EXAM 4

PLEASE FILL IN THE INFORMATION BELOW

Name (printed):

Name (signed):

Student ID Number

Discussion Instructor: Chad  Chris  Peter
Data: Use these constants (where it states, for example, 1 ft, the 1 is exact for significant figure purposes).

1 ft = 12 in (exact)  
1 m = 3.28 ft

1 mile = 5280 ft (exact)  
1 hour = 3600 sec = 60 min (exact)

1 day = 24 hr (exact)  
g_{\text{earth}} = 9.80 \text{ m/s}^2 = 32.2 \text{ ft/s}^2

g_{\text{moon}} = 1.67 \text{ m/s}^2 = 5.48 \text{ ft/s}^2

1 year = 365.25 days

1 kg = 0.0685 slug  
1 N = 0.225 pound

1 horsepower = 550 ft-lb/s (exact)

M_{\text{earth}} = 5.98 \times 10^{24} \text{ kg}
R_{\text{earth}} = 6.38 \times 10^3 \text{ km}
M_{\text{sun}} = 1.99 \times 10^{30} \text{ kg}
R_{\text{sun}} = 6.96 \times 10^8 \text{ m}
M_{\text{moon}} = 7.35 \times 10^{22} \text{ kg}
R_{\text{moon}} = 1.74 \times 10^3 \text{ km}

G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2
k = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2
\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)

\text{e}_{\text{electron charge}} = -1.60 \times 10^{-19} \text{ C}

m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}
\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A (exact)}

N(Avogadro's No.) = 6.02 \times 10^{23} \text{ atoms/gm-mole}
\quad = 6.02 \times 10^{26} \text{ atoms/kg-mole}

1 Tesla = 10,000 gauss (exact)

\rho(\text{H}_2\text{O}) = 1000 \text{ kg/m}^3

\cos(a \pm b) = \cos a \cos b \mp a \sin b

\sin(a \pm b) = \sin a \cos b \pm \sin b

m_{\text{proton}} = 1.67 \times 10^{-27} \text{ kg}

h = 6.64 \times 10^{-34} \text{ J}

\pi = 3.14

c = 3.00 \times 10^8 \text{ m/s}

\int x\sqrt{x^2 \pm a^2} \, dx = \frac{1}{3} \sqrt{\left(x^2 \pm a^2\right)^{3/2}}

\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \pm x \sqrt{x^2 \pm a^2}

\int e^{-ax} \, dx = -\frac{1}{a} e^{-ax}

\int \frac{xdx}{\left(x^2 \pm a^2\right)^{3/2}} = -\frac{1}{\sqrt{x^2 \pm a^2}}

\int \frac{xdx}{\sqrt{a^2 - x^2}} = \sqrt{a^2 - x^2}

\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln \left(x + \sqrt{x^2 \pm a^2}\right)

\int \frac{dx}{x\sqrt{x^2 + a^2}} = -\frac{1}{a} \ln \left(\frac{a + \sqrt{x^2 + a^2}}{x}\right)

\int \frac{xdx}{\sqrt{x^2 \pm a^2}} = \sqrt{x^2 \pm a^2}

\int \frac{dx}{\sqrt{a^2 - x^2}} = \sin^{-1}\left(\frac{x}{a}\right), \quad \text{or} \quad -\cos^{-1}\left(\frac{x}{a}\right)

\int \frac{dx}{a + bx} = \frac{1}{b} \ln (a + bx)

\int \frac{dx}{(a + bx)^2} = -\frac{1}{b(a + bx)}
The figure shows voltage and current graphs for a capacitor.

(a)  [11 pts.] What is the emf frequency $f$?
(b)  [11 pts.] What is the value of the capacitance $C$?
(c)  [11 pts.] Draw the capacitor’s voltage and current phasors at $t = 7.5$ ms. For each, specify the value of the phasor magnitude and of its angle with the $x$ axis.
A 3.0-cm-tall object is 9 cm in front of a converging lens that has an 18 cm focal length.

(a) [12 pts.] Use ray tracing on the figure below to approximately draw the image. Do this as accurately as you can. [4 points for each ray, no credit for sloppy or extra rays.]

(b) [10 pts.] Is the image real or virtual? Upright or inverted?

(c) [12 pts.] Using appropriate formulas, calculate the image position and height.
Photons from a helium-neon laser (wavelength 633 nm) pass through a 10-μm-wide slit and create a diffraction pattern on a screen 1.0 m behind the slit.

(a) [11 pts.] What is the width of the central maximum on the screen?
(b) [11 pts.] If the photons are replaced by electrons, what wavelength must the electrons have to produce the same diffraction pattern on the screen?
(c) [11 pts.] What is the speed of such electrons?
Show all work!! Report all numbers to three (3) significant figures.

The figure shows voltage and current graphs for a capacitor.

(a) [11 pts.] What is the emf frequency \( f \)?

(b) [11 pts.] What is the value of the capacitance \( C \)?

(c) [11 pts.] Draw the capacitor's voltage and current phasors at \( t = 7.5 \) ms. For each, specify the value of the phasor magnitude and of its angle with the \( x \) axis.

\[(a) \quad f = \frac{1}{T} \]

we see from the graph that \( T = 0.025 \) s

\[f = 50 \text{ Hz} \]

\[(b) \quad V_{c,\text{max}} = I_{c,\text{max}} \times C \]

\[C = \frac{1}{\omega C}, \quad V_{c,\text{max}} = 10 \text{ V}, \quad I_{c,\text{max}} = 15 \text{ mA} \]

\[V_{c,\text{max}} = \frac{I_{c,\text{max}}}{\omega C} \]

\[C = \frac{I_{c,\text{max}}}{\omega V_{c,\text{max}}} = 4.77 \mu \text{F} \]

\[(c) \quad \phi = \omega t = 2\pi ft = 135^\circ \]

\[\phi_{v_c} = \phi_{v_c} + \frac{\pi}{2} = 225^\circ \]

length of phasors:

\[V = V_{c,\text{max}} = 10 \text{ V} \]

\[I = I_{c,\text{max}} = 15 \text{ mA} \]
A 3.0-cm-tall object is 9 cm in front of a converging lens that has an 18 cm focal length.

(a) [12 pts.] Use ray tracing on the figure below to approximately draw the image. Do this as accurately as you can. [4 points for each ray, no credit for sloppy or extra rays.]

(b) [10 pts.] Is the image real or virtual? Upright or inverted? Virtual, Upright

(c) [12 pts.] Using appropriate formulas, calculate the image position and height.

\[ \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{9} + \frac{1}{s'} = \frac{1}{18} \]

\[ s' = (\frac{1}{18} - \frac{1}{9})^{-1} = -18 \text{ cm} \]

\[ m = \frac{s'}{s} = -\frac{(18)}{9} = 2 \]

\[ \frac{h'}{h_o} \rightarrow h' = 2h_o = 6 \text{ cm} \]
Photons from a helium-neon laser (wavelength 633 nm) pass through a 10-μm-wide slit and create a diffraction pattern on a screen 1.0 m behind the slit.

(a) [11 pts.] What is the width of the central maximum on the screen?

(b) [11 pts.] If the photons are replaced by electrons, what wavelength must the electrons have to produce the same diffraction pattern on the screen?

(c) [11 pts.] What is the speed of such electrons?

\[ \omega = \frac{\lambda}{\alpha} \tan \theta \]

Thus:
\[ \omega = (2L) \cdot \tan \theta = (2L) \cdot \tan \left[ \sin^{-1} \left( \frac{\lambda}{\alpha} \right) \right] \approx (2L) \cdot \frac{\lambda}{\alpha} \]

\[ \omega = (2 \times 10^{-6} \text{m}) \cdot \tan \left[ \sin^{-1} \left( \frac{633 \times 10^{-9} \text{m}}{10 \times 10^{-6} \text{m}} \right) \right] \approx 0.127 \text{m} = 12.7 \text{ cm} \]

(b) Same interference pattern requires the same wavelength, other things being equal. Thus \( \lambda_{\text{electron}} = 6.33 \text{ nm} \)

(c) \[ \lambda_{\text{el}} = \frac{h}{p_{\text{el}}} = \frac{h}{m_{\text{el}} v_{\text{el}}} \Rightarrow \frac{h}{m_{\text{el}} \lambda_{\text{el}}} = \frac{6.63 \times 10^{-34} \text{ J s}}{9.11 \times 10^{-31} \text{ kg} \times 633 \times 10^{-9} \text{ m}} \]

\[ v_{\text{el}} = 1.15 \times 10^3 \text{ m/s} \]