Physics 115A Spring 2014
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EXAM 3

DO NOT take an extra copy; only enough for 1 per person!

DO NOT OPEN THIS YET!

Please read the following carefully:

1. Fill in your name (Last, First) and student ID number on your mark-sense (bubble) sheet. Your name should be given exactly as it appears on your course registration.
DOUBLE-CHECK that you have the right bubbles marked for name and student ID.

2. Only calculators may be used (graphing calculators are OK).
You must NOT use phones or computers during the exam.

3. Open the exam and **begin when the bell rings**.

4. **PLEASE NOTE** – you <u>must</u> turn in this copy before leaving. If you want to keep your paper, **write your name on it** and you can pick it up outside my office (B-303 PAB) after 3:30 pm today.

There are 17 questions on this exam, points as marked, 100 pts total.
There are 6 sheets with 12 pages. Check your paper for completeness.
Time allowed: until 2:15 pm; no papers accepted after 2:20pm.

List of formulae

Electric Current $I = \Delta Q / \Delta t$ = Rate of flow of electric charge

Ohm's Law $V = IR$

$R = \rho L / A$, ρ resistivity

Series $R = R_1 + R_2 + \ldots\ldots$ Parallel $R^{-1} = R_1^{-1} + R_2^{-1} + \ldots\ldots$
$Q = CV$
Series $C^{-1} = C_1^{-1} + C_2^{-1} + \ldots$ Parallel $C = C_1 + C_2 + \ldots\ldots$
Charging a capacitor in an RC circuit
$Q(t) = Q_{max}(1 - e^{-t/\tau})$ $\tau = RC$, Q_{max} = maximum charge on C (at t=infinity)

$F_B = q v B \sin(\theta)$, $F_E = q E$ (on a charge q)

Work $= q V$

$F_B = I l B \sin(\theta)$ (on wire with length l)

Torque on coil of N loops $= N I B A \sin(\theta)$

Force per unit length between parallel currents $= \mu_0 I_1 I_2 / 2\pi D$
D is distance between wires

Magnetic Permeability of Vacuum $\mu_0 = 4 \pi \times 10^{-7}$

Power $= V I$
Loop Rule Sum of Voltage Drops around any Loop = Zero
Junction Rule Sum of Currents In = Sum of Currents Out at any junction
Magnetic field at distance R from a long straight wire with current I
$B = 2 \times 10^{-7} I/R$
Cyclotron formula for charged particle moving perpendicular to uniform field B
$R = mv/(qB)$, R radius of the circular trajectory
Solenoid field $B = \mu_0 N I / l$ (N turns over length l)
Transformers: $(V_2 / V_1) = (N_2 / N_1) = (I_1 / I_2)$
Inductance $L = \Delta \Phi_m / \Delta I$ Inductance of solenoid (N turns, length l): $L = \mu_0 N^2 A / l$
Kinetic energy for mass m, speed $v = \frac{1}{2} mv^2$

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1) [4 pts] The length of a certain wire is doubled and at the same time its radius is reduced by a factor of 2. How does the resistance of this wire change ?

A) It is doubled.
B) It is quadrupled.
C) It increases by a factor of 6.
D) It increases by a factor of 8.
E) It is reduced by a factor of 2.
Answer: D

$$R = \rho \frac{L}{A} = \rho \frac{L}{\pi r^2} \qquad R' = \rho \frac{2L}{\pi (r/2)^2} = \rho \frac{8L}{\pi r^2} = 8R$$
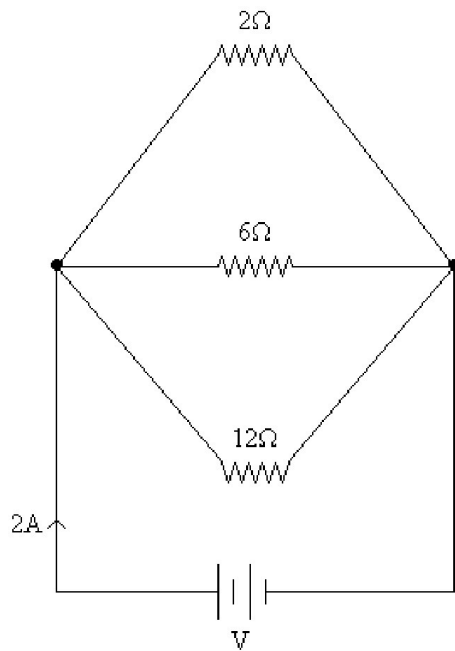

Figure: for problems 2 and 3.

2) [6 pts] Three resistors of values 2 Ω, 6 Ω and 12 Ω are connected across a DC voltage source as shown above.
If the total current from the source is 2.0 A, what is the applied voltage V?
A) 6.0 V
B) 3.0 V
C) 2.0 V
D) 2.7 V
E) 1.5 V

3

$$\frac{1}{R_{eq}} = \frac{1}{2\Omega} + \frac{1}{6\Omega} + \frac{1}{12\Omega} \rightarrow R_{eq} = 1.33\Omega$$

Answer: D

$$V = I\,R_{eq} = 2A\left(1.33\Omega\right) = 2.66V$$

3) (4 pts) In the circuit above, what is the current in the 6 ohm resistor?
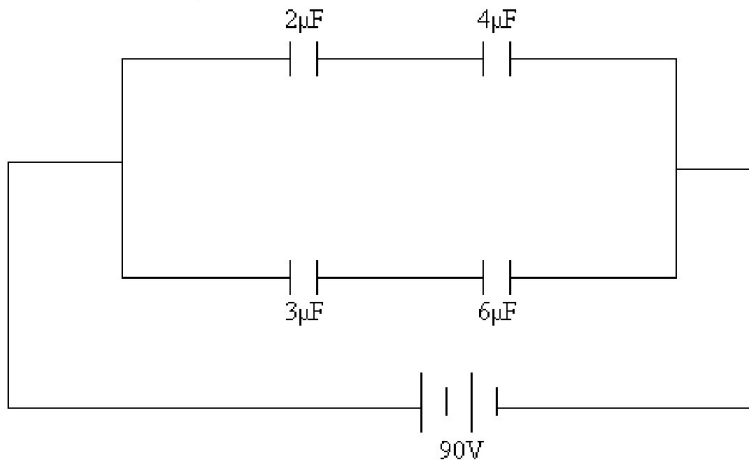A) 0.44 A
B) 0.56 A
C) 0.30 A
D) 1.33 A
E) None of the above

Ans: A $I = V/R = 2.66V/6\Omega = 0.443A$

4) [6 pts] The power rating of a resistor is 0.80 W. (This means it will be damaged if it is required to dissipate more than 0.80 W) The value of the resistor is 400 Ω .
What is the maximum voltage drop V this resistor can handle?
A) 110 V
B) 17.9 V
C) 170 V
D) 1.80 V
Answer: B

$$P_{MAX} = V^2/R \Rightarrow V^2_{MAX} = P_{MAX}R \rightarrow V_{MAX} = \sqrt{0.80W\left(400\Omega\right)} = 17.88V$$
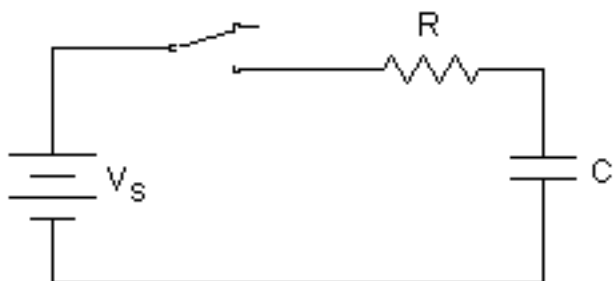
5) [6 pts] In the circuit shown above, what is the voltage across the 6-µF capacitor?
A) 10 V
B) 20 V
C) 30 V
D) 60 V
E) 90 V
Answer: C

$$90V = V_6 + V_3 = \frac{Q_6}{6\mu F} + \frac{Q_3}{3\mu F};$$

$$Q_6 = Q_3 \rightarrow \frac{V_6}{V_3} = \frac{3\mu F}{6\mu F} \rightarrow V_3 = 2V_6 \rightarrow 90V = 3V_6 \rightarrow V_6 = 30V$$

(For 6, 7): A capacitor with C=8.0 µF is connected in series with a resistor R=6.0 kΩ, across a DC source with V_S=20 V, and an open switch, as shown above.

6) [6 pts] The switch is closed at t=0. After a long time has passed, approximately how much charge does the capacitor hold?
A) 160 C
B) 1.6 x 10^{-4} C
C) 48 C
D) 4.8 x 10^{-5} C
E) none of the above
Answer: B

$$q(t) = C\mathcal{E}\left(1 - e^{-t/\tau}\right); \quad q_{MAX} = q(t = \infty) = C\mathcal{E} = \left(8.0 \times 10^{-6} \, F\right)20V = 1.6 \times 10^{-4} C$$

7. [6 pts] How long after the switch is closed will the charge on the capacitor be 63% of its maximum charge?

A) 160 microseconds
B) 3.3 milliseconds
C) 48 milliseconds
D) 48 seconds
E) None of the above.

$$q(t) = q_{MAX}\left(1 - e^{-t/\tau}\right) \rightarrow \frac{q(t)}{q_{MAX}} = 0.63 = \left(1 - e^{-t/\tau}\right)$$

$$\rightarrow e^{-t/\tau} = 0.37 \rightarrow \left(-\frac{t}{\tau}\right) = \ln(0.37) = -1 \rightarrow t = \tau$$

Answer: C

$$\tau = RC = \left(6.0 \times 10^3 \, \Omega\right)\left(8.0 \times 10^{-6} \, F\right) = 48.0 \times 10^{-3} s \quad (48 \text{ ms})$$
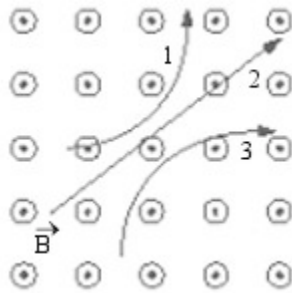
6

8) [6 pts] An electron moves at right angles to a magnetic field of 1 tesla . What is its speed if the force exerted on it is 10^{-15} N ? Charge on the electron is -1.6 X 10^{-19} C

A)   4527   m/s
B)   1758
C)   8992
D)   6250
E)   1449
Answer: D

Right angle between v and B, so F_B = q v B

→ v= F_B /(qB)=10^{-15} N /{(1.6 x 10^{-19} C) (1 T) } = 0.625 x 10^4 m/s

9) [6 pts] Three particles travel through a region of space where the magnetic field is out of the page, as shown above. Which statement correctly describes the electric charge of each of the three particles?

A) 1 is neutral, 2 is negative, and 3 is positive.   *No: 1 bends, so it cannot be neutral.*
B) 1 is neutral, 2 is positive, and 3 is negative.   *No: 1 bends, so it cannot be neutral.*
C) 1 is positive, 2 is neutral, and 3 is negative.   *No: 2 and 3 bend in directions* opposite *to RHR.*
D) 1 is positive, 2 is negative, and 3 is neutral.   *No: 3 bends, so it cannot be neutral.*
E) 1 is negative, 2 is neutral, and 3 is positive.   *CORRECT: 1 and 3 bend according to RHR*

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10) [8 pts] An electron is accelerated   from rest through a potential difference of 100 V, and then enters a uniform magnetic field. The electron follows a circular path of radius 1 m . What is the strength of the magnetic field ? Mass of the electron is 9.1×10^{-31} kg

A)   34   micro Tesla
B)   19
C)   118
D)   67
E)   351

Answer: A

$$e\Delta V = KE = mv^2 / 2$$

$$v = \sqrt{2e\Delta V / m} = \sqrt{2\left(1.60\times10^{-19}\,C\right)\left(100\ V\right)/\left(9.11\times10^{-31}\,kg\right)} = 5.92\times10^6 \text{ m/s}$$

$$r = \frac{mv}{eB} \rightarrow B = \frac{mv}{er} = \frac{\left(9.11\times10^{-31}\,kg\right)\left(5.92\times10^6\text{ m/s}\right)}{\left(1.60\times10^{-19}\,C\right)\left(1m\right)} = 33.7\times10^{-6}\,T$$

11) [6 pts] A 2-m long wire is carrying a current of 2 A. The wire is placed at an angle of 60° with respect to a magnetic field. If the wire experiences a force of 0.2 N, what is the strength of the magnetic field?
A) 0.02 T
B) 0.03 T
C) 0.04 T
D) 0.05 T
E) 0.06 T
Answer: E

F_B = $I\,l$ B Sin (θ) (on wire with length l) $\rightarrow$ B = F_B / (I l Sin (60deg))
B= (0.2N)/{ (2A) (2m) (0.866) = 0.057T

12) [6 pts] A circular loop of wire of radius 0.50 m is in a uniform magnetic field of 0.30 T. The current in the loop is 2.0 A. What is the magnetic torque when the direction of the magnetic field lies in plane of the loop ?
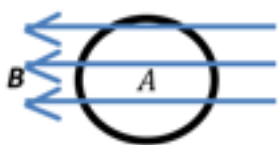A) zero
B) 0.41 m · N
C) 0.47 m · N
D) 0.52 m · N
E) 0.58 m · N
Answer: C

$\tau = NIAB \sin\theta$, $\quad N =$ turns, A=area of loop

$\theta =$ angle between *normal* to plane of loop and $\vec{B}$, here $\theta=90°\ \rightarrow \sin\theta = 1$.

$\tau = (A)I B = (\pi r^2)I B = 3.14(0.5m)^2(2A)(0.3T) = 0.47Nm$

13) [8 pts] Two long parallel wires carry currents of 20 A and 5.0 A in opposite directions. The wires are separated by 0.20 m. What is the magnitude of the magnetic field midway between the two wires?
A) 1.0×10^{-5} T
B) 2.0×10^{-5} T
C) 3.0×10^{-5} T
D) 4.0×10^{-5} T
E) 5.0×10^{-5} T
Answer: E

$$B_1 = \frac{\mu_0 I_1}{2\pi r_1}, \quad B_2 = \frac{\mu_0 I_2}{2\pi r_2}$$

$r_2 = r_1 = 0.10m,$

$$|B_1| = \frac{\mu_0 I}{2\pi r} = \frac{(1.26\times10^{-6}T \cdot m/A)20A}{2\pi(0.1m)} = 4.0\times10^{-5}T$$

$$|B_2| = \frac{(1.26\times10^{-6}T \cdot m/A)5A}{2\pi(0.1m)} = 1.0\times10^{-5}T$$

Contributions from the 2 wires point in the same direction (RHR: same direction for B between wires, for opposite directions of I), so they add: total field magnitude is $(4.0+1.0) \times 10^{-5}$ T.

14) [6 pts] The current in a 110 V reading lamp is 2 A . If the cost of electricity is 10 cents per kilowatt-hour , how much does it cost to operate the lamp for 7 hours ?

A)   17.3 cents
B)   9.2
C)   23.2
D)   5.8
E)   15.4

P=IV=220W; energy = 0.220kW (7hr)=1.54 kw-hr → cost = 1.54*(10¢)=15.4 cents

15) [4 pts] How many turns should a 10-cm long solenoid have, if it is to generate a magnetic field of 1.5×10^{-3} T when carrying 1.0 A of current?
A) 12
B) 15
C) 119
D) 1194
E) 3183
Answer: C

$$B_{SOLENOID} = \mu_0 n I \rightarrow n = \frac{B}{\mu_0 I} = \frac{\left(1.5 \times 10^{-3} T\right)}{\left(1.26 \times 10^{-6} T \cdot m / A\right) 1.0 A} = 1190 / m$$

$$N = nL = 1190 / m \left(0.1m\right) = 119$$

16. [6 pts] How would the self-inductance, L, of a solenoid coil change if you increase its radius by a factor of two and increase its length by a factor of two? (Number of turns remains the same),
        A) L would not change.
        B) L would be doubled.
        C) L would be quadrupled.
        D) L would be halved.
        E) L would be reduced by 4

Ans: B

$$L_{solenoid} = \frac{\mu_0 N^2 A}{\ell}$$

$$r \rightarrow 2r, \quad \ell \rightarrow 2\ell : L'_{solenoid} = \frac{\mu_0 N^2 4A}{2\ell} = 2L_{solenoid}$$

17. [6 pts] The primary coil of a transformer has 100 turns and its secondary coil has 400 turns. If the ac current in the secondary coil is 2 A, what is the current in its primary coil?

    A) 2 A
    B) 8 A
    C) 1/2 A
    D) 1/4 A
    E) 4 A
    Answer: B

$(N_2 / N_1) = (I_1 / I_2) \rightarrow I_1 = I_2 (N_2 / N_1) = 2A (400/100) = 8A$

END OF EXAM

Use back of this sheet as scratch paper if needed