Instructor: *Field/Mitselmakher*

PHYSICS DEPARTMENT

PHY 2054 Final Exam April 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 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 & 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): $\vec{F} = k\dfrac{q_1 q_2}{r^2}\hat{r}$ (r = distance between charge q_1 and charge q_2, units = N)

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

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 = Nm²/C)

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

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

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/m³)

Electric Current and Circuits

Current (through directed area A)**:** $I = \dfrac{dQ}{dt} = nq\vec{v}_{drift}\cdot\vec{A}$ (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)**:** $P = \varepsilon I$ **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)**:** $\tau = RC$ (units = Ω·F = s)

PHY2054 Exam 2 Formula Sheet

Vectors

$\vec{a} = a_x\hat{x} + a_y\hat{y} + a_z\hat{z}$ $\quad \vec{b} = b_x\hat{x} + b_y\hat{y} + b_z\hat{z}$ **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): $\vec{F}_{EM} = \vec{F}_E + \vec{F}_B = q\vec{E} + q\vec{v}\times\vec{B}$ $\quad \vec{F}_E = q\vec{E}$ $\quad \vec{F}_B = q\vec{v}\times\vec{B}$

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

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

$k_B = k/c^2 = \mu_0/(4\pi) \approx 10^{-7}$ Tm/A $\qquad \mu_0 \approx 4\pi \times 10^{-7}$ Tm/A $\qquad c \approx 3 \times 10^8$ 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) $\quad \vec{B} = k_B\dfrac{Q}{r^2}\vec{V}\times\hat{r}$ (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): $u_E = \frac{1}{2}\varepsilon_0 E^2$ $\quad u_B = \frac{1}{2\mu_0}B^2$ (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) $\vec{A} = A\hat{n}$ $\quad$ **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: $\left|\vec{B}\right| = 2k_B I / r_{perp}$ $\qquad$ **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): $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta = B_{perp}A$ $\quad$ 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) $\quad U_L = \frac{1}{2}LI^2$ (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) $\quad \omega = 1/\sqrt{LC}$

Oscillating LC Circuit (no resistance): $\mathbf{f = \omega/2\pi}$ (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: $I_{\max} = \dfrac{\varepsilon_{\max}}{Z}$ $\quad P_{ave} = \frac{1}{2}I_{\max}\varepsilon_{\max}X_R/Z$

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

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): $\mathbf{f}$
Period (in s): $\mathbf{T = 1/f}$

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: $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$, $\left|\vec{S}\right| = S = \frac{1}{\mu_0}EB = \frac{E^2}{\mu_0 c} = \frac{P_{power}}{A}$ (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 off Medium 2: (phase shift $n_2 > n_1$) $\Delta\phi = \pi$ (phase shift $n_2 < n_1$) $\Delta\phi = 0$
(lateral shift $n_2 > n_1$) $\Delta l = \Delta\phi/k = \lambda/2$ (lateral shift $n_2 < n_1$) $\Delta l = 0$

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

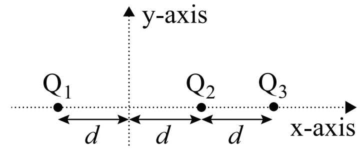
Maximal Destructive: (phase shift) $\Delta\phi = 2\pi(m+\frac{1}{2})$ (lateral shift) $\Delta l = (m+\frac{1}{2})\lambda$ $m = 0,\pm1,\pm2,\cdots$

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:** $\Delta\theta \approx 1.22\lambda/D$

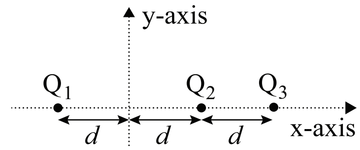
Double-Slit (and grating): (max constructive) $d\sin\theta = m\lambda$ (max destructive) $d\sin\theta = (m+\frac{1}{2})\lambda$

1. Three point particles lie on the x-axis. Charge Q_1 is at $x = -d$, charge Q_2 is at $x = d$, and charge Q_3 is at $x = 2d$, as shown in the figure. If $Q_1 = q$ and $Q_2 = 2q$, and if the net electric field from the three charges is zero at the origin (*i.e.*, $x = y = 0$), what is Q_3?



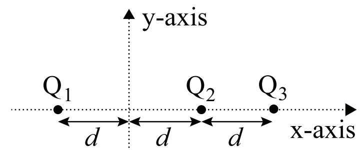
(1) $-4q$ (2) $-8q$ (3) $4q$ (4) $8q$ (5) $-2q$

2. Three point particles lie on the x-axis. Charge Q_1 is at $x = -d$, charge Q_2 is at $x = d$, and charge Q_3 is at $x = 2d$, as shown in the figure. If $Q_1 = q$ and $Q_2 = 3q$, and if the net electric field from the three charges is zero at the origin (*i.e.*, $x = y = 0$), what is Q_3?



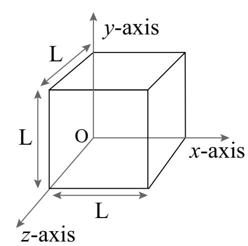
(1) $-8q$ (2) $-4q$ (3) $4q$ (4) $8q$ (5) $-2q$

3. Three point particles lie on the x-axis. Charge Q_1 is at $x = -d$, charge Q_2 is at $x = d$, and charge Q_3 is at $x = 2d$, as shown in the figure. If $Q_1 = 2q$ and $Q_2 = q$, and if the net electric field from the three charges is zero at the origin (*i.e.*, $x = y = 0$), what is Q_3?



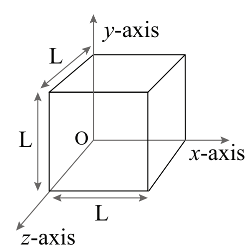
(1) $4q$ (2) $-4q$ (3) $-8q$ (4) $8q$ (5) $-2q$

4. 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 $\vec{E}(x, y) = ax\,\hat{x} + by\,\hat{y}$, where $a = 40$ V/m^2 and $b = -20$ V/m^2 are constants. The x-component of the electric field is $E_y(y) = by$. What is the net electric charge (in nanoC) contained within the cube?



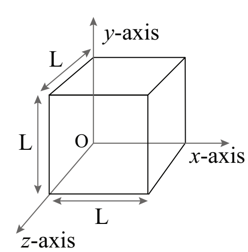
(1) 1.42 (2) 2.83 (3) 4.25 (4) 5.67 (5) 7.08

5. 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 $\vec{E}(x, y) = ax\,\hat{x} + by\,\hat{y}$, where $a = 60$ V/m^2 and $b = -20$ V/m^2 are constants. The x-component of the electric field is $E_y(y) = by$. What is the net electric charge (in nanoC) contained within the cube?



(1) 2.83 (2) 1.42 (3) 4.25 (4) 5.67 (5) 7.08

6. 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 $\vec{E}(x, y) = ax\,\hat{x} + by\,\hat{y}$, where $a = 80$ V/m^2 and $b = -20$ V/m^2 are constants. The x-component of the electric field is $E_y(y) = by$. What is the net electric charge (in nanoC) contained within the cube?



(1) 4.25 (2) 1.42 (3) 2.83 (4) 5.67 (5) 7.08

7. How much electric energy (in microJ) is stored by a solid spherical conductor with a charge of 100 nC and a radius of 0.2 m?

(1) 224.8 (2) 149.8 (3) 112.4 (4) 280.9 (5) 499.4

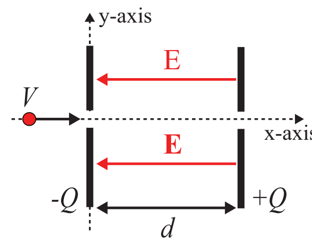
8. How much electric energy (in microJ) is stored by a solid spherical conductor with a charge of 100 nC and a radius of 0.3 m?

(1) 149.8 (2) 224.8 (3) 112.4 (4) 280.9 (5) 499.4

9. How much electric energy (in microJ) is stored by a solid spherical conductor with a charge of 100 nC and a radius of 0.4 m?

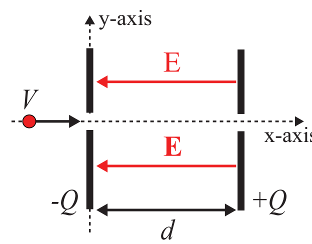
(1) 112.4 (2) 224.8 (3) 149.8 (4) 280.9 (5) 499.4

10. A positively charged particle with a charge to mass ratio $q/m = 0.01$ C/kg is traveling to the right along the x-axis. At $x = 0$ it enters an ideal parallel plate capacitor through a small hole with speed $V = 18$ m/s as shown in the figure. The plates of the capacitor have area $A = 10$ m^2 and lie in the y-z plane. The plate at $x = 0$ carries charge $-Q$ and the plate at $x = d$ carries charge $+Q$. If $Q = 8.85\,\mu$C and $d = 5$ cm, what is the speed (in m/s) of the particle when it exits the capacitor through the small hole at $x = d$?



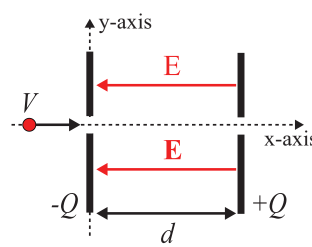
(1) 15.0 (2) 11.1 (3) 4.9 (4) 2.4 (5) 16.3

11. A positively charged particle with a charge to mass ratio $q/m = 0.02$ C/kg is traveling to the right along the x-axis. At $x = 0$ it enters an ideal parallel plate capacitor through a small hole with speed $V = 18$ m/s as shown in the figure. The plates of the capacitor have area $A = 10$ m^2 and lie in the y-z plane. The plate at $x = 0$ carries charge $-Q$ and the plate at $x = d$ carries charge $+Q$. If $Q = 8.85\,\mu$C and $d = 5$ cm, what is the speed (in m/s) of the particle when it exits the capacitor through the small hole at $x = d$?



(1) 11.1 (2) 15.0 (3) 4.9 (4) 2.4 (5) 16.3

12. A positively charged particle with a charge to mass ratio $q/m = 0.03$ C/kg is traveling to the right along the x-axis. At $x = 0$ it enters an ideal parallel plate capacitor through a small hole with speed $V = 18$ m/s as shown in the figure. The plates of the capacitor have area $A = 10$ m^2 and lie in the y-z plane. The plate at $x = 0$ carries charge $-Q$ and the plate at $x = d$ carries charge $+Q$. If $Q = 8.85\,\mu$C and $d = 5$ cm, what is the speed (in m/s) of the particle when it exits the capacitor through the small hole at $x = d$?



(1) 4.9 (2) 15.0 (3) 11.1 (4) 2.4 (5) 16.3

13. An electron (charge $e = 1.6 \times 10^{-19}$C) is undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity. How many revolutions per second must the electron undergo in order to produce a magnetic field at the center of the circle with a magnitude of 0.8μT?

(1) 1.59×10^{11} (2) 3.18×10^{11} (3) 4.77×10^{11} (4) 8.45×10^{10} (5) 6.89×10^{11}

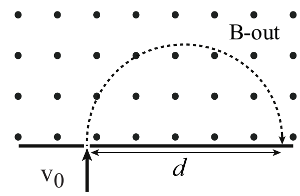
14. An electron (charge $e = 1.6 \times 10^{-19}$C) is undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity. How many revolutions per second must the electron undergo in order to produce a magnetic field at the center of the circle with a magnitude of 1.6μT?

(1) 3.18×10^{11} (2) 1.59×10^{11} (3) 4.77×10^{11} (4) 8.45×10^{10} (5) 6.89×10^{11}

15. An electron (charge $e = 1.6 \times 10^{-19}$C) is undergoing uniform circular motion with a radius $r = 2 \times 10^{-8}$ m and constant angular velocity. How many revolutions per second must the electron undergo in order to produce a magnetic field at the center of the circle with a magnitude of 2.4μT?

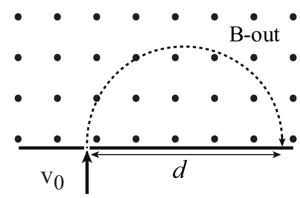
(1) 4.77×10^{11} (2) 1.59×10^{11} (3) 3.18×10^{11} (4) 8.45×10^{10} (5) 6.89×10^{11}

16. At time $t = 0$ a charged particle with speed v_0 and a charge to mass ratio of 0.5 C/kg 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 the magnitude of the magnetic field (in T)?



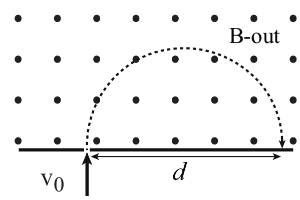
(1) 2.0 (2) 0.5 (3) 0.2 (4) 0.1 (5) 1.0

17. At time $t = 0$ a charged particle with speed v_0 and a charge to mass ratio of 2.0 C/kg 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 the magnitude of the magnetic field (in T)?



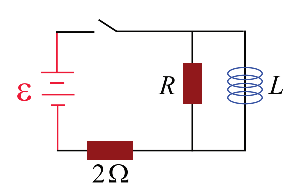
(1) 0.5 (2) 2.0 (3) 0.2 (4) 0.1 (5) 1.0

18. At time $t = 0$ a charged particle with speed v_0 and a charge to mass ratio of 5.0 C/kg 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 the magnitude of the magnetic field (in T)?



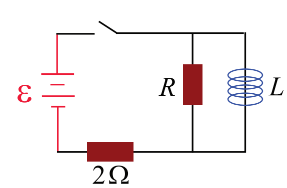
(1) 0.2 (2) 2.0 (3) 0.5 (4) 0.1 (5) 1.0

19. 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 $2\,\Omega$ resistor is I_{short} and a long time after the switch is closed (*i.e.,* steady state) the current is I_{long}. If $I_{\text{long}} = 4I_{\text{short}}$, what is the resistance R (in Ω)?



(1) 6 (2) 10 (3) 14 (4) 4 (5) 2

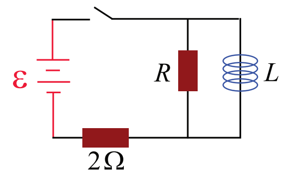
20. Consider the LR circuit shown in the figure. Initially the inductor has no magnetic stored energy and the switch is closed at $t = 0$. Immediately after the switch is closed the current through the $2\,\Omega$ resistor is I_{short} and a long time after the switch is closed (*i.e.,* steady state) the current is I_{long}. If $I_{\text{long}} = 6I_{\text{short}}$, what is the resistance R (in Ω)?



(1) 10 (2) 6 (3) 14 (4) 4 (5) 2

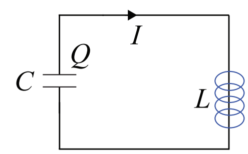
 77777

21. 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 $2\,\Omega$ resistor is I_{short} and a long time after the switch is closed (*i.e.*, steady state) the current is I_{long}. If $I_{\text{long}} = 8I_{\text{short}}$, what is the resistance R (in Ω)?



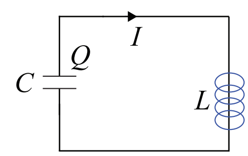
(1) 14 (2) 6 (3) 10 (4) 4 (5) 2

22. Consider an oscillating LC circuit consisting of a capacitor with $C = 2$ mF, no resistance, and an unknown inductor L as shown in the figure. If the frequency of the oscillations is 0.3183 Hz and the maximum current during the oscillations is 0.4 A, what is the stored magnetic energy (in J) in the inductor when the stored electgric energy in the capacitor is 2 J?



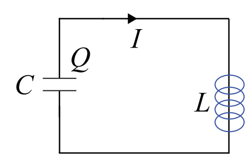
(1) 8 (2) 7 (3) 6 (4) 5 (5) 10

23. Consider an oscillating LC circuit consisting of a capacitor with $C = 2$ mF, no resistance, and an unknown inductor L as shown in the figure. If the frequency of the oscillations is 0.3183 Hz and the maximum current during the oscillations is 0.4 A, what is the stored magnetic energy (in J) in the inductor when the stored electgric energy in the capacitor is 3 J?



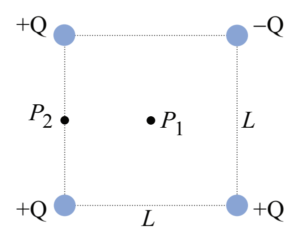
(1) 7 (2) 8 (3) 6 (4) 5 (5) 10

24. Consider an oscillating LC circuit consisting of a capacitor with $C = 2$ mF, no resistance, and an unknown inductor L as shown in the figure. If the frequency of the oscillations is 0.3183 Hz and the maximum current during the oscillations is 0.4 A, what is the stored magnetic energy (in J) in the inductor when the stored electgric energy in the capacitor is 4 J?



(1) 6 (2) 8 (3) 7 (4) 5 (5) 10

25. Two $+Q$ point charges and two $-Q$ point charges are placed at the corners of a square with sides of length L as shown in the figure. If $Q = 6.0$ nC and $L = 0.25$ m, what is the electric potential difference $\Delta V = V_2 - V_1$ (in V) between the point P_2 on the side of the square at the midpoint of the line between the two positive charges and the point P_1 at the center of the square?

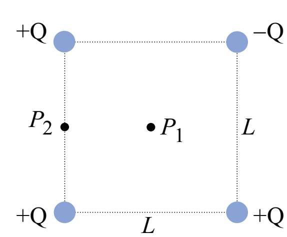


(1) 477 (2) 636 (3) 795 (4) 322 (5) 897

26. What is the electric potential energy (in μJ) of the charge configuration in the previous problem?

(1) −1.83 (2) −3.25 (3) −5.09 (4) 1.83 (5) 3.25

27. Two $+Q$ point charges and two $-Q$ point charges are placed at the corners of a square with sides of length L as shown in the figure. If $Q = 8.0$ nC and $L = 0.25$ m, what is the electric potential difference $\Delta V = V_2 - V_1$ (in V) between the point P_2 on the side of the square at the midpoint of the line between the two positive charges and the point P_1 at the center of the square?

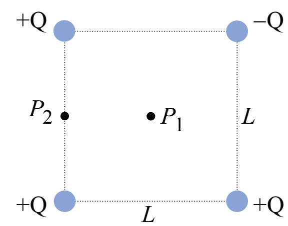


(1) 636 (2) 477 (3) 795 (4) 322 (5) 897

28. What is the electric potential energy (in μJ) of the charge configuration in the previous problem?

(1) -3.25 (2) -1.83 (3) -5.09 (4) 1.83 (5) 3.25

29. Two $+Q$ point charges and two $-Q$ point charges are placed at the corners of a square with sides of length L as shown in the figure. If $Q = 10.0$ nC and $L = 0.25$ m, what is the electric potential difference $\Delta V = V_2 - V_1$ (in V) between the point P_2 on the side of the square at the midpoint of the line between the two positive charges and the point P_1 at the center of the square?

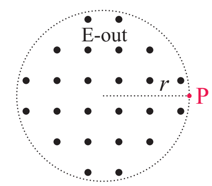


(1) 795 (2) 477 (3) 636 (4) 322 (5) 897

30. What is the electric potential energy (in μJ) of the charge configuration in the previous problem?

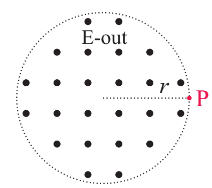
(1) -5.09 (2) -1.83 (3) -5.09 (4) 1.83 (5) 5.09

31. A uniform electric field pointing out of the page, as shown in the figure, is confined to a circular region of radius $r = 30$ m and varies with time according to $E(t) = bt$, where b is a constant (*i.e.,* it varies linearly with time). If $b = 3000$ V/(m·s), what is the magnitude of the induced magnetic field (in pT) at the point P at $r = 30$ m from the center at time $t = 5$ s?



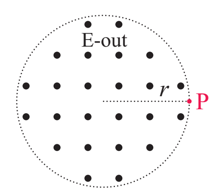
(1) 0.5 (2) 1.0 (3) 1.5 (4) 2.0 (5) 3.0

32. A uniform electric field pointing out of the page, as shown in the figure, is confined to a circular region of radius $r = 60$ m and varies with time according to $E(t) = bt$, where b is a constant (*i.e.,* it varies linearly with time). If $b = 3000$ V/(m·s), what is the magnitude of the induced magnetic field (in pT) at the point P at $r = 60$ m from the center at time $t = 5$ s?



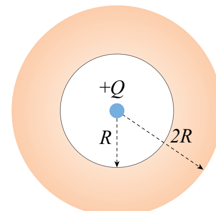
(1) 1.0 (2) 0.5 (3) 1.5 (4) 2.0 (5) 3.0

33. A uniform electric field pointing out of the page, as shown in the figure, is confined to a circular region of radius $r = 90$ m and varies with time according to $E(t) = bt$, where b is a constant (*i.e.,* it varies linearly with time). If $b = 3000$ V/(m·s), what is the magnitude of the induced magnetic field (in pT) at the point P at $r = 90$ m from the center at time $t = 5$ s?



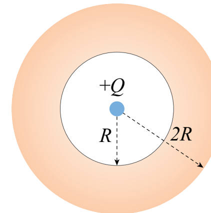
(1) 1.5 (2) 0.5 (3) 1.0 (4) 2.0 (5) 3.0

34. A solid conducting sphere with outer radius $2R$ has a a spherical hole at its center with radius R. At the center of the hole there is a point charge of $Q = 5$ nC, as shown in the figure. If there is no net charge on the conductor and $R = 0.2$ m, what is the magnitude of the electric field (in V/m) at the outer surface of the conductor?



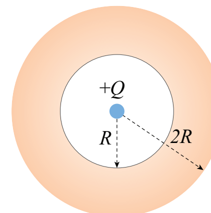
(1) 280.9 (2) 124.9 (3) 70.2 (4) zero (5) 1,123.8

35. A solid conducting sphere with outer radius $2R$ has a a spherical hole at its center with radius R. At the center of the hole there is a point charge of $Q = 5$ nC, as shown in the figure. If there is no net charge on the conductor and $R = 0.3$ m, what is the magnitude of the electric field (in V/m) at the outer surface of the conductor?



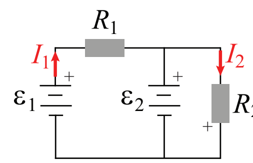
(1) 124.9 (2) 280.9 (3) 70.2 (4) zero (5) 499.4

36. A solid conducting sphere with outer radius $2R$ has a a spherical hole at its center with radius R. At the center of the hole there is a point charge of $Q = 5$ nC, as shown in the figure. If there is no net charge on the conductor and $R = 0.4$ m, what is the magnitude of the electric field (in V/m) at the outer surface of the conductor?



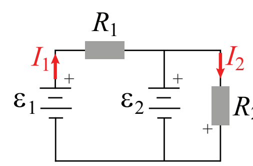
(1) 70.2 (2) 280.9 (3) 124.9 (4) zero (5) 1,123.8

37. Consider the circuit consisting of two EMF's and two resistors shown in the figure. If $\epsilon_1 = 12$ V, $\epsilon_2 = 3$ V, and $R_2 = 2R_1$, what is the ratio of current I_1 (through resistor R_1) to current I_2 (through resistor R_2)? Namely, what is I_1/I_2?



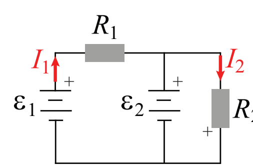
(1) 6 (2) 4 (3) 2 (4) 3 (5) 5

38. Consider the circuit consisting of two EMF's and two resistors shown in the figure. If $\epsilon_1 = 12$ V, $\epsilon_2 = 4$ V, and $R_2 = 2R_1$, what is the ratio of current I_1 (through resistor R_1) to current I_2 (through resistor R_2)? Namely, what is I_1/I_2?



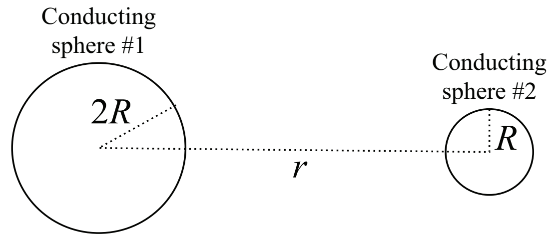
(1) 4 (2) 6 (3) 2 (4) 3 (5) 5

39. Consider the circuit consisting of two EMF's and two resistors shown in the figure. If $\epsilon_1 = 12$ V, $\epsilon_2 = 6$ V, and $R_2 = 2R_1$, what is the ratio of current I_1 (through resistor R_1) to current I_2 (through resistor R_2)? Namely, what is I_1/I_2?



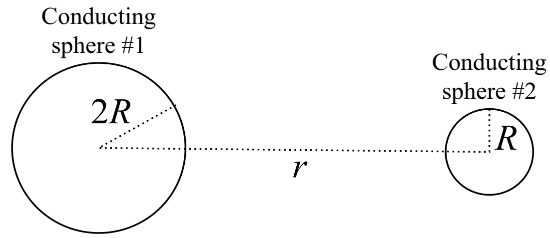
(1) 2 (2) 6 (3) 4 (4) 3 (5) 5

40. Consider two equally charged conducting spheres. Sphere #1 has a radius of $2R$ and charge Q and sphere #2 has radius R and charge Q. Initially the two spheres are isolated (*i.e.,* they are a large distance apart, $r \gg R$) and the total stored energy of the system is 9 J. The two conducting spheres are then connected by a long thin wire and after the system comes to equilibrium, the wire is removed. What is the new total stored energy of the system (in J)?



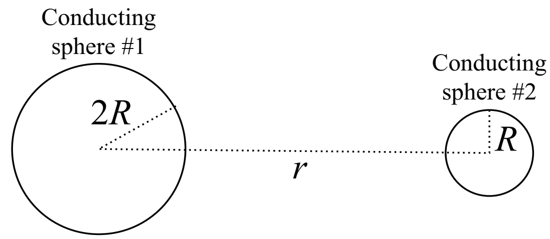
(1) 8 (2) 16 (3) 24 (4) 4 (5) 9

41. Consider two equally charged conducting spheres. Sphere #1 has a radius of $2R$ and charge Q and sphere #2 has radius R and charge Q. Initially the two spheres are isolated (*i.e.,* they are a large distance apart, $r \gg R$) and the total stored energy of the system is 18 J. The two conducting spheres are then connected by a long thin wire and after the system comes to equilibrium, the wire is removed. What is the new total stored energy of the system (in J)?



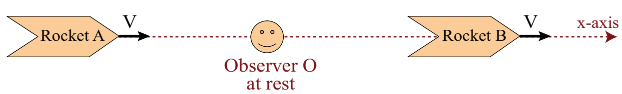
(1) 16 (2) 8 (3) 24 (4) 4 (5) 9

42. Consider two equally charged conducting spheres. Sphere #1 has a radius of $2R$ and charge Q and sphere #2 has radius R and charge Q. Initially the two spheres are isolated (*i.e.,* they are a large distance apart, $r \gg R$) and the total stored energy of the system is 27 J. The two conducting spheres are then connected by a long thin wire and after the system comes to equilibrium, the wire is removed. What is the new total stored energy of the system (in J)?



(1) 24 (2) 8 (3) 16 (4) 4 (5) 9

43. Two Rockets A and B are both travelling in the +x direction at the same constant speed of V and both emit radio waves at a rest frequency of 200 MHz to communicate with an observer O at rest on the x-axis as shown in the figure. If observer O must tune his radio to 800 MHz in order to get a clear signal from the Rocket A, what is the speed V of Rocket A (in m/s)?

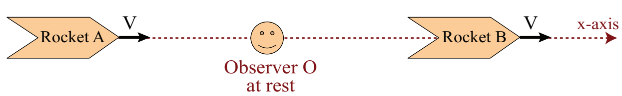


(1) 2.65×10^8 (2) 1.80×10^8 (3) 8.40×10^7 (4) 2.95×10^8 (5) 1.65×10^7

44. In the previous problem, what is the frequency that observer O must tune his radio in order to get a clear signal from Rocket B?

(1) 50 MHz (2) 200 MHz (3) 450 MHz (4) 25 MHz (5) 550 MHz

45. Two Rockets A and B are both travelling in the +x direction at the same constant speed of V and both emit radio waves at a rest frequency of 400 MHz to communicate with an observer O at rest on the x-axis as shown in the figure. If observer O must tune his radio to 800 MHz in order to get a clear signal from the Rocket A, what is the speed V of Rocket A (in m/s)?

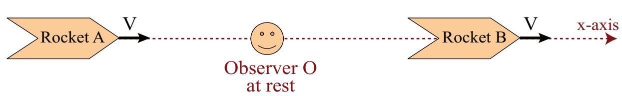


(1) 1.80×10^8 (2) 2.65×10^8 (3) 8.40×10^7 (4) 2.95×10^8 (5) 1.65×10^7

46. In the previous problem, what is the frequency that observer O must tune his radio in order to get a clear signal from Rocket B?

(1) 200 MHz (2) 50 MHz (3) 450 MHz (4) 25 MHz (5) 550 MHz

47. Two Rockets A and B are both travelling in the +x direction at the same constant speed of V and both emit radio waves at a rest frequency of 600 MHz to communicate with an observer O at rest on the x-axis as shown in the figure. If observer O must tune his radio to 800 MHz in order to get a clear signal from the Rocket A, what is the speed V of Rocket A (in m/s)?



(1) 8.40×10^7 (2) 2.65×10^8 (3) 1.80×10^8 (4) 2.95×10^8 (5) 1.65×10^7

48. In the previous problem, what is the frequency that observer O must tune his radio in order to get a clear signal from Rocket B?

(1) 450 MHz (2) 50 MHz (3) 200 MHz (4) 25 MHz (5) 550 MHz

49. The radiation power P of the sun is 3.9×10^{26} W. If the intensity of the sun on the surface of a rocket ship that is exploring outer space is 0.69 kW/m^2, how far is the rocket from the sun?

(1) 2.12×10^{11} m (2) 1.06×10^{11} m (3) 8.66×10^{10} m (4) 1.50×10^{11} m (5) 4.26×10^{10} m

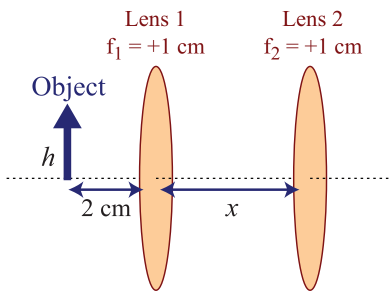
50. The radiation power P of the sun is 3.9×10^{26} W. If the intensity of the sun on the surface of a rocket ship that is exploring outer space is 2.76 kW/m^2, how far is the rocket from the sun?

(1) 1.06×10^{11} m (2) 2.12×10^{11} m (3) 8.66×10^{10} m (4) 1.50×10^{11} m (5) 4.26×10^{10} m

51. The radiation power P of the sun is 3.9×10^{26} W. If the intensity of the sun on the surface of a rocket ship that is exploring outer space is 4.14 kW/m^2, how far is the rocket from the sun?

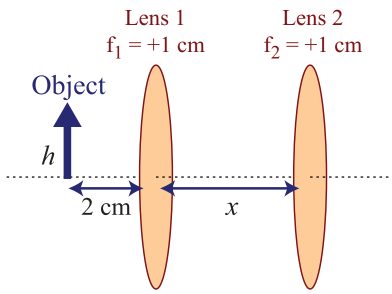
(1) 8.66×10^{10} m (2) 2.12×10^{11} m (3) 1.06×10^{11} m (4) 1.50×10^{11} m (5) 4.26×10^{10} m

52. The optical system shown in the figure consists of two converging lenses with equal focal lengths $f_1 = f_2 = +1$ cm. A luminous object with a height h is placed 2 cm in front of the first lens. The second lens can slide along the principle axis and is located a variable distance x from the first lens. At what value of x (in cm) will the optical system produce an inverted final overall image with a height of $2h$? Is the final image real or virtual?



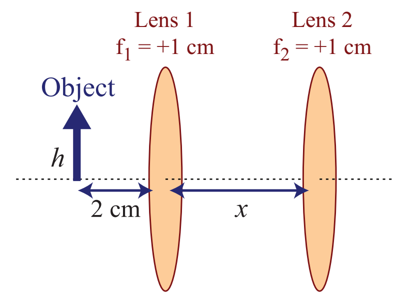
(1) 2.5, virtual
(2) 3.5, real
(3) 5.0, real
(4) 2.5, real
(5) 3.5, virtual

53. The optical system shown in the figure consists of two converging lenses with equal focal lengths $f_1 = f_2 = +1$ cm. A luminous object with a height h is placed 2 cm in front of the first lens. The second lens can slide along the principle axis and is located a variable distance x from the first lens. At what value of x (in cm) will the optical system produce an upright final overall image with a height of $2h$? Is the final image real or virtual?



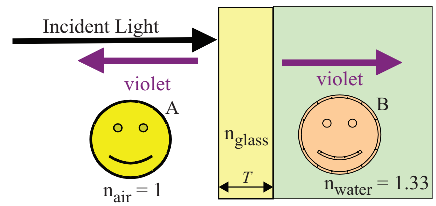
(1) 3.5, real
(2) 2.5, virtual
(3) 5.0, real
(4) 2.5, real
(5) 3.5, virtual

54. The optical system shown in the figure consists of two converging lenses with equal focal lengths $f_1 = f_2 = +1$ cm. A luminous object with a height h is placed 2 cm in front of the first lens. The second lens can slide along the principle axis and is located a variable distance x from the first lens. At what value of x (in cm) will the optical system produce an upright final overall image with a height of $h/2$? Is the final image real or virtual?



(1) 5.0, real
(2) 2.5, virtual
(3) 3.5, real
(4) 2.5, real
(5) 5.0, virtual

55. Observers A and B are on opposite sides of a flat glass plate with thickness T and refractive index $n_{glass} = 1.5$ as shown in the figure. Observer A is in the air ($\mathrm{n_{air}} = 1$) and observer B is under water ($\mathrm{n_{water}} = 1.33$). The light is incident from the left and observer A sees the light that is reflected off the glass and observer B sees the light that passes through the glass. What is the minimum thickness T of the glass plate (in nm) such that observer A on the left sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\mathrm{violet}} = 300$ nm?

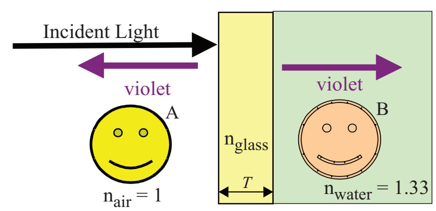


(1) 50 (2) 30 (3) 25 (4) 100 (5) 60

56. In the previous problem, what is the minimum thickness T of the glass plate (in nm) such that observer B on the right sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\mathrm{violet}} = 300$ nm?

(1) 100 (2) 60 (3) 50 (4) 40 (5) 25

57. Observers A and B are on opposite sides of a flat glass plate with thickness T and refractive index $n_{glass} = 2.5$ as shown in the figure. Observer A is in the air ($\mathrm{n_{air}} = 1$) and observer B is under water ($\mathrm{n_{water}} = 1.33$). The light is incident from the left and observer A sees the light that is reflected off the glass and observer B sees the light that passes through the glass. What is the minimum thickness T of the glass plate (in nm) such that observer A on the left sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\mathrm{violet}} = 300$ nm?

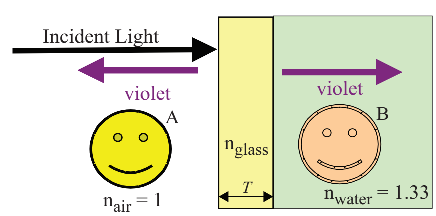


(1) 30 (2) 50 (3) 25 (4) 100 (5) 60

58. In the previous problem, what is the minimum thickness T of the glass plate (in nm) such that observer B on the right sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\mathrm{violet}} = 300$ nm?

(1) 60 (2) 100 (3) 50 (4) 40 (5) 25

59. Observers A and B are on opposite sides of a flat glass plate with thickness T and refractive index $n_{glass} = 3.0$ as shown in the figure. Observer A is in the air ($\mathrm{n_{air}} = 1$) and observer B is under water ($\mathrm{n_{water}} = 1.33$). The light is incident from the left and observer A sees the light that is reflected off the glass and observer B sees the light that passes through the glass. What is the minimum thickness T of the glass plate (in nm) such that observer A on the left sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\mathrm{violet}} = 300$ nm?



(1) 25 (2) 50 (3) 30 (4) 100 (5) 60

60. In the previous problem, what is the minimum thickness T of the glass plate (in nm) such that observer B on the right sees maximum constructive interference for violet light with a vacuum wavelength of $\lambda_{\text{violet}} = 300$ nm?

(1) 50 (2) 100 (3) 60 (4) 40 (5) 25

THE FOLLOWING QUESTIONS, NUMBERED IN THE ORDER OF THEIR APPEARANCE ON THE ABOVE LIST, HAVE BEEN FLAGGED AS CONTINUATION QUESTIONS: 26 28 30 44 46 48 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
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 26
Q# S 27 28
Q# S 29 30
TYPE 10
Q# S 31
Q# S 32
Q# S 33
TYPE 11
Q# S 34
Q# S 35
Q# S 36
TYPE 12
Q# S 37
Q# S 38
Q# S 39
TYPE 13
Q# S 40
Q# S 41
Q# S 42
TYPE 14
Q# S 43 44
Q# S 45 46
Q# S 47 48
TYPE 15
Q# S 49
Q# S 50
Q# S 51
TYPE 16

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Q# S 52
Q# S 53
Q# S 54
TYPE 17
Q# S 55 56
Q# S 57 58
Q# S 59 60