a time interval of \(89.0\, \text{ms}\), what is the magnitude of the emf in the outer coil while the current in the solenoid is changing?

13. [1pt] In the above figures \(f\) is located at the focal point of the lens. For each statement enter T or F.

A) An object placed between \(f\) and the lens in Fig. \(a\) produces a virtual image. 
B) An object placed to the left of \(f\) and the lens in Fig. \(a\) produces a real image. 
C) The lens in Fig. \(b\) is a converging lens. 
D) An object placed to the left of \(f\) in Fig. \(a\) results in an image on the right side of the lens. 
E) An object placed between \(f\) and the lens in Fig. \(a\) results in an image on the left side of the lens. 
F) An object placed to the left of \(f\) and the lens in Fig. \(b\) produces a real image. 
G) An object placed to the left of \(f\) in Fig. \(b\) results in an image on the left side of the lens.

A magnifying glass uses a converging lens with a focal length of 15.5 cm. It produces a virtual and upright image that is 3.3 times larger than the object.

14. [1pt] How far is the object from the lens?