Instructor: *Profs. Field, Korytov*

PHYSICS DEPARTMENT

PHY 2054 Final Exam December 12, 2015

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 blue or black 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

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

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 $\vec{b}$)

Electrostatic Force and Electric Field

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

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

Electric Field (at q_2 due to q_1): $\vec{E} = \vec{F}/q_2 = k\dfrac{q_1}{r^2}\hat{r}$ (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 (net flux through closed surface **S**)**:** $\Phi_E = \oint_S \vec{E}\cdot d\vec{A} = \dfrac{Q_{enclosed}}{\varepsilon_0}$ ($Q_{enclosed}$ = 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)**:** $V(r) = k\dfrac{q}{r}$ N point charges: $V(r) = \sum_{i=1}^{N} k\dfrac{q_i}{r_i}$

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)

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)**:** $I = \dfrac{dQ}{dt} = \vec{J}\cdot\vec{A} = nq\vec{v}_{drift}\cdot\vec{A}$ (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).

Conducting Wire (length L, cross sectional area A)**:** $J = \sigma E$, $I = \sigma EA = EA/\rho$, $|\Delta V| = EL$

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

Resistivity (at temperature T in °C)**:** $\rho(T) = \rho_0(1+\alpha\Delta T)$, where $\Delta T = T - T_0$

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:** $\left|\vec{a}\times\vec{b}\right| = |\vec{a}||\vec{b}|\sin\theta_{ab}$

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

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

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

Electric Field (due to Q): $\vec{E} = k\dfrac{Q}{r^2}\hat{r}$ (units = N/C = V/m)

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

Magnetic Field (due to current I): $\vec{B} = k_B\dfrac{I}{r^2}\vec{l}\times\hat{r}$ (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/m^3)

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

Magnetic Dipole Moment (N loops, current I, area A): $\vec{\mu}_B = NI\vec{A}$ (units = A·m^2) $\vec{A} = A\hat{n}$

Magnetic Torque on a Magnetic Dipole: $\vec{\tau} = \vec{\mu}_B \times \vec{B}$ (units = N·m)

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

Magnetic Field (Examples)

Infinite Straight Wire Carrying Current I: $\left|\vec{B}\right| = 2k_B I / r_{perp}$ (units = T)

Center of a Circular Loop Carrying Current I: $\left|\vec{B}\right| = 2\pi k_B I / R$ (units = T)

Infinite Solenoid (current I, n loops per unit length): $\left|\vec{B}\right| = \mu_0 n I$ (units = T)

Electromagnetic Induction, RL Circuits, and LC Circuits

Magnetic Flux (uniform B, surface A): $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta = B_{perp}A$ units = Tm^2 = Wb

Faraday's Law of Induction: $\varepsilon = -\dfrac{\Delta\Phi_B}{\Delta t}$ (ε = induced EMF, units = V)

Inductor (inductance L units = H): $\Delta V_L = -L\dfrac{\Delta I}{\Delta t}$ (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): $Q(t) = Q_0\sin(\omega t + \varphi)$ $I(t) = I_0\cos(\omega t + \varphi)$

Oscillating LC Circuit (no resistance): **$f = \omega/2\pi$** (frequency of oscillations in Hz)

PHY2054 Final Exam Formula Sheet

Ampere's Law (complete)

Rick's Lectures: $\oint_{\substack{Closed\\Curve}} \vec{B}\cdot d\vec{l} = \mu_0 I_{enclosed} + \mu_0\varepsilon_0 \frac{d\Phi_E}{dt}$ **Textbook:** $\sum_{\substack{Closed\\Curve}} B_{\parallel}\Delta l = \mu_0 I_{enclosed} + \mu_0\varepsilon_0 \frac{\Delta\Phi_E}{\Delta t}$

Electromagnetic Plane Wave

$\vec{E}(x,t) = E_{\max}\sin(kx-\omega t)\hat{y}$

$\vec{B}(x,t) = B_{\max}\sin(kx-\omega t)\hat{z}$

$E(x,t) = cB(x,t)$

Wavelength (in m): λ
Wavenumber (in m^{-1}): $\mathbf{k = 2\pi/\lambda}$
Angular Frequence (in rad/s): $\boldsymbol{\omega = 2\pi f}$
Frequency (in Hz): **f**
Period (in s): **T = 1/f**

Speed in Vacuum: $c = \frac{\omega}{k} = f\lambda = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$ **Speed in Medium (n = index of refraction):** $v_n = \frac{c}{n} < c$

Wavelength in Medium: $\lambda_n = \frac{\lambda_0}{n}$ (λ_0 = **Wavelength in Vacuum, n = index of refraction)**

Poynting Vector: $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$, $|\vec{S}| = S = \frac{1}{\mu_0}EB = \frac{E^2}{\mu_0 c} = \frac{P_{power}}{A}$ (units = W/m^2)

Intensity: $I = \langle S\rangle = \frac{\langle P_{power}\rangle}{A} = \frac{E_{rms}^2}{\mu_0 c} = \frac{cB_{rms}^2}{\mu_0} = \frac{E_0^2}{2\mu_0 c} = \frac{cB_0^2}{2\mu_0}$ (units = W/m^2)

Intensity Transmitted by a Polorizer: $I = \frac{1}{2}I_0$ (random) $I = I_0\cos^2\theta$ (polarized)

Relativistic Doppler Shift

(f_0 = frequency at rest with source, λ_0 = wavelength at rest with source, $f_0\lambda_0 = c$)

Source Moving Away from Observer: $\lambda_{away} = \sqrt{\frac{1+\beta}{1-\beta}}\lambda_0$ $f_{away} = \sqrt{\frac{1-\beta}{1+\beta}}f_0$ $\vec{\beta} = \vec{V}/c$ **(V = relative velocity)**

Source Moving Toward the Observer: $\lambda_{toward} = \sqrt{\frac{1-\beta}{1+\beta}}\lambda_0$ $f_{toward} = \sqrt{\frac{1+\beta}{1-\beta}}f_0$ $\vec{\beta} = \vec{V}/c$ **(V = relative velocity)**

Reflection & Refraction

Snell's Law: $n_1\sin\theta_1 = n_2\sin\theta_2$ **Total Internal Reflection in Medium (1):** $\sin\theta_c = n_2/n_1$ ($n_2 < n_1$)

Brewster's Angle in Medium (1): $\tan\theta_B = n_2/n_1$

Mirrors & Thin Lens

Spherical Mirrors (R = radius of curvature): $|f| = R/2$

Object and Image Position (mirrors & thin lens): $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

Magnification (mirrors & thin lens): $m = -\frac{q}{p}$, $h' = |m|\cdot h$

f = focal length (>0 concave, <0 convex)
p = objrct distance
q = image distance (>0 real, <0 virtual)
h = object height
h' = image height
m = magnification (>0 upright, <0 inverted)

Reflection & Interference

Reflection in Medium 1: (phase shift $n_2 > n_1$) $\Delta\phi = \pi$ (phase shift $n_2 < n_1$) $\Delta\phi = 0$

Maximal Constructive: (phase shift) $\Delta\phi = 2\pi m$ (lateral shift) $\Delta l = m\lambda$ $m = 0,\pm1,\pm2,\cdots$

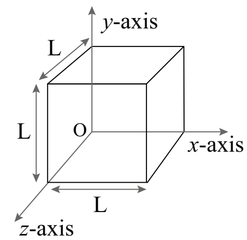
Maximal Destructive: (phase shift) $\Delta\phi = 2\pi(m+\frac{1}{2})$ (lateral shift) $\Delta l = (m+\frac{1}{2})\lambda$ $m = 0,\pm1,\pm2,\cdots$

Intensity: (max constructive) $I = I_1 + I_2 + 2\sqrt{I_1 I_2}$ (max destructive) $I = I_1 + I_2 - 2\sqrt{I_1 I_2}$

Single-Slit Minima: $d\sin\theta = m\lambda$ **Resolving Power (lens diameter D:** $\Delta\theta \approx 1.22\lambda/D$

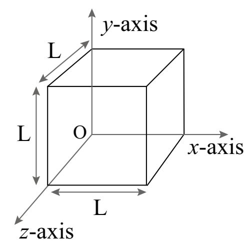
Double-Slit (and grating): (max constructive) $d\sin\theta = m\lambda$ (max destructive) $d\sin\theta = (m+\frac{1}{2})\lambda$

1. Consider a cube of sides $L = 2$ m as shown in the figure and suppose that a non-uniform electric field is present and is given by $\vec{E}(x) = (a - bx)\hat{x}$, where $a = 200$ V and $b = 100$ V/m^2 are constants. What is the net electric charge (in nC) contained within the cube?



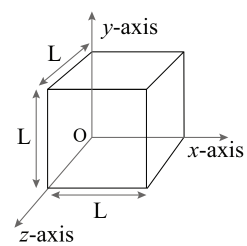
(1) -7.08 (2) -23.90 (3) -56.65 (4) $+7.08$ (5) $+23.90$

2. Consider a cube of sides $L = 3$ m as shown in the figure and suppose that a non-uniform electric field is present and is given by $\vec{E}(x) = (a - bx)\hat{x}$, where $a = 200$ V and $b = 100$ V/m^2 are constants. What is the net electric charge (in nanoC) contained within the cube?



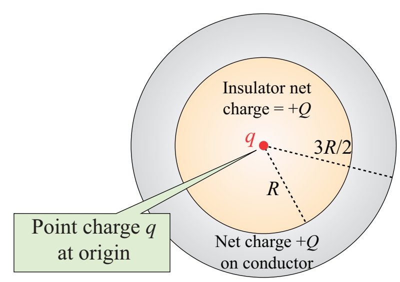
(1) -23.90 (2) -7.08 (3) -56.65 (4) $+7.08$ (5) $+23.90$

3. Consider a cube of sides $L = 4$ m as shown in the figure and suppose that a non-uniform electric field is present and is given by $\vec{E}(x) = (a - bx)\hat{x}$, where $a = 200$ V and $b = 100$ V/m^2 are constants. What is the net electric charge (in nanoC) contained within the cube?



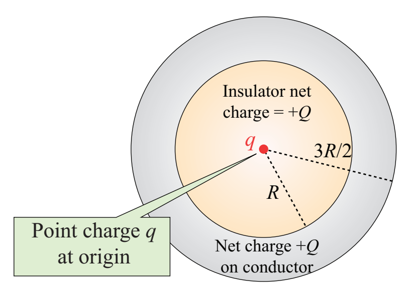
(1) -56.65 (2) -7.08 (3) -23.90 (4) $+7.08$ (5) $+56.65$

4. A solid insulating ball with radius R has a uniform charge density ρ and total charge $+Q$. There is a point charge $q = +2Q$ embedded at the center of the insulator (not part of the insulator). The insulating ball is surrounded by a spherical conducting shell with inner radius R and outer radius $3R/2$ as shown in the figure. The net charge on the conductor is $+Q$. How much charge is located on the outer surface ($r = 3R/2$) of the conductor?



(1) $+4Q$ (2) $+5Q$ (3) $+6Q$ (4) zero (5) $-2Q$

5. A solid insulating ball with radius R has a uniform charge density ρ and total charge $+Q$. There is a point charge $q = +3Q$ embedded at the center of the insulator (not part of the insulator). The insulating ball is surrounded by a spherical conducting shell with inner radius R and outer radius $3R/2$ as shown in the figure. The net charge on the conductor is $+Q$. How much charge is located on the outer surface ($r = 3R/2$) of the conductor?



(1) $+5Q$ (2) $+4Q$ (3) $+6Q$ (4) zero (5) $-2Q$

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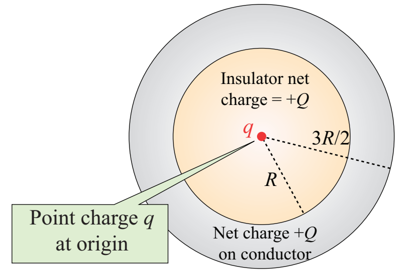
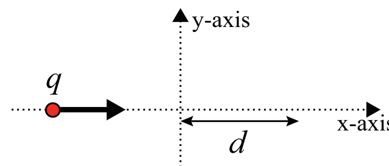
6. A solid insulating ball with radius R has a uniform charge density ρ and total charge $+Q$. There is a point charge $q = +4Q$ embedded at the center of the insulator (not part of the insulator). The insulating ball is surrounded by a spherical conducting shell with inner radius R and outer radius $3R/2$ as shown in the figure. The net charge on the conductor is $+Q$. How much charge is located on the outer surface ($r = 3R/2$) of the conductor?



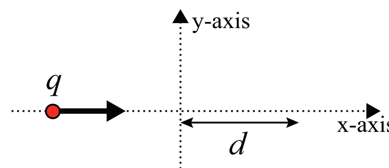
(1) $+6Q$ (2) $+4Q$ (3) $+5Q$ (4) zero (5) $-2Q$

7. A charged particle q traveling to the right along the negative x-axis as shown in the figure has an initial kinetic energy of $80\,\mu$J. At $x = 0$ it experiences a non-uniform electric potential given by $V(x) = bx^3$, where $b = 5$ V/m^3 is a constant and x is measured in meters. If $q = 2\,\mu$C, what is the largest positive x-value (in meters) reached by the particle before it comes to rest?



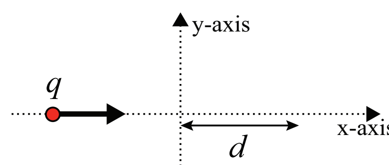
(1) 2 (2) 3 (3) 4 (4) 1 (5) 5

8. A charged particle q traveling to the right along the negative x-axis as shown in the figure has an initial kinetic energy of $270\,\mu$J. At $x = 0$ it experiences a non-uniform electric potential given by $V(x) = bx^3$, where $b = 5$ V/m^3 is a constant and x is measured in meters. If $q = 2\,\mu$C, what is the largest positive x-value (in meters) reached by the particle before it comes to rest?



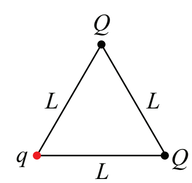
(1) 3 (2) 2 (3) 4 (4) 1 (5) 5

9. A charged particle q traveling to the right along the negative x-axis as shown in the figure has an initial kinetic energy of $640\,\mu$J. At $x = 0$ it experiences a non-uniform electric potential given by $V(x) = bx^3$, where $b = 5$ V/m^3 is a constant and x is measured in meters. If $q = 2\,\mu$C, what is the largest positive x-value (in meters) reached by the particle before it comes to rest?



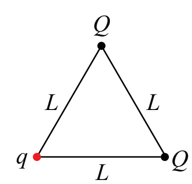
(1) 4 (2) 2 (3) 3 (4) 1 (5) 5

10. Three point charges $Q_1 = q$, $Q_2 = Q$, and $Q_3 = Q$ are fixed at the vertices of an equilateral triangle with sides of length L as shown in the figure. If $q = 2Q$, how much work is required to move charge q to the mid-point of the straight line between Q_2 and Q_3? Note $k = 1/(4\pi\epsilon_0)$.



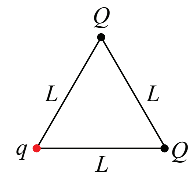
(1) $4kQ^2/L$ (2) $6kQ^2/L$ (3) $8kQ^2/L$ (4) $2kQ^2/L$ (5) $10kQ^2/L$

11. Three point charges $Q_1 = q$, $Q_2 = Q$, and $Q_3 = Q$ are fixed at the vertices of an equilateral triangle with sides of length L as shown in the figure. If $q = 3Q$, how much work is required to move charge q to the mid-point of the straight line between Q_2 and Q_3? Note $k = 1/(4\pi\epsilon_0)$.



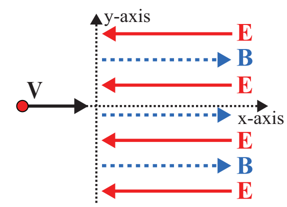
(1) $6kQ^2/L$ (2) $4kQ^2/L$ (3) $8kQ^2/L$ (4) $2kQ^2/L$ (5) $10kQ^2/L$

12. Three point charges $Q_1 = q$, $Q_2 = Q$, and $Q_3 = Q$ are fixed at the vertices of an equilateral triangle with sides of length L as shown in the figure. If $q = 4Q$, how much work is required to move charge q to the mid-point of the straight line between Q_2 and Q_3? Note $k = 1/(4\pi\epsilon_0)$.



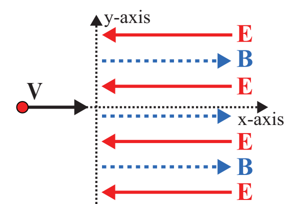
(1) $8kQ^2/L$ (2) $4kQ^2/L$ (3) $6kQ^2/L$ (4) $2kQ^2/L$ (5) $10kQ^2/L$

13. A positively charged particle with a charge to mass ratio $q/m = 1$ C/kg is traveling to the right along the x-axis with speed V = 2 m/s. At $t = 0$ and $x = 0$ it encounters uniform anti-parallel electric and magnetic fields. The magnetic field points in the positive x-direction and the electric field points in the negative x-direction, as shown in the figure. If the magnitudes of the E and B fields are 1.0 V/m and 0.2 T, respectively, what is the particle's speed (in m/s) at $t = 2$ s?



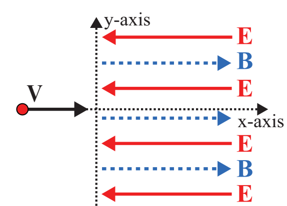
(1) 0 (2) 1 (3) 2 (4) 3 (5) 4

14. A positively charged particle with a charge to mass ratio $q/m = 1$ C/kg is traveling to the right along the x-axis with speed V = 3 m/s. At $t = 0$ and $x = 0$ it encounters uniform anti-parallel electric and magnetic fields. The magnetic field points in the positive x-direction and the electric field points in the negative x-direction, as shown in the figure. If the magnitudes of the E and B fields are 1.0 V/m and 0.2 T, respectively, what is the particle's speed (in m/s) at $t = 2$ s?



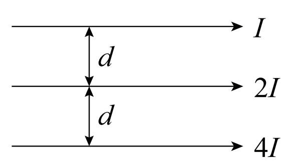
(1) 1 (2) 0 (3) 2 (4) 3 (5) 4

15. A positively charged particle with a charge to mass ratio $q/m = 1$ C/kg is traveling to the right along the x-axis with speed V = 4 m/s. At $t = 0$ and $x = 0$ it encounters uniform anti-parallel electric and magnetic fields. The magnetic field points in the positive x-direction and the electric field points in the negative x-direction, as shown in the figure. If the magnitudes of the E and B fields are 1.0 V/m and 0.2 T, respectively, what is the particle's speed (in m/s) at $t = 2$ s?



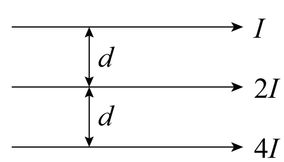
(1) 2 (2) 0 (3) 1 (4) 3 (5) 4

16. Three infinitely long straight wires lie in a plane and carry current in the same direction as shown in the figure. The top wire carries current I and is a distance d from the center wire which carries current $2I$. The bottom wire carries current $4I$ and is a distance d from the center wire. What is the magnitude of the net force on a length $L = d/4$ of the center wire due to the other two wires? (Note that $k_B = \mu_0/4\pi$)



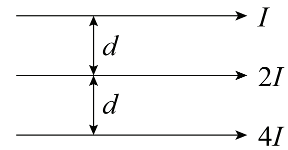
(1) $3k_BI^2$ (2) $6k_BI^2$ (3) $9k_BI^2$ (4) $2k_BI^2$ (5) $4k_BI^2$

17. Three infinitely long straight wires lie in a plane and carry current in the same direction as shown in the figure. The top wire carries current I and is a distance d from the center wire which carries current $2I$. The bottom wire carries current $4I$ and is a distance d from the center wire. What is the magnitude of the net force on a length $L = d/2$ of the center wire due to the other two wires? (Note that $k_B = \mu_0/4\pi$)



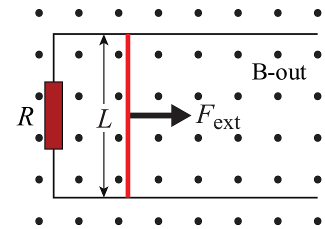
(1) $6k_BI^2$ (2) $3k_BI^2$ (3) $9k_BI^2$ (4) $2k_BI^2$ (5) $4k_BI^2$

18. Three infinitely long straight wires lie in a plane and carry current in the same direction as shown in the figure. The top wire carries current I and is a distance d from the center wire which carries current $2I$. The bottom wire carries current $4I$ and is a distance d from the center wire. What is the magnitude of the net force on a length $L = 3d/4$ of the center wire due to the other two wires? (Note that $k_B = \mu_0/4\pi$)



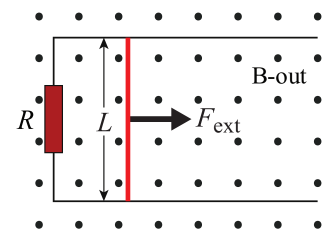
(1) $9k_BI^2$ (2) $3k_BI^2$ (3) $6k_BI^2$ (4) $2k_BI^2$ (5) $4k_BI^2$

19. A moveable (massless and frictionless) 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 $F_{\text{ext}} = 3$ N, as shown in the figure. The entire system is immersed in a uniform constant magnetic field (z-axis out of the paper). If the induced current in the resistor R is 2 A, what is the magnitude of the magnetic field B (in T)?



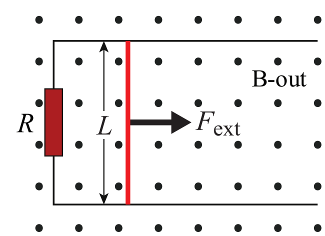
(1) 3 (2) 2 (3) 1 (4) 4 (5) 5

20. A moveable (massless and frictionless) 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 $F_{\text{ext}} = 3$ N, as shown in the figure. The entire system is immersed in a uniform constant magnetic field (z-axis out of the paper). If the induced current in the resistor R is 3 A, what is the magnitude of the magnetic field B (in T)?



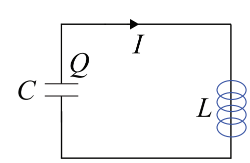
(1) 2 (2) 3 (3) 1 (4) 4 (5) 5

21. A moveable (massless and frictionless) 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 $F_{\text{ext}} = 3$ N, as shown in the figure. The entire system is immersed in a uniform constant magnetic field (z-axis out of the paper). If the induced current in the resistor R is 6 A, what is the magnitude of the magnetic field B (in T)?



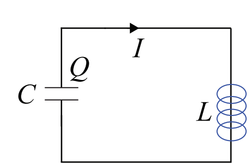
(1) 1 (2) 3 (3) 2 (4) 4 (5) 5

22. 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 through the inductor 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?



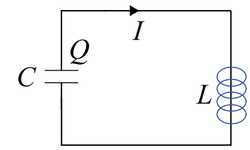
(1) 5 (2) 12 (3) 32 (4) 28 (5) 40

23. 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 through the inductor 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

24. 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 through the inductor 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

25. Two light bulbs have the following ratings: 40W, 120V and 60W, 120V. If the two lights are connected in series with a 120V EMF, what is the total power dissipated by the lights?

(1) 24 (2) 30 (3) 36 (4) 100 (5) 135

26. Two light bulbs have the following ratings: 45W, 120V and 90W, 120V. If the two lights are connected in series with a 120V EMF, what is the total power dissipated by the lights?

(1) 30 (2) 24 (3) 36 (4) 100 (5) 135

27. Two light bulbs have the following ratings: 60W, 120V and 90W, 120V. If the two lights are connected in series with a 120V EMF, what is the total power dissipated by the lights?

(1) 36 (2) 24 (3) 30 (4) 100 (5) 150

28. Initially two isolated capacitors with capacitance C_1 and C_2 both carry charge Q. The two capacitors are then connected together in parallel (*i.e.,* the positive plate of C_1 connected to the positive plate of C_2 and the negative plate of C_1 connected to the negative plate of C_2). If $C_2 = 2C_1$, what is the charge on capacitor C_2 after they come to equilibrium?

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

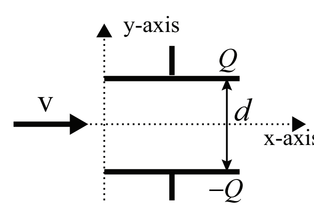
29. Initially two isolated capacitors with capacitance C_1 and C_2 both carry charge Q. The two capacitors are then connected together in parallel (*i.e.,* the positive plate of C_1 connected to the positive plate of C_2 and the negative plate of C_1 connected to the negative plate of C_2). If $C_2 = 3C_1$, what is the charge on capacitor C_2 after they come to equilibrium?

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

30. Initially two isolated capacitors with capacitance C_1 and C_2 both carry charge Q. The two capacitors are then connected together in parallel (*i.e.,* the positive plate of C_1 connected to the positive plate of C_2 and the negative plate of C_1 connected to the negative plate of C_2). If $C_2 = C_1/2$, what is the charge on capacitor C_2 after they come to equilibrium?

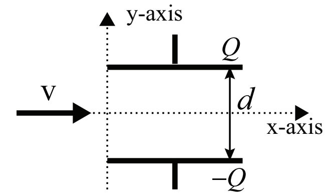
(1) $2Q/3$ (2) $4Q/3$ (3) $3Q/2$ (4) Q (5) $2Q$

31. A point particle with charge $Q = 1$ mC and mass $M = 2$ grams enters along the center of a parallel plate capacitor (x-axis) with a speed of 10 m/s as shown in the figure. The plates of the capacitor are separated by a distance d with one plate at $y = +d/2$ and the other at $y = -d/2$. If $d = 2$ cm and if the charged particle hits the bottom plate of the capacitor after traveling a horizontal distance of 0.4 cm inside the capacitor, what is the electric potential difference across the capacitor (in V)?



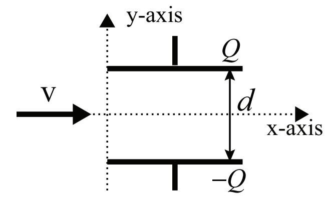
(1) 5,000 (2) 3,200 (3) 1,250 (4) 2,500 (5) 1,600

32. A point particle with charge $Q = 1$ mC and mass $M = 2$ grams enters along the center of a parallel plate capacitor (x-axis) with a speed of 10 m/s as shown in the figure. The plates of the capacitor are separated by a distance d with one plate at $y = +d/2$ and the other at $y = -d/2$. If $d = 2$ cm and if the charged particle hits the bottom plate of the capacitor after traveling a horizontal distance of 0.5 cm inside the capacitor, what is the electric potential difference across the capacitor (in V)?



(1) 3,200 (2) 5,000 (3) 1,250 (4) 2,500 (5) 1,600

33. A point particle with charge $Q = 1$ mC and mass $M = 2$ grams enters along the center of a parallel plate capacitor (x-axis) with a speed of 10 m/s as shown in the figure. The plates of the capacitor are separated by a distance d with one plate at $y = +d/2$ and the other at $y = -d/2$. If $d = 2$ cm and if the charged particle hits the bottom plate of the capacitor after traveling a horizontal distance of 0.8 cm inside the capacitor, what is the electric potential difference across the capacitor (in V)?



(1) 1,250 (2) 5,000 (3) 3,200 (4) 2,500 (5) 1,600

34. A current of 0.75 A flows through a copper wire 0.40 mm in diameter when it is connected to a potential difference of 15 V. If the resistivity of copper is $1.7 \times 10^{-8} \Omega \cdot \mathrm{m}$, how long is the wire (in m)?

(1) 147.8 (2) 231.0 (3) 332.6 (4) 591.4 (5) 924.0

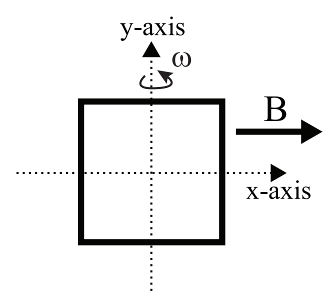
35. A current of 0.75 A flows through a copper wire 0.50 mm in diameter when it is connected to a potential difference of 15 V. If the resistivity of copper is $1.7 \times 10^{-8} \Omega \cdot \mathrm{m}$, how long is the wire (in m)?

(1) 231.0 (2) 147.8 (3) 332.6 (4) 591.4 (5) 924.0

36. A current of 0.75 A flows through a copper wire 0.60 mm in diameter when it is connected to a potential difference of 15 V. If the resistivity of copper is $1.7 \times 10^{-8} \Omega \cdot \mathrm{m}$, how long is the wire (in m)?

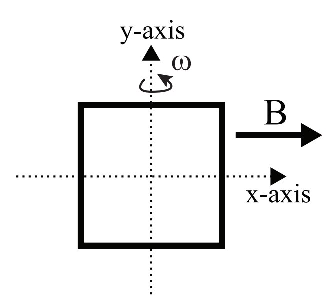
(1) 332.6 (2) 147.8 (3) 231.0 (4) 591.4 (5) 1330.6

37. 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 maximum emf induced in the loop is 50 V, what is the magnitude of the magnetic field (in mT)?



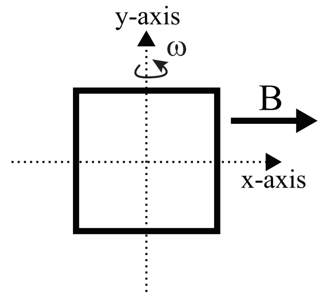
(1) 33.2
(2) 49.7
(3) 66.3
(4) 21.6
(5) 85.2

38. 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 maximum emf induced in the loop is 75 V, what is the magnitude of the magnetic field (in mT)?



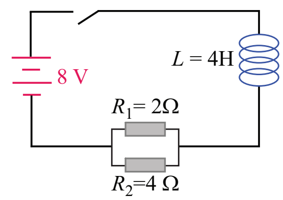
(1) 49.7
(2) 33.2
(3) 66.3
(4) 21.6
(5) 85.2

39. A square wire loop with area $A = 4.0\ \mathrm{m}^2$ 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 maximum emf induced in the loop is 100 V, what is the magnitude of the magnetic field (in mT)?



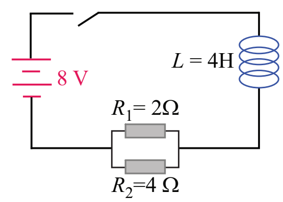
(1) 66.3
(2) 33.2
(3) 49.7
(4) 21.6
(5) 85.2

40. 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 $2\,\Omega$ resistor is equal to 1 A?



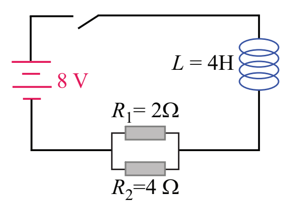
(1) 4.5 (2) 18.0 (3) 40.5 (4) 72.0 (5) 2.0

41. 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 $2\,\Omega$ resistor is equal to 2 A?



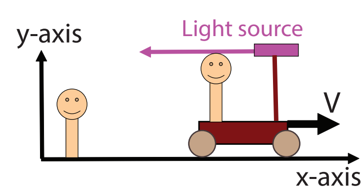
(1) 18.0 (2) 4.5 (3) 40.5 (4) 72.0 (5) 2.0

42. 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 $2\,\Omega$ resistor is equal to 3 A?



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

43. A train is travelling (in a vacuum) along the x-axis at speed V, as shown in the figure. There is a light source at rest on the train that emits light in the negative x-direction. An observer at rest on the train measures the wavelength of the light to be 500 nm and the speed of the light to be c. An observer at rest on the side of the track and sees the train pass him at speed $V = 0.2c$, where c is the speed of light in a vacuum. What is the wavelength of light (in nm) measured by the observer on the side of the track after the train has passed?

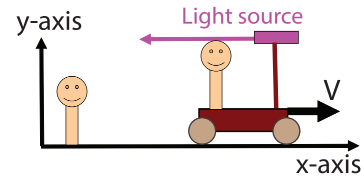


(1) 612.4 (2) 763.8 (3) 1000.0 (4) 408.2 (5) 327.3

44. In the previous problem, what is the speed of light measured by the observer on the side of the track after the train has passed?

(1) c (2) $0.8c$ (3) $0.6c$ (4) $0.4c$ (5) $0.2c$

45. A train is travelling (in a vacuum) along the x-axis at speed V, as shown in the figure. There is a light source at rest on the train that emits light in the negative x-direction. An observer at rest on the train measures the wavelength of the light to be 500 nm and the speed of the light to be c. An observer at rest on the side of the track and sees the train pass him at speed $V = 0.4c$, where c is the speed of light in a vacuum. What is the wavelength of light (in nm) measured by the observer on the side of the track after the train has passed?

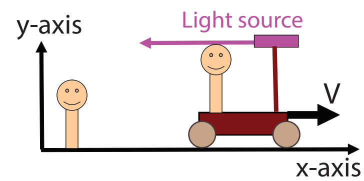


(1) 763.8 (2) 612.4 (3) 1000.0 (4) 408.2 (5) 327.3

46. In the previous problem, what is the speed of light measured by the observer on the side of the track after the train has passed?

(1) c (2) $0.8c$ (3) $0.6c$ (4) $0.4c$ (5) $0.2c$

47. A train is travelling (in a vacuum) along the x-axis at speed V, as shown in the figure. There is a light source at rest on the train that emits light in the negative x-direction. An observer at rest on the train measures the wavelength of the light to be 500 nm and the speed of the light to be c. An observer at rest on the side of the track and sees the train pass him at speed $V = 0.6c$, where c is the speed of light in a vacuum. What is the wavelength of light (in nm) measured by the observer on the side of the track after the train has passed?

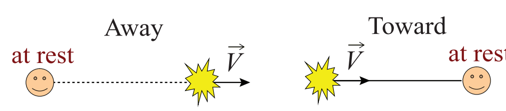


(1) 1000.0 (2) 612.4 (3) 763.8 (4) 408.2 (5) 250.0

48. In the previous problem, what is the speed of light measured by the observer on the side of the track after the train has passed?

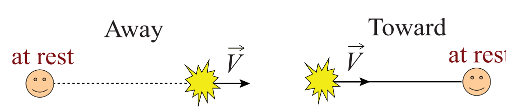
(1) c (2) $0.8c$ (3) $0.6c$ (4) $0.4c$ (5) $0.2c$

49. An observer at rest in the O-frame measures the wavelength of the light from a comet that is travelling at a constant speed V. The observer measures wavelength λ_{toward} when the comet is travelling radially toward him and wavelength λ_{away} when the comet is travelling radially away from him. If $\lambda_{\text{away}} = 2\lambda_{\text{toward}}$, what is the speed V of the comet? (Note that c is the speed of light in a vacuum.)



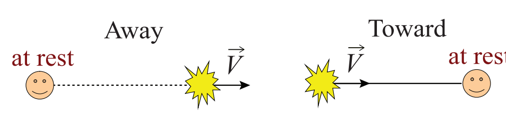
(1) $c/3$ (2) $c/2$ (3) $3c/5$ (4) $c/4$ (5) $3c/4$

50. An observer at rest in the O-frame measures the wavelength of the light from a comet that is travelling at a constant speed V. The observer measures wavelength λ_{toward} when the comet is travelling radially toward him and wavelength λ_{away} when the comet is travelling radially away from him. If $\lambda_{\text{away}} = 3\lambda_{\text{toward}}$, what is the speed V of the comet? (Note that c is the speed of light in a vacuum.)



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

51. An observer at rest in the O-frame measures the wavelength of the light from a comet that is travelling at a constant speed V. The observer measures wavelength λ_{toward} when the comet is travelling radially toward him and wavelength λ_{away} when the comet is travelling radially away from him. If $\lambda_{\text{away}} = 4\lambda_{\text{toward}}$, what is the speed V of the comet? (Note that c is the speed of light in a vacuum.)



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

52. A small underwater pool light is 1.2 m below the surface of a swimming pool. What is the area (in m^2) of the circle of light on the surface, from which light emerges from the water? (Use $n_{\text{water}} = 4/3$ and $n_{\text{air}} = 1$.)

(1) 5.82 (2) 7.92 (3) 10.34 (4) 4.04 (5) 12.56

53. A small underwater pool light is 1.4 m below the surface of a swimming pool. What is the area (in m^2) of the circle of light on the surface, from which light emerges from the water? (Use $n_{\text{water}} = 4/3$ and $n_{\text{air}} = 1$.)

(1) 7.92 (2) 5.82 (3) 10.34 (4) 4.04 (5) 12.56

54. A small underwater pool light is 1.6 m below the surface of a swimming pool. What is the area (in m^2) of the circle of light on the surface, from which light emerges from the water? (Use $n_{\text{water}} = 4/3$ and $n_{\text{air}} = 1$.)

(1) 10.34 (2) 5.82 (3) 7.92 (4) 4.04 (5) 12.56

55. Two light waves travel in air with wavelength 500 nm, and they are initially in phase. Each passes through a block of length L before passing back into the air. One travels through glass with index of refraction $n_1 = 1.7$, and the other passes through ice with index of refraction $n_2 = 1.3$. What is the minimum value of L (in nm) for which the waves will undergo maximum destructive interference?

(1) 625 (2) 700 (3) 750 (4) 480 (5) 820

56. Two light waves travel in air with wavelength 560 nm, and they are initially in phase. Each passes through a block of length L before passing back into the air. One travels through glass with index of refraction $n_1 = 1.7$, and the other passes through ice with index of refraction $n_2 = 1.3$. What is the minimum value of L (in nm) for which the waves will undergo maximum destructive interference?

(1) 700 (2) 625 (3) 750 (4) 480 (5) 820

57. Two light waves travel in air with wavelength 600 nm, and they are initially in phase. Each passes through a block of length L before passing back into the air. One travels through glass with index of refraction $n_1 = 1.7$, and the other passes through ice with index of refraction $n_2 = 1.3$. What is the minimum value of L (in nm) for which the waves will undergo maximum destructive interference?

(1) 750 (2) 625 (3) 700 (4) 480 (5) 820

58. Two identical converging lenses each with a focal length of 1 m are placed 0.5 m apart. What is the overall magnification of the two-lens system for an object placed 0.5 m away from the front lens?

(1) -4 (2) -2 (3) -1 (4) 4 (5) 2

59. Two identical converging lenses each with a focal length of 1 m are placed 1.0 m apart. What is the overall magnification of the two-lens system for an object placed 0.5 m away from the front lens?

(1) -2 (2) -4 (3) -1 (4) 4 (5) 2

60. Two identical converging lenses each with a focal length of 1 m are placed 2 m apart. What is the overall magnification of the two-lens system for an object placed 0.5 m away from the front lens?

(1) -1 (2) -4 (3) -2 (4) 4 (5) 2

THE FOLLOWING QUESTIONS, NUMBERED IN THE ORDER OF THEIR APPEARANCE ON THE ABOVE LIST, HAVE BEEN FLAGGED AS CONTINUATION QUESTIONS: 44 46 48 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
Q# S 8
Q# S 9
TYPE 4
Q# S 10
Q# S 11
Q# S 12
TYPE 5
Q# S 13
Q# S 14
Q# S 15
TYPE 6
Q# S 16
Q# S 17
Q# S 18
TYPE 7
Q# S 19
Q# S 20
Q# S 21
TYPE 8
Q# S 22
Q# S 23
Q# S 24
TYPE 9
Q# S 25
Q# S 26
Q# S 27
TYPE 10
Q# S 28
Q# S 29
Q# S 30
TYPE 11
Q# S 31
Q# S 32
Q# S 33
TYPE 12
Q# S 34
Q# S 35
Q# S 36
TYPE 13
Q# S 37
Q# S 38
Q# S 39
TYPE 14
Q# S 40
Q# S 41
Q# S 42
TYPE 15
Q# S 43 44
Q# S 45 46
Q# S 47 48
TYPE 16
Q# S 49
Q# S 50
Q# S 51
TYPE 17
Q# S 52
Q# S 53
Q# S 54
TYPE 18
Q# S 55
Q# S 56
Q# S 57

TYPE 19
Q# S 58
Q# S 59
Q# S 60