Instructor: *Field/Mitselmakher*

PHYSICS DEPARTMENT

PHY 2054 Exam 2 March 23, 2016

Name (PRINT, last, first): _____ Signature: _____

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

DIRECTIONS

(1) **Code your test number on your answer sheet (use 76–80 for the 5-digit number)**. Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your student number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout with scratch work most questions demand.
(4) **Blacken the circle of your intended answer completely, using a #2 pencil or <u>blue</u> or <u>black</u> ink**. Do not make any stray marks or the answer sheet may not read properly.
(5) The answers are rounded off. Choose the closest to exact. There is no penalty for guessing.

>>>>>>>>**WHEN YOU FINISH** <<<<<<<<
Hand in the answer sheet separately.

Constants			
$\epsilon_0 = 8.85 \times 10^{-12}$ F/m	$m_e = 9.11 \times 10^{-31}$ kg	$m_p = m_n = 1.67 \times 10^{-27}$ kg	$e = 1.6 \times 10^{-19}$ C
$k = 8.99 \times 10^9$ N m^2/C^2	$\mu_0 = 12.56 \times 10^{-7}$ H/m	$N_A = 6.02 \times 10^{23}$ atoms/mole	$c = 3 \times 10^8$ m/s
milli $= 10^{-3}$	micro $= 10^{-6}$	nano $= 10^{-9}$	pico $= 10^{-12}$

PHY2054 Exam 1 Formula Sheet

Vectors & Quadratic Formula

$\vec{a} = a_x\hat{x} + a_y\hat{y} + a_z\hat{z}$ $\vec{b} = b_x\hat{x} + b_y\hat{y} + b_z\hat{z}$ **Magnitudes:** $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$ $|\vec{b}| = \sqrt{b_x^2 + b_y^2 + b_z^2}$

Scalar Product: $\vec{a}\cdot\vec{b} = a_x b_x + a_y b_y + a_z b_z = |\vec{a}||\vec{b}|\cos\theta$ (θ = angle between $\vec{a}$ and $\vec{b}$)

Quadratic Formula: if $ax^2 + bx + c = 0$ then $x = \left(-b \pm \sqrt{b^2 - 4ac}\right)/(2a)$

Electrostatic Force and Electric Field

Electrostatic Force (vector): $\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r}$ (r = distance between charge q_1 and charge q_2, units = N)

$k = 1/(4\pi\varepsilon_0) = 8.99\text{x}10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$ $\varepsilon_0 = 8.85\text{x}10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$

Electric Field (at q_2 due to q_1): $\vec{E} = \vec{F}/q_2 = k\frac{q_1}{r^2}\hat{r}$ (units = N/C = V/m)

Electric Flux (through the infinitesimal surface area dA)**:** $d\Phi_E = \vec{E}\cdot d\vec{A}$ (units = Nm^2/C)

Vector Area (directed area): $\vec{A} = A\hat{n}$ (where $\hat{n}$ = normal to the surface)

Gauss' Law: $\Phi_E = \oint_S \vec{E}\cdot d\vec{A} = \sum_S \vec{E}\cdot\Delta\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$ ($Q_{enclosed}$ = charge enclosed)

Gauss' Law: Net flux through closed surface **S** = the charge enclosed by surface S divided by ε_0

Electric Potential and Potential Energy

Electric Potential Energy: work done against a constant field E in moving charge q a distance d along straight line path from A to B, $\Delta U = U_B - U_A = -q\vec{E}\cdot\vec{d}$ (units = J)

Electric Potential: Work done per unit charge against a constant field E in moving charge q a distance d along straight line path from A to B, $\Delta V = \Delta U/q = -\vec{E}\cdot\vec{d}$ (units = J/C = V)

Electric Potential (distance r from a point charge q)**:** $V(r) = k\frac{q}{r}$ N point charges: $V(r) = \sum_{i=1}^{N} k\frac{q_i}{r_i}$

Electric Potential Energy (N point charges): $U = \frac{1}{2}\sum_{i=1}^{N} q_i V_i$, where V_i is the electric potential at q_i due to the other charges

Stored Electric Potential Energy (N conductors with charge Q_i and electric potential V_i)**:** $U = \frac{1}{2}\sum_{i=1}^{N} Q_i V_i$

Capacitance (definition)**: C = Q/V** or **C = Q/ΔV** (units = C/V = F)

Parallel Plate Capacitor with Dielectric κ: $C = \kappa\varepsilon_0 A/d$

Energy Density of the Electric Field: $u = \frac{1}{2}\varepsilon_0 E^2$ (units = J/m^3)

Electric Current and Circuits

Current (through directed area A)**:** $I = \frac{dQ}{dt} = nq\vec{v}_{drift}\cdot\vec{A}$ (units = C/s = A, n is the number of charged particles q per unit volume, v_{drift} is the average velocity of the charged particles).

Ohm's Law: $|\Delta V| = IR$, $R = \rho L/A$ (Resistance R units = V/A = Ω)

Power (supplied by EMF ε)**:** P = εI **Power** (dissipated in resistor R)**:** $P = I^2R$ (units = J/s = W)

RC Circuits (charging capacitor C through resistor R with EMF ε)**:** $Q(t) = \varepsilon C(1 - e^{-t/\tau})$

RC Circuits (discharging capacitor C with initial charge Q_0 through resistor R)**:** $Q(t) = Q_0 e^{-t/\tau}$

RC Circuits (time constant)**:** τ = RC (units = Ω·F = s)

PHY2054 Exam 2 Formula Sheet

Vectors

$\vec{a} = a_x\hat{x} + a_y\hat{y} + a_z\hat{z}$ $\vec{b} = b_x\hat{x} + b_y\hat{y} + b_z\hat{z}$ **Cross Product Magbitude:** $\left|\vec{a}\times\vec{b}\right| = \left|\vec{a}\right|\left|\vec{b}\right|\sin\theta_{ab}$

Cross Product Vector: $\vec{c} = \vec{a}\times\vec{b} = (a_y b_z - a_z b_y)\hat{x} - (a_x b_z - a_z b_x)\hat{y} + (a_x b_y - a_y b_x)\hat{z}$

Electromagnetic Force

Electrmagnetic Force (vector): $\vec{F}_{EM} = \vec{F}_E + \vec{F}_B = q\vec{E} + q\vec{v}\times\vec{B}$ $\vec{F}_E = q\vec{E}$ $\vec{F}_B = q\vec{v}\times\vec{B}$

(r = distance between charge Q and charge q, v = velocity of charge q, V = velocity of charge Q)

$\vec{F}_E = k\dfrac{Qq}{r^2}\hat{r}$ (units = N) $\vec{F}_B = k\dfrac{Qq}{c^2 r^2}\vec{v}\times\vec{V}\times\hat{r}$ (units = N)

$k = 1/(4\pi\varepsilon_0) \approx 8.99\text{x}10^9$ N·m²/C² $\varepsilon_0 \approx 8.85\text{x}10^{-12}$ C²/(N·m²)

$k_B = k/c^2 = \mu_0/(4\pi) \approx 10^{-7}$ Tm/A $\mu_0 \approx 4\pi \times 10^{-7}$ Tm/A $c \approx 3 \times 10^8$ m/s (speed of light)

Electric and Magnetic Field (due to Q): $\vec{E} = k\dfrac{Q}{r^2}\hat{r}$ (N/C = V/m) $\vec{B} = k_B\dfrac{Q}{r^2}\vec{V}\times\hat{r}$ (N/(C·m/s) = T)

Magnetic Field (due to current I in length d*l* of wire): $d\vec{B} = k_B\dfrac{I}{r^2}d\vec{l}\times\hat{r}$ (units = N/(C·m/s) = T)

Energy Density (Electric & Magnetic Field): $u_E = \frac{1}{2}\varepsilon_0 E^2$ $u_B = \frac{1}{2\mu_0}B^2$ (units = J/m³)

Magnetic Force (on a long straight wire carrying current I): $\vec{F}_B = I\vec{L}\times\vec{B}$ (units = N)

Magnetic Dipole Moment: $\vec{\mu}_B = NI\vec{A}$ (units = A·m²) $\vec{A} = A\hat{n}$ **Torque:** $\vec{\tau} = \vec{\mu}_B\times\vec{B}$ (units = N·m)

Ampere's Law: $\oint_C \vec{B}\cdot d\vec{l} = \sum_C B_{\parallel}\Delta l = \mu_0 I_{enclosed}$ (closed loop)

Magnetic Field (Examples)

Infinite Straight Wire: $\left|\vec{B}\right| = 2k_B I / r_{perp}$ **Center of a Circular Current Loop:** $\left|\vec{B}\right| = 2\pi k_B I / r$

Electromagnetic Induction, RL Circuits, LC Circuits, AC Circuits

Magnetic Flux (uniform B, surface A)**:** $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta = B_{perp}A$ units = Tm² = Wb

Faraday's Law of Induction: $\varepsilon = -\dfrac{d\Phi_B}{dt}$ (ε = induced emf, units = V)

Rate of Change with Time: $\dfrac{d\cos(\omega t)}{dt} = -\omega\sin(\omega t)$

Inductor (inductance L units = H)**:** $\Delta V_L = -L\dfrac{dI}{dt}$ (potential difference) $U_L = \frac{1}{2}LI^2$ (stored energy)

RL Circuits (time constant)**:** $\tau_L = L/R$ (units = H/Ω = s)

RL Circuits (EMF ε, Resistor R, Inductor L, swirch closed at t = 0)**:** $I(t) = \varepsilon(1 - e^{-t/\tau_L})/R$

Oscillating LC Circuit (no resistance)**:** $U_{tot} = \frac{1}{2}Q^2/C + \frac{1}{2}LI^2$ (stored energy) $\omega = 1/\sqrt{LC}$

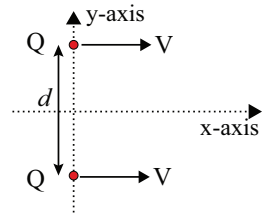
Oscillating LC Circuit (no resistance)**: f = ω/2π** (frequency of oscillations in Hz)

AC Circuit Impedance ($\varepsilon(t) = \varepsilon_{max}\sin(\omega t+\phi)$, $X_R = R$, $X_L = \omega L$, $X_C = 1/\omega C$): $Z = \sqrt{X_R^2 + (X_L - X_C)^2}$

AC Circuit Maximum Current & Average Power: $I_{\max} = \dfrac{\varepsilon_{\max}}{Z}$ $P_{ave} = \frac{1}{2}I_{\max}\varepsilon_{\max}X_R/Z$

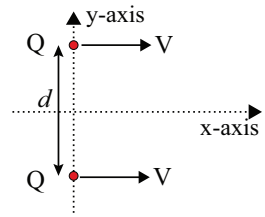
AC Circuit RMS Current & Voltage: $I_{rms} = I_{\max}/\sqrt{2}$ $\varepsilon_{rms} = \varepsilon_{\max}/\sqrt{2}$

1. Two identical charged particles, separated by a distance d, are moving parallel to each other in the x-direction with velocity V as shown in the figure. If V = 0.5c, what is the magnitude of the net electromagnetic force F_{EM} that one of the particles exerts on the other? Note that $c \approx 3 \times 10^8$ m/s is the speed of light in a vacuum and $k = 1/(4\pi\epsilon_0)$.



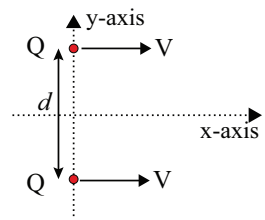
(1) $0.75\frac{kQ^2}{d^2}$ (2) $0.64\frac{kQ^2}{d^2}$ (3) $0.51\frac{kQ^2}{d^2}$ (4) $\frac{kQ^2}{d^2}$ (5) $1.25\frac{kQ^2}{d^2}$

2. Two identical charged particles, separated by a distance d, are moving parallel to each other in the x-direction with velocity V as shown in the figure. If V = 0.6c, what is the magnitude of the net electromagnetic force F_{EM} that one of the particles exerts on the other? Note that $c \approx 3 \times 10^8$ m/s is the speed of light in a vacuum and $k = 1/(4\pi\epsilon_0)$.



(1) $0.64\frac{kQ^2}{d^2}$ (2) $0.75\frac{kQ^2}{d^2}$ (3) $0.51\frac{kQ^2}{d^2}$ (4) $\frac{kQ^2}{d^2}$ (5) $1.25\frac{kQ^2}{d^2}$

3. Two identical charged particles, separated by a distance d, are moving parallel to each other in the x-direction with velocity V as shown in the figure. If V = 0.7c, what is the magnitude of the net electromagnetic force F_{EM} that one of the particles exerts on the other? Note that $c \approx 3 \times 10^8$ m/s is the speed of light in a vacuum and $k = 1/(4\pi\epsilon_0)$.



(1) $0.51\frac{kQ^2}{d^2}$ (2) $0.75\frac{kQ^2}{d^2}$ (3) $0.64\frac{kQ^2}{d^2}$ (4) $\frac{kQ^2}{d^2}$ (5) $1.25\frac{kQ^2}{d^2}$

4. An electron (charge $e = 1.6 \times 10^{-19}$C) undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity produces a magnetic field at the center of the circle with a magnitude of 0.8μT. What is the speed of the electron (in km/s)?

(1) 20.0 (2) 40.0 (3) 60.0 (4) 10.0 (5) 50.0

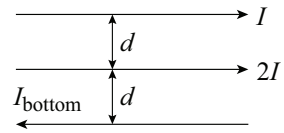
5. An electron (charge $e = 1.6 \times 10^{-19}$C) undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity produces a magnetic field at the center of the circle with a magnitude of 1.6μT. What is the speed of the electron (in km/s)?

(1) 40.0 (2) 20.0 (3) 60.0 (4) 10.0 (5) 50.0

6. An electron (charge $e = 1.6 \times 10^{-19}$C) undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity produces a magnetic field at the center of the circle with a magnitude of 2.4μT. What is the speed of the electron (in km/s)?

(1) 60.0 (2) 20.0 (3) 40.0 (4) 10.0 (5) 50.0

7. Three infinitely long straight wires lie in a plane as shown in the figure. The top wire carries current I to the right and is a distance d from the center wire which carries current $2I$ to the right. The bottom wire carries current I_{bottom} to the left and is a distance d from the center wire. If the magnitude of the net force on the top wire due to the other two wires is zero, what is I_{bottom}?

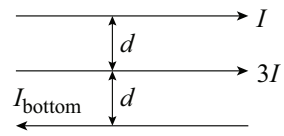


(1) $4I$ (2) $6I$ (3) $8I$ (4) $2I$ (5) I

8. In the previous problem, what is the magnitude of the net force on a length $L = d/2$ of the center wire due to the other two wires?

(1) $10k_BI^2$ (2) $21k_BI^2$ (3) $36k_BI^2$ (4) $6k_BI^2$ (5) $15k_BI^2$

9. Three infinitely long straight wires lie in a plane as shown in the figure. The top wire carries current I to the right and is a distance d from the center wire which carries current $3I$ to the right. The bottom wire carries current I_{bottom} to the left and is a distance d from the center wire. If the magnitude of the net force on the top wire due to the other two wires is zero, what is I_{bottom}?

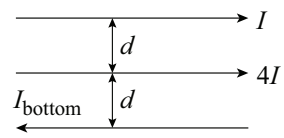


(1) $6I$ (2) $4I$ (3) $8I$ (4) $2I$ (5) I

10. In the previous problem, what is the magnitude of the net force on a length $L = d/2$ of the center wire due to the other two wires?

(1) $21k_BI^2$ (2) $10k_BI^2$ (3) $36k_BI^2$ (4) $6k_BI^2$ (5) $15k_BI^2$

11. Three infinitely long straight wires lie in a plane as shown in the figure. The top wire carries current I to the right and is a distance d from the center wire which carries current $4I$ to the right. The bottom wire carries current I_{bottom} to the left and is a distance d from the center wire. If the magnitude of the net force on the top wire due to the other two wires is zero, what is I_{bottom}?

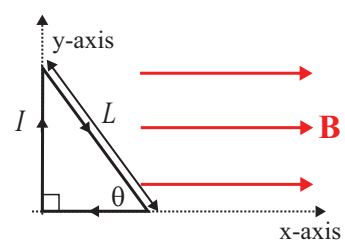


(1) $8I$ (2) $4I$ (3) $6I$ (4) $2I$ (5) I

12. In the previous problem, what is the magnitude of the net force on a length $L = d/2$ of the center wire due to the other two wires?

(1) $36k_BI^2$ (2) $10k_BI^2$ (3) $21k_BI^2$ (4) $6k_BI^2$ (5) $28k_BI^2$

13. A current loop in the shape of a right triangle with hypotenuse of length $L = 0.75$ m lies in the xy-plane and carries a current $I = 2$ A in the clockwise direction as shown in the figure. The current loop is immersed in a uniform external 0.5 T magnetic field which points in the x-direction. If $\theta = 10°$, what is the magnitude of the magnetic force on the hypotenuse of the right triangle due to the external magnetic field (in N)?

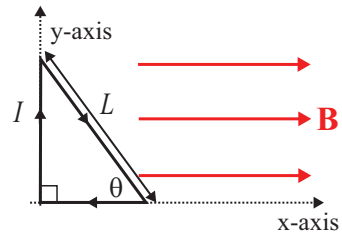


(1) 0.130 (2) 0.257 (3) 0.375 (4) 0.090 (5) 0.425

14. In the previous problem, what is the magnitude of the torque on the current loop (in N·m) due to the external magnetic field?

(1) 0.048 (2) 0.090 (3) 0.122 (4) 0.024 (5) 0.225

15. A current loop in the shape of a right triangle with hypotenuse of length $L = 0.75$ m lies in the xy-plane and carries a current $I = 2$ A in the clockwise direction as shown in the figure. The current loop is immersed in a uniform external 0.5 T magnetic field which points in the x-direction. If $\theta = 20°$, what is the magnitude of the magnetic force on the hypotenuse of the right triangle due to the external magnetic field (in N)?

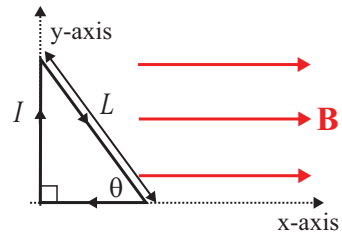


(1) 0.257 (2) 0.130 (3) 0.375 (4) 0.090 (5) 0.425

16. In the previous problem, what is the magnitude of the torque on the current loop (in N·m) due to the external magnetic field?

(1) 0.090 (2) 0.048 (3) 0.122 (4) 0.024 (5) 0.225

17. A current loop in the shape of a right triangle with hypotenuse of length $L = 0.75$ m lies in the xy-plane and carries a current $I = 2$ A in the clockwise direction as shown in the figure. The current loop is immersed in a uniform external 0.5 T magnetic field which points in the x-direction. If $\theta = 30°$, what is the magnitude of the magnetic force on the hypotenuse of the right triangle due to the external magnetic field (in N)?

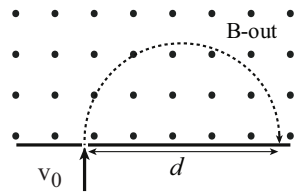


(1) 0.375 (2) 0.130 (3) 0.257 (4) 0.090 (5) 0.425

18. In the previous problem, what is the magnitude of the torque on the current loop (in N·m) due to the external magnetic field?

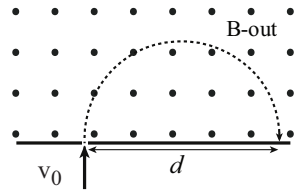
(1) 0.122 (2) 0.048 (3) 0.090 (4) 0.024 (5) 0.225

19. At time $t = 0$ a charged particle with speed $v_0 = 1$ m/s enters a region through a slit and travels perpendicular to a uniform magnetic field (pointing out of the page) as shown in the figure. If the particle hits the bottom wall a distance d from the slit at $t = 3.14$ s, what is d (in m)?



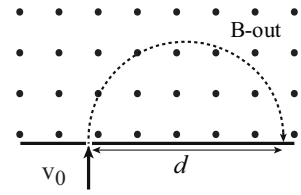
(1) 2 (2) 4 (3) 8 (4) 1 (5) 3

20. At time $t = 0$ a charged particle with speed $v_0 = 2$ m/s enters a region through a slit and travels perpendicular to a uniform magnetic field (pointing out of the page) as shown in the figure. If the particle hits the bottom wall a distance d from the slit at $t = 3.14$ s, what is d (in m)?



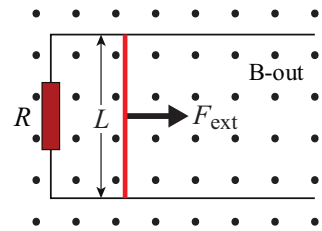
(1) 4 (2) 2 (3) 8 (4) 1 (5) 3

21. At time $t = 0$ a charged particle with speed $v_0 = 4$ m/s enters a region through a slit and travels perpendicular to a uniform magnetic field (pointing out of the page) as shown in the figure. If the particle hits the bottom wall a distance d from the slit at $t = 3.14$ s, what is d (in m)?



(1) 8 (2) 2 (3) 4 (4) 1 (5) 3

22. A moveable (massless and frictionless) conducting rod with a length of $L = 0.5$ meters is being moved at a constant speed along two conducting rails by a constant external force, as shown in the figure. The entire system is immersed in a uniform constant 3 T magnetic field (out of the paper). If the resistance $R = 4\Omega$ and the power dissipated in the resistor is 16 Watts, what is the magnitude of the external force F_{ext} (in N)?

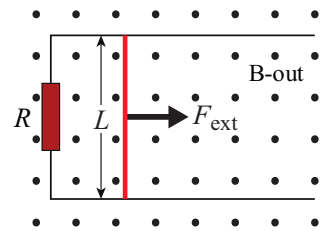


(1) 3 (2) 6 (3) 12 (4) 9 (5) 15

23. What is the induced emf in the previous problem (in Volts)?

(1) 8 (2) 16 (3) 32 (4) 4 (5) 24

24. A moveable (massless and frictionless) conducting rod with a length of $L = 0.5$ meters is being moved at a constant speed along two conducting rails by a constant external force, as shown in the figure. The entire system is immersed in a uniform constant 3 T magnetic field (out of the paper). If the resistance $R = 4\Omega$ and the power dissipated in the resistor is 64 Watts, what is the magnitude of the external force F_{ext} (in N)?

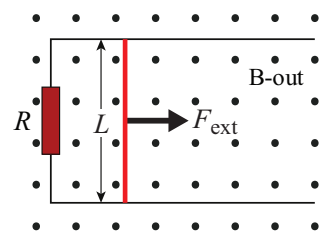


(1) 6 (2) 3 (3) 12 (4) 9 (5) 15

25. What is the induced emf in the previous problem (in Volts)?

(1) 16 (2) 8 (3) 32 (4) 4 (5) 24

26. A moveable (massless and frictionless) conducting rod with a length of $L = 0.5$ meters is being moved at a constant speed along two conducting rails by a constant external force, as shown in the figure. The entire system is immersed in a uniform constant 3 T magnetic field (out of the paper). If the resistance $R = 4\Omega$ and the power dissipated in the resistor is 256 Watts, what is the magnitude of the external force F_{ext} (in N)?

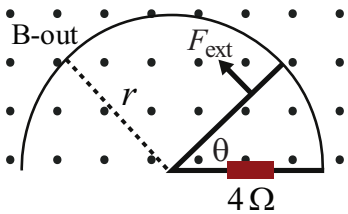


(1) 12 (2) 3 (3) 6 (4) 9 (5) 15

27. What is the induced emf in the previous problem (in Volts)?

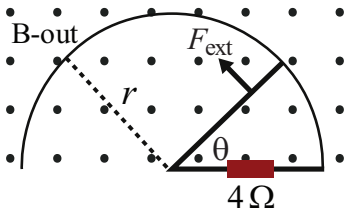
(1) 32 (2) 8 (3) 16 (4) 4 (5) 24

28. A massless and frictionless conducting rod is being rotated about one end at a constant angular speed ω along a semicircular conducting rail with radius $r = 0.5$ m by a constant external force F_{ext} that is perpendicular to the rod. The fixed end of the rotating rod is connected to the semicircular conducting rail through a 4Ω resistor forming a pie shaped circuit, as shown in the figure. The entire system is immersed in a uniform constant 2T magnetic field (out of the paper). If $\omega = 8$ rad/s, what is the induced current in the resistor (in A)?



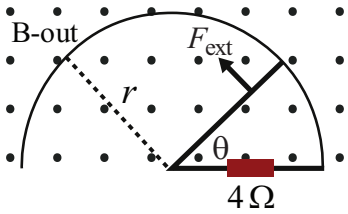
(1) 0.50 (2) 0.75 (3) 1.0 (4) 1.5 (5) 2.0

29. A massless and frictionless conducting rod is being rotated about one end at a constant angular speed ω along a semicircular conducting rail with radius $r = 0.5$ m by a constant external force F_{ext} that is perpendicular to the rod. The fixed end of the rotating rod is connected to the semicircular conducting rail through a 4Ω resistor forming a pie shaped circuit, as shown in the figure. The entire system is immersed in a uniform constant 2T magnetic field (out of the paper). If $\omega = 12$ rad/s, what is the induced current in the resistor (in A)?



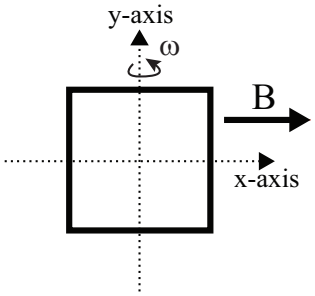
(1) 0.75 (2) 0.50 (3) 1.0 (4) 1.5 (5) 2.0

30. A massless and frictionless conducting rod is being rotated about one end at a constant angular speed ω along a semicircular conducting rail with radius $r = 0.5$ m by a constant external force F_{ext} that is perpendicular to the rod. The fixed end of the rotating rod is connected to the semicircular conducting rail through a 4Ω resistor forming a pie shaped circuit, as shown in the figure. The entire system is immersed in a uniform constant 2T magnetic field (out of the paper). If $\omega = 16$ rad/s, what is the induced current in the resistor (in A)?



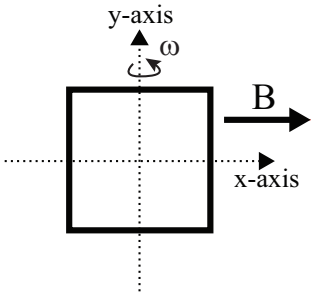
(1) 1.0 (2) 0.50 (3) 0.75 (4) 1.5 (5) 2.0

31. A square wire loop with area $A = 4.0$ m^2 rotates about the vertical y-axis at 3,600 rev/min in a uniform magnetic field that points in the x-direction, as shown in the figure. If the magnitude of the magnetic field B = 20 mT, what is the maximum emf induced in the loop (in V)?



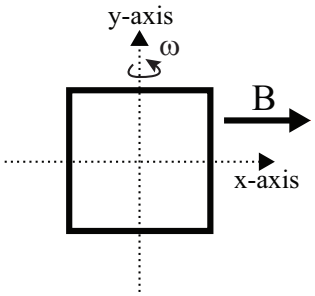
(1) 30.2
(2) 45.2
(3) 60.3
(4) 21.6
(5) 85.2

32. A square wire loop with area $A = 4.0$ m^2 rotates about the vertical y-axis at 3,600 rev/min in a uniform magnetic field that points in the x-direction, as shown in the figure. If the magnitude of the magnetic field B = 30 mT, what is the maximum emf induced in the loop (in V)?



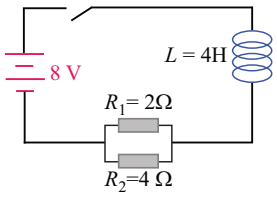
(1) 45.2
(2) 30.2
(3) 60.3
(4) 21.6
(5) 85.2

33. A square wire loop with area $A = 4.0$ m^2 rotates about the vertical y-axis at 3,600 rev/min in a uniform magnetic field that points in the x-direction, as shown in the figure. If the magnitude of the magnetic field B = 40 mT, what is the maximum emf induced in the loop (in V)?



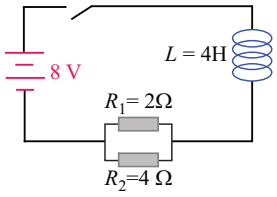
(1) 60.3
(2) 30.2
(3) 45.2
(4) 21.6
(5) 85.2

34. Consider the LR circuit shown in the figure which consists of an 8 Volt emf, an inductor, $L = 4$ H, and two resistors. After the switch is closed, what is the stored energy in the inductor (in J) at the instant the current through the 2 Ω resistor is equal to 1 A?



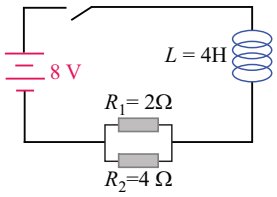
(1) 4.5 (2) 18.0 (3) 40.5 (4) 72.0 (5) 2.0

35. Consider the LR circuit shown in the figure which consists of an 8 Volt emf, an inductor, $L = 4$ H, and two resistors. After the switch is closed, what is the stored energy in the inductor (in J) at the instant the current through the 2 Ω resistor is equal to 2 A?



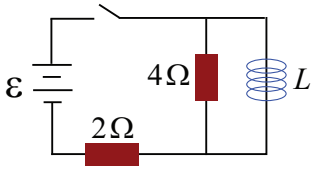
(1) 18.0 (2) 4.5 (3) 40.5 (4) 72.0 (5) 2.0

36. Consider the LR circuit shown in the figure which consists of an 8 Volt emf, an inductor, $L = 4$ H, and two resistors. After the switch is closed, what is the stored energy in the inductor (in J) at the instant the current through the 2 Ω resistor is equal to 3 A?



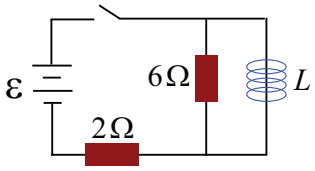
(1) 40.5 (2) 4.5 (3) 18.0 (4) 72.0 (5) 2.0

37. Consider the LR circuit shown in the figure. Initially the inductor has no magnetic stored energy and the switch is closed at $t = 0$. Immediately after the switch is closed the current through the 2Ω resistor is I_{short} and a long time after the switch is closed (*i.e.,* steady state) the current is I_{long}. What is the ratio $I_{\text{long}}/I_{\text{short}}$?



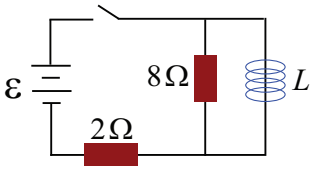
(1) 3 (2) 4 (3) 5 (4) 1/3 (5) 1/4

38. Consider the LR circuit shown in the figure. Initially the inductor has no magnetic stored energy and the switch is closed at $t = 0$. Immediately after the switch is closed the current through the 2Ω resistor is I_{short} and a long time after the switch is closed (*i.e.,* steady state) the current is I_{long}. What is the ratio $I_{\text{long}}/I_{\text{short}}$?



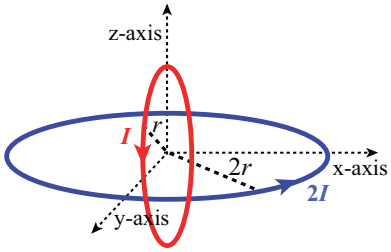
(1) 4 (2) 3 (3) 5 (4) 1/3 (5) 1/4

39. Consider the LR circuit shown in the figure. Initially the inductor has no magnetic stored energy and the switch is closed at $t = 0$. Immediately after the switch is closed the current through the 2Ω resistor is I_{short} and a long time after the switch is closed (*i.e.,* steady state) the current is I_{long}. What is the ratio $I_{\text{long}}/I_{\text{short}}$?



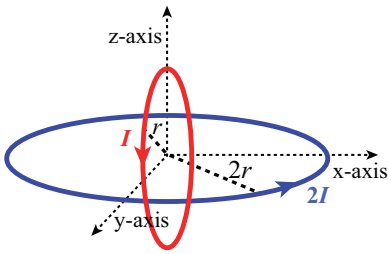
(1) 5 (2) 3 (3) 4 (4) 1/3 (5) 1/5

40. Consider the two circular current loops with centers at the origin (x = y = z = 0) shown in the figure. The smaller loop has radius r, carries current I, and lies in the yz-plane. The larger loop has radius $2r$, carries a current $2I$, and lies in the xy-plane. If $r = 0.5$ m and $I = 1$ A, what is the magnitude of the net magnetic field (in μT) at the origin due to the two current loops?



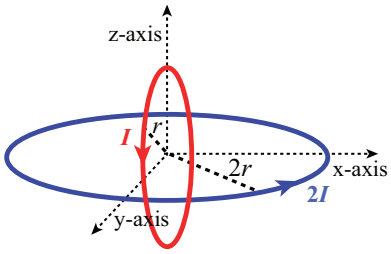
(1) 1.78 (2) 3.55 (3) 5.33 (4) 2.51 (5) zero

41. Consider the two circular current loops with centers at the origin (x = y = z = 0) shown in the figure. The smaller loop has radius r, carries current I, and lies in the yz-plane. The larger loop has radius $2r$, carries a current $2I$, and lies in the xy-plane. If $r = 0.5$ m and $I = 2$ A, what is the magnitude of the net magnetic field (in μT) at the origin due to the two current loops?



(1) 3.55 (2) 1.78 (3) 5.33 (4) 5.03 (5) zero

42. Consider the two circular current loops with centers at the origin (x = y = z = 0) shown in the figure. The smaller loop has radius r, carries current I, and lies in the yz-plane. The larger loop has radius $2r$, carries a current $2I$, and lies in the xy-plane. If $r = 0.5$ m and $I = 3$ A, what is the magnitude of the net magnetic field (in μT) at the origin due to the two current loops?



(1) 5.33 (2) 1.78 (3) 3.55 (4) 7.54 (5) zero

43. What electric field strength (in kV/m) has the same energy density (in J/m^3) as does a 4μT magnetic field?

(1) 1.2 (2) 1.5 (3) 1.8 (4) 1.0 (5) 2.0

44. What electric field strength (in kV/m) has the same energy density (in J/m^3) as does a 5μT magnetic field?

(1) 1.5 (2) 1.2 (3) 1.8 (4) 1.0 (5) 2.0

45. What electric field strength (in kV/m) has the same energy density (in J/m^3) as does a 6μT magnetic field?

(1) 1.8 (2) 1.2 (3) 1.5 (4) 1.0 (5) 2.0

46. A 60 W lightbulb is designed to be connected to an AC voltage of 120 V (rms). What is the resistance (in Ω) of the lightbulb filament at normal operating conditions?

(1) 240 (2) 180 (3) 144 (4) 120 (5) 90

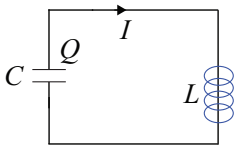
47. A 80 W lightbulb is designed to be connected to an AC voltage of 120 V (rms). What is the resistance (in Ω) of the lightbulb filament at normal operating conditions?

(1) 180 (2) 240 (3) 144 (4) 120 (5) 90

48. A 100 W lightbulb is designed to be connected to an AC voltage of 120 V (rms). What is the resistance (in Ω) of the lightbulb filament at normal operating conditions?

(1) 144 (2) 240 (3) 180 (4) 120 (5) 90

49. Consider an oscillating LC circuit consisting of a capacitor with $C = 1$ mF, no resistance, and an unknown inductor L as shown in the figure. At a certain moment of time the charge on the capacitor is 4 mC and the current is 2 A. If the maximum charge on the capacitor during the oscillations is 6 mC, what is the inductance (in mH) of the unknown inductor L?

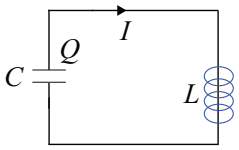


(1) 5 (2) 12 (3) 32 (4) 28 (5) 40

50. In the previous problem, how much magnetic energy (in mJ) is in the inductor when the electric energy in the capacitor is 6 mJ?

(1) 12 (2) 24 (3) 54 (4) 6 (5) 8

51. Consider an oscillating LC circuit consisting of a capacitor with $C = 1$ mF, no resistance, and an unknown inductor L as shown in the figure. At a certain moment of time the charge on the capacitor is 4 mC and the current is 2 A. If the maximum charge on the capacitor during the oscillations is 8 mC, what is the inductance (in mH) of the unknown inductor L?

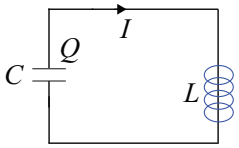


(1) 12 (2) 5 (3) 32 (4) 28 (5) 40

52. In the previous problem, how much magnetic energy (in mJ) is in the inductor when the electric energy in the capacitor is 8 mJ?

(1) 24 (2) 12 (3) 54 (4) 6 (5) 8

53. Consider an oscillating LC circuit consisting of a capacitor with $C = 1$ mF, no resistance, and an unknown inductor L as shown in the figure. At a certain moment of time the charge on the capacitor is 4 mC and the current is 2 A. If the maximum charge on the capacitor during the oscillations is 12 mC, what is the inductance (in mH) of the unknown inductor L?

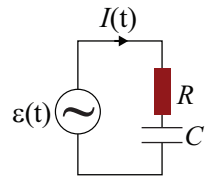


(1) 32 (2) 5 (3) 12 (4) 28 (5) 40

54. In the previous problem, how much magnetic energy (in mJ) is in the inductor when the electric energy in the capacitor is 18 mJ?

(1) 54 (2) 12 (3) 24 (4) 6 (5) 8

55. Consider a resistor R and a capacitor C connected with an emf with oscillating voltage given by $\epsilon(t) = \epsilon_{\max} \sin(\omega t + \phi)$ as shown in the figure. If $R = 2\Omega$, $C = 0.01$ F, $\epsilon_{\max} = 8$ V, and $\omega = 28.868$ rad/s, what is the maximum current in the circuit (in A)?

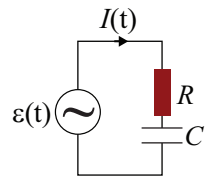


(1) 2 (2) 3 (3) 4 (4) 6 (5) 8

56. What is the average power dissipated in the resistor (in W) in the previous problem?

(1) 4 (2) 9 (3) 16 (4) 8 (5) 18

57. Consider a resistor R and a capacitor C connected with an emf with oscillating voltage given by $\epsilon(t) = \epsilon_{\max} \sin(\omega t + \phi)$ as shown in the figure. If $R = 2\Omega$, $C = 0.01$ F, $\epsilon_{\max} = 12$ V, and $\omega = 28.868$ rad/s, what is the maximum current in the circuit (in A)?

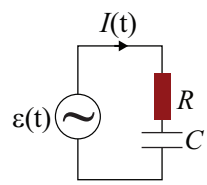


(1) 3 (2) 2 (3) 4 (4) 6 (5) 8

58. What is the average power dissipated in the resistor (in W) in the previous problem?

(1) 9 (2) 4 (3) 16 (4) 8 (5) 18

59. Consider a resistor R and a capacitor C connected with an emf with oscillating voltage given by $\epsilon(t) = \epsilon_{\max} \sin(\omega t + \phi)$ as shown in the figure. If $R = 2\Omega$, $C = 0.01$ F, $\epsilon_{\max} = 16$ V, and $\omega = 28.868$ rad/s, what is the maximum current in the circuit (in A)?



(1) 4 (2) 2 (3) 3 (4) 6 (5) 8

60. What is the average power dissipated in the resistor (in W) in the previous problem?

(1) 16 (2) 4 (3) 9 (4) 8 (5) 32

THE FOLLOWING QUESTIONS, NUMBERED IN THE ORDER OF THEIR APPEARANCE ON THE ABOVE LIST, HAVE BEEN FLAGGED AS CONTINUATION QUESTIONS: 8 10 12 14 16 18 23 25 27 50 52 54 56 58 60 FOLLOWING GROUPS OF QUESTIONS WILL BE SELECTED AS ONE GROUP FROM EACH TYPE

TYPE 1
Q# S 1
Q# S 2
Q# S 3
TYPE 2
Q# S 4
Q# S 5
Q# S 6

TYPE 3
Q# S 7 8
Q# S 9 10
Q# S 11 12
TYPE 4
Q# S 13 14
Q# S 15 16
Q# S 17 18
TYPE 5
Q# S 19
Q# S 20
Q# S 21
TYPE 6
Q# S 22 23
Q# S 24 25
Q# S 26 27
TYPE 7
Q# S 28
Q# S 29
Q# S 30
TYPE 8
Q# S 31
Q# S 32
Q# S 33
TYPE 9
Q# S 34
Q# S 35
Q# S 36
TYPE 10
Q# S 37
Q# S 38
Q# S 39
TYPE 11
Q# S 40
Q# S 41
Q# S 42
TYPE 12
Q# S 43
Q# S 44
Q# S 45
TYPE 13
Q# S 46
Q# S 47
Q# S 48
TYPE 14
Q# S 49 50
Q# S 51 52
Q# S 53 54
TYPE 15
Q# S 55 56
Q# S 57 58
Q# S 59 60