Development towards an electromagnetic and circuit theory concept inventory of undergraduate engineering students

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Why — Students making common mistakes in exams

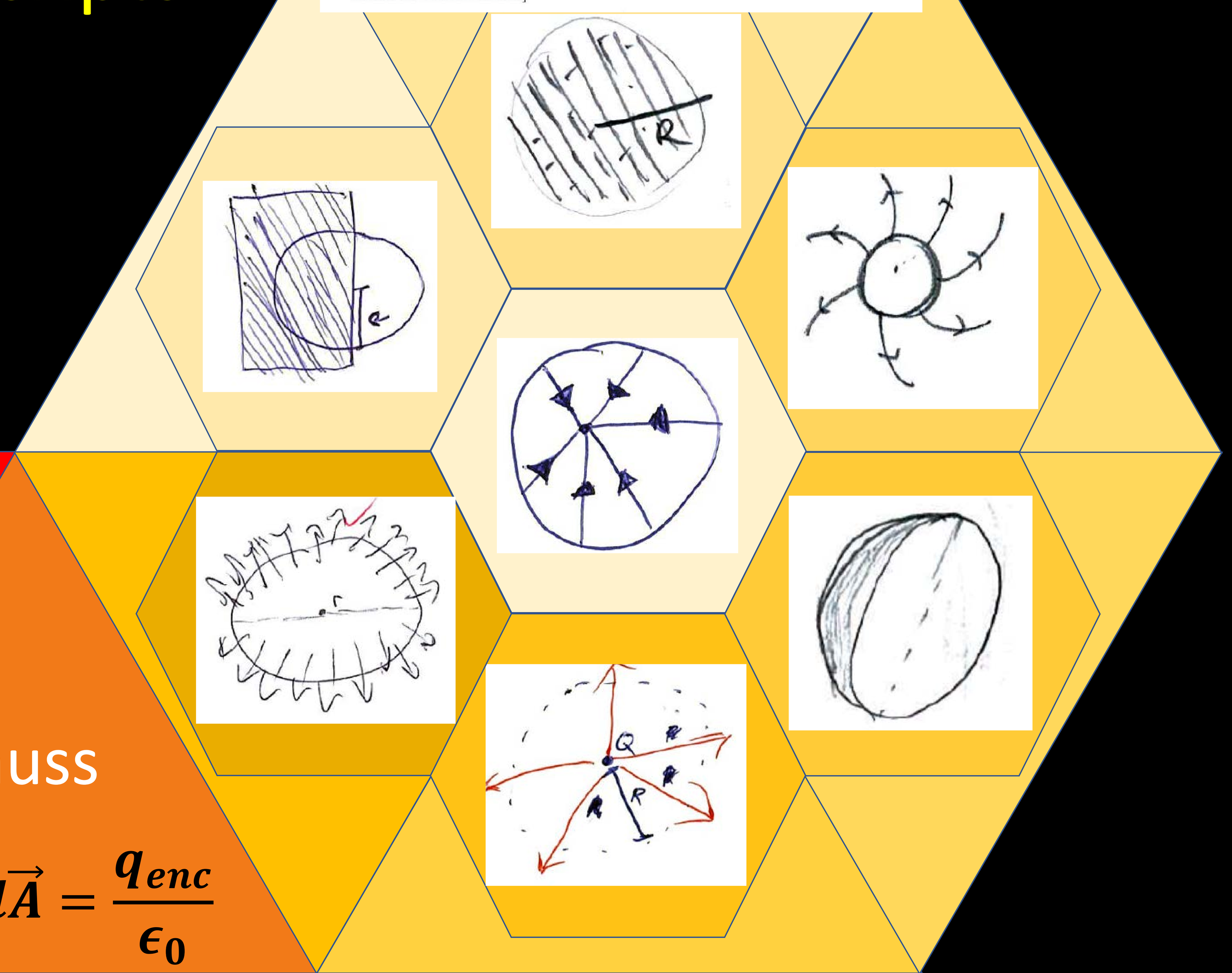
How — By cataloguing mistakes from past exam scripts

Whom — First year physics and engineering students

Student Gaussian Surfaces

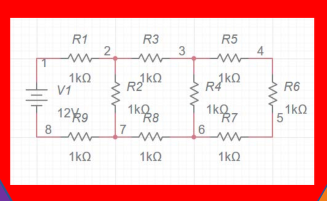
C1. A charge Q is distributed uniformly throughout a sphere of radius R.

(a) Draw a diagram (a 2-d sketch) showing a Gaussian surface appropriate for calculating the electric field at any point a distance r from the centre of the sphere. [Use a dashed line to indicate the Gaussian surface.]



Electromagnetic Concepts

Kirchhoff



Coulomb $\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$

- Halved the distance between charges
- Distance not squared
- Charge not squared

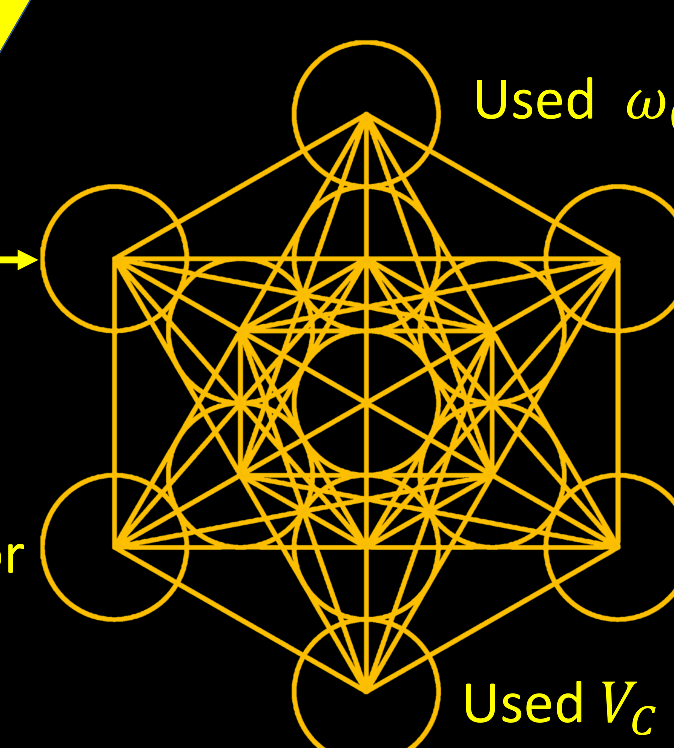
Gauss $\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$

Faraday $\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$

Ampere $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$

- Used force on a current carrying wire
- Used area of loop instead of integrating around the loop
- Used the perpendicular side of the loop instead of the parallel one
- Only used one parallel side of Ampere's loop instead of two

RLC Circuits $\omega_0 = \frac{1}{\sqrt{LC}}$



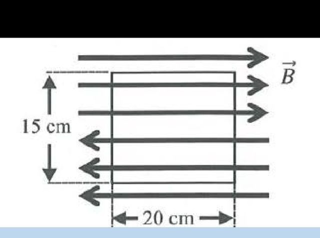
- Used $\omega_0 = LC$
- Mixed up ω_0 and f
- Used $X_L = \frac{1}{\omega L}$
- RMS error
- Used $V_C = \varepsilon\left(1 - e^{-t/RC}\right)$

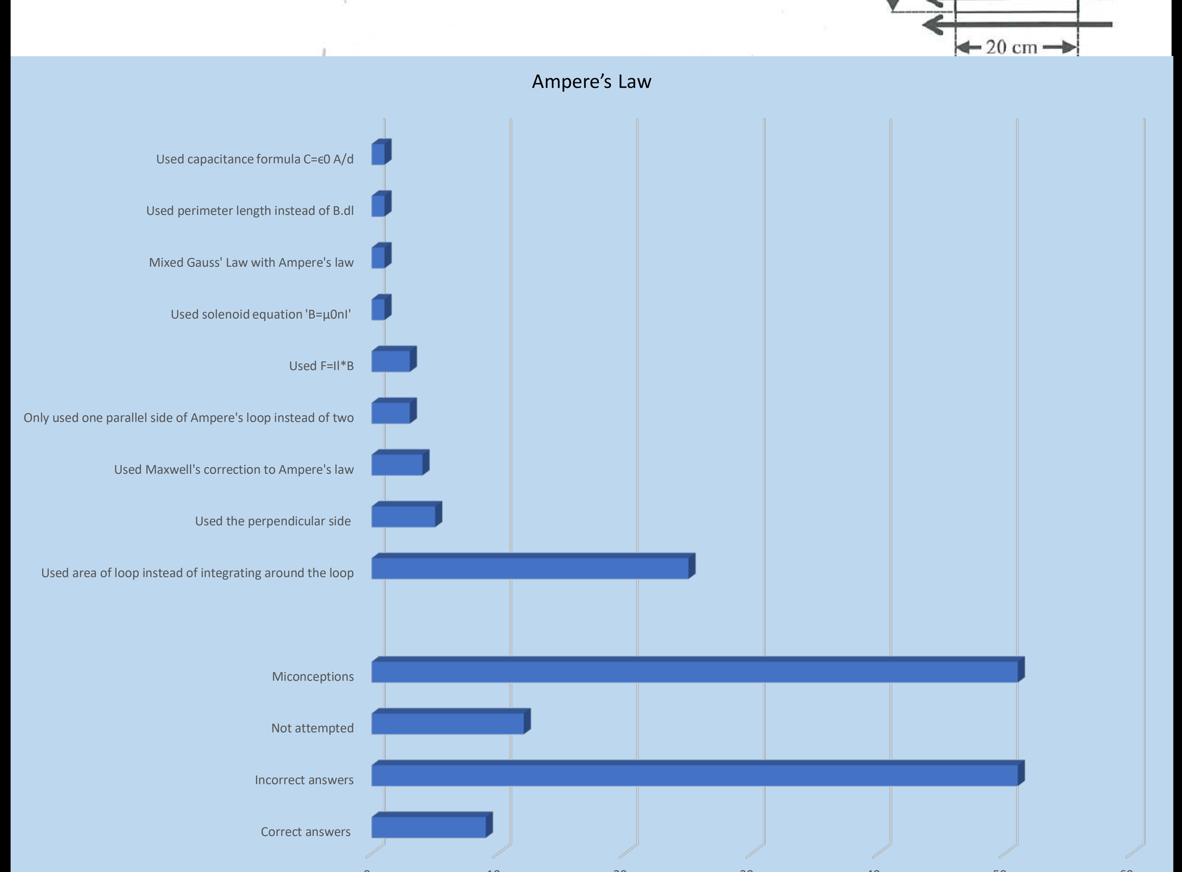
Student Misconceptions

- Used current in a capacitor
- Used Ampere's law
- Used Maxwell's correction to Ampere's law
- Thought emf was current
- Used Biot-Savart law
- Neglected area of loop

Exam Questions

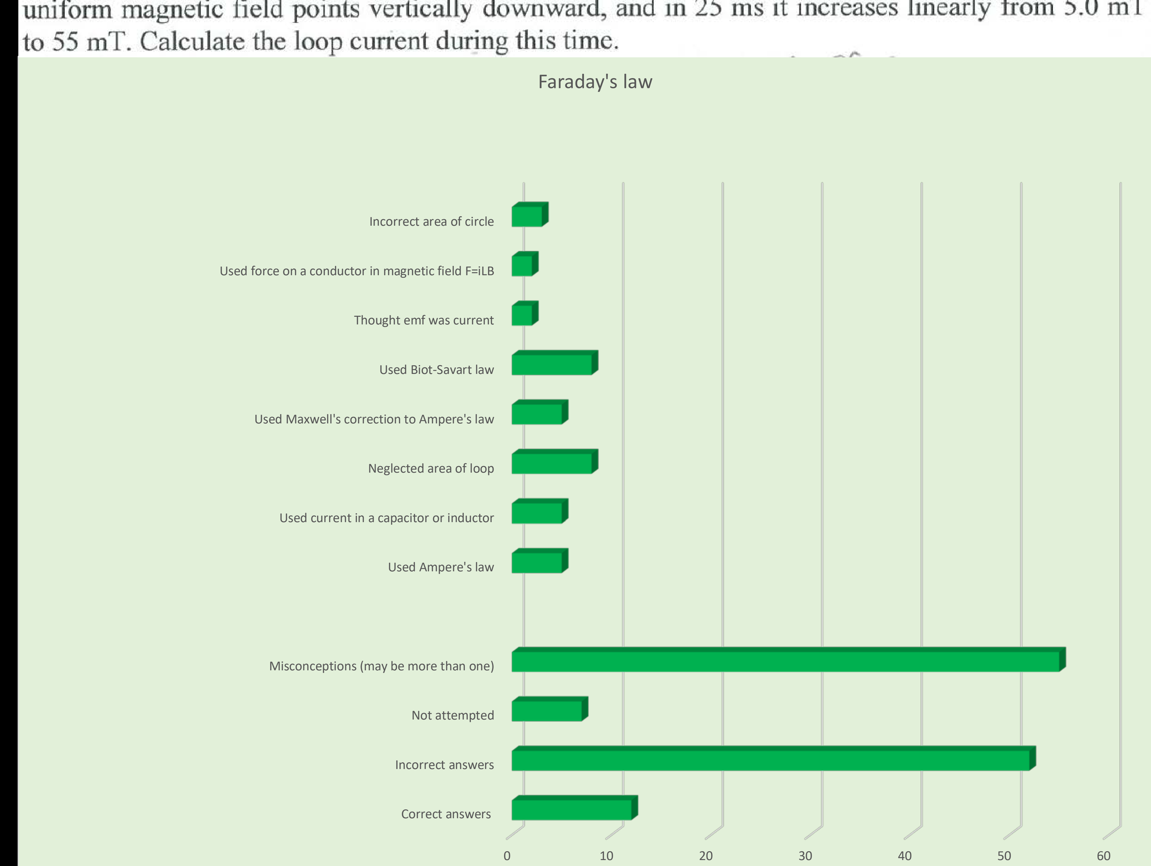
B7. The magnetic field shown in the figure at right has uniform magnitude 82 μT, but its direction reverses abruptly. Use Ampere's Law to calculate the current encircled by the rectangular loop shown.





Exam Questions

B8. A circular wire loop 45 cm in diameter has resistance 120 Ω and lies in a horizontal plane. A uniform magnetic field points vertically downward, and in 25 ms it increases linearly from 5.0 mT to 55 mT. Calculate the loop current during this time.



Proposed Questions

1 Coulomb's Law

When finding the electrostatic force between 2 charges with the same magnitude but opposite signs, +q and -q, at a distance d apart, do we divide the product k(+q)(-q) by

1. square the of distance between the charges $\vec{F}_e = k\frac{(+q)(-q)}{d^2}$
2. half the distance between the charges, then square $\vec{F}_e = k\frac{(+q)(-q)}{(\frac{d}{2})^2}$
3. double the distance between the charges, then square $\vec{F}_e = k\frac{(+q)(-q)}{(2d)^2}$
4. the distance between the charges $\vec{F}_e = k\frac{(+q)(-q)}{d}$

2 Electric flux

If two charges, q_1 and q_2, are inside an uncharged, conductive sphere, then to calculate the electric flux through the sphere, we

1. add the charges together $q_1 + q_2$
2. add the charges together and divide by ϵ_0, $\Rightarrow \frac{q_1+q_2}{\epsilon_0}$
3. can not be done because the charges are enclosed

3 Charge and energy

If a 3 C charge is moved from the positive plate of a 9 Volt battery to the negative plate, then to find the energy imparted to the charge by the battery

1. $W = Q\Delta V = 3 \times 9 = 27J$
2. $U = \frac{1}{2}CV^2 = \frac{1}{2}(3)(9)^2 = 121.5J$
3. $U = \frac{1}{2}CV = (\frac{1}{2})(\frac{3}{9})(9)^2 = 13.5J$