Physics 262 Spring 2010 Exam #3

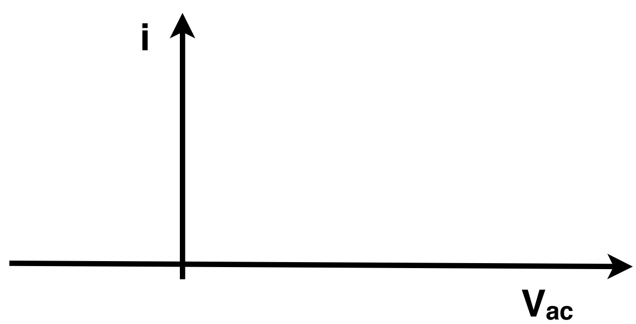
Name:____

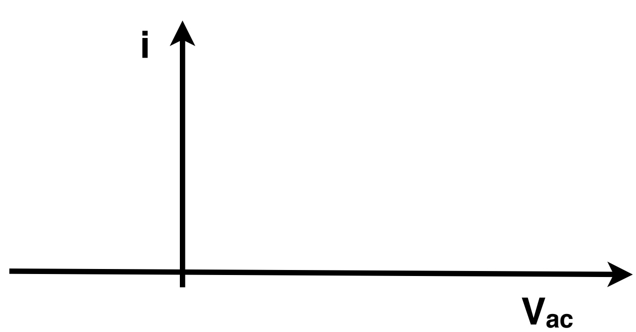
CLOSED BOOK, CALCULATORS ONLY SHOW ALL WORK! Use extra blank sheets if necessary

Useful Things	
hc	1240 nm eV
$\hbar^2/m$	0.0762 eV nm^2
c	3.00 x 10^8 m s^{-1}
Joules to calories (dietary)	1 J=2.39 x 10^{-4} cal (dietary)
Stefan-Boltzmann constant	5.67 x 10^{-8} J/ (s^1 m^2 K^4)
Temperature	273.2 K = 0 °C

1) (20 points)

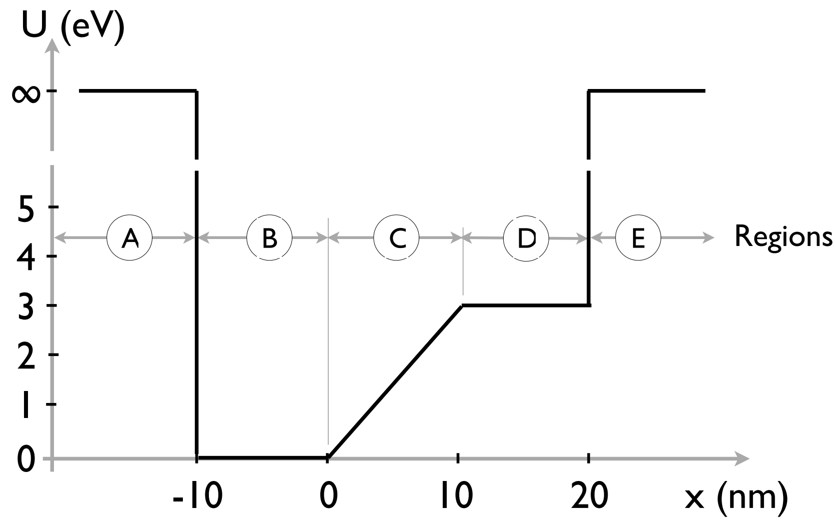
1) PHOTOELECTRIC EFFECT:
Sketch the current i versus anode-cathode potential V_{ac} for light with two different intensities but the same frequency (top graph), and for two different frequencies but the same intensity (bottom graph).





2) (35 points)

Consider a quantum mechanical particle-in-a-box problem with the potential energy shown below:



2) A (20 points)

Fill in the table below by writing out the complete time independent (x only, no time) Schrödinger's Equation for each region using the appropriate expression for the potential energy. Write out the best wavefunction solution you can think of without actually solving anything.

Region	Schrödinger's Equation	Expression for ψ(x)
A		
B		
C		
D		
E		

2) B (10 points)

Suppose the energy associated with a wavefunction is E = 2 eV. Complete the table below with the appropriate expression for k for each region.

Region	Expression for k^2
A	
B	
C	
D	
E	

2) C (5 points)

What are the SI units of the one-dimensional wavefunction ψ(x)?

3) (20 points)

People emit blackbody radiation. An average person has about 2 m^2 of skin area and an average skin temperature of 33 °C. Our surroundings are 300 K.

3)A (10 points)

Find the net blackbody power balance between the average person and the environment

3)B (10 points)

Assuming this power balance holds over a 24 hour day, what is the minimum caloric intake required by the average person to meet this power balance?

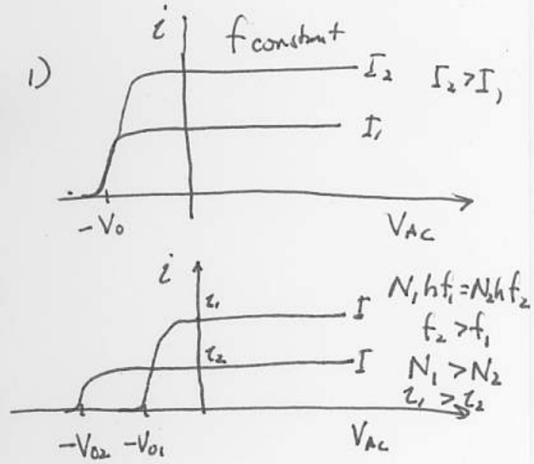
4) (25 points)

An electron has a kinetic energy that is equal to its rest mass energy of $0.511 \text{x} 10^{6} eV$. A photon has this same energy. Fill in the following table(the units labeled are suggested but are not the only correct choice):

	Electron	**Photon**
Speed (c)		
Total Energy (eV)		
Momentum (eV s/m)		
Wavenumber (m^{-1})		
Frequency (Hz)		
Wavelength (m)		

EXAM #3 SOLUTIONS

1)



2A)

Region	Schrödinger's Equation	Expression for $\psi(x)$
A	$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + \infty\,\psi(x) = E\psi(x)$ OR $-0.0762\,\text{eV nm}^2\frac{\partial^2\psi}{\partial x^2} + \infty\psi(x) = E(x)$	$\psi(x) = 0$
B	$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + 0 = E\psi(x)$ $-0.0762\,\text{eV nm}^2\frac{\partial^2\psi}{\partial x^2} = E\psi(x)$	$\psi(x) = A\sin kx + B\cos kx$ $= A\exp(ikx) + B\exp(-ikx)$
C	$-\hbar^2\frac{\partial^2\psi}{\partial x^2} + U(x)\psi = E\psi(x)$ $-0.0762\,\text{eV nm}^2\frac{\partial^2\psi}{\partial x^2} + \frac{3eV}{10nm}x\psi(x) = E\psi(x)$	$\psi(x) = ??$ (ANYTHING OK)
D	$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + U\psi(x) = E\psi(x)$ $-0.0762\,\text{eV nm}^2\frac{\partial^2\psi}{\partial x^2} + 3eV\,\psi(x) = E\psi(x)$	$\psi(x) = A\sin kx + B\cos kx$ $= A\exp(ikx) + B\exp(-ikx)$
E	$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + U(x)\psi(x) = E\psi(x)$ $-0.0762\,\text{eV nm}^2\frac{\partial^2\psi}{\partial x^2} + \infty\psi(x) = E\psi(x)$	$\psi(x) = 0$

2 B)

Region	Expression for k^2
A	$k^2 = \frac{2m}{\hbar^2}(E-\infty) = -\infty = 0$?
B	$k^2 = \frac{2m}{\hbar^2}(E) = \frac{2mE}{\hbar^2}$
C	$k^2 = \frac{2m}{\hbar^2}(E - U(x))$?? (ANYTHING OK)
D	$k^2 = \frac{2m}{\hbar^2}(E - 3eV) = -\frac{2m}{\hbar^2} < 0$
E	$k^2 = 0$

2C) SINCE $\int_x |\psi(x)|^2 dx = 1$, $\boxed{\psi(x) \text{ must have units of } m^{-1/2}}$

3 a) $P = A\sigma T^4$; $P_{BAL} = A\sigma(T^4_{SKIN} - T^4_{ENVIR})$

$= 2m^2\, 5.67\times10^{-8}\frac{W}{m^2K^4}\left((273.2+33)^4 - 300^4\right)$

$\boxed{= 78.3\,W}$

3 b) $78.3W = 78.3\frac{J}{s}\cdot\frac{60s}{min}\cdot\frac{60min}{hr}\cdot\frac{24hrs}{day}\cdot 2.39\times10^{-1}\frac{cal}{J}$

$= \boxed{1620\,\frac{cal}{DAY}}$

4

	Electron	Photon	Photon/2
Speed (c)	0.87 c	1.0 c	1.0 c
Total Energy (eV)	1.022×10^6 eV	1.022×10^6 eV	0.511×10^6 eV
Momentum (eV s/m)	$p = \gamma m_o v = \gamma\frac{mc^2}{c}\frac{v}{c} = 2.95\text{x}10^{-3}\,\text{eV s/m}$	$p = E/c = 3.41\text{x}10^{-3}\,\text{eV s/m}$	1.70×10^{-3} eV s/m
Wavenumber (m^{-1})	$k = p/\hbar = \gamma\,vmc^2/\hbar c c = \gamma\frac{2\pi mc^2}{hc}\frac{v}{c} = 4.48\text{x}10^{12}\,m^{-1}$	$k = \omega/c = \hbar\omega/\hbar c = 2\pi E/hc = 5.18\text{x}10^{12}\,m^{-1}$	$2.59 \times 10^{12}\ m^{-1}$
Frequency (Hz)	f=Ec/hc =2.47×10^{20} Hz	f=Ec/hc =2.47×10^{20} Hz	f=Ec/hc =1.24×10^{20} Hz
Wavelength (m)	λ=hc/pc=$1.40\text{x}10^{-12}$ m	λ=hc/E=$1.21\text{x}0^{-12}$ m	λ=hc/E=2.43×0^{-12} m

THESE ARE THE SAME

$\gamma = 2 = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$

$\therefore 1 - \frac{V^2}{c^2} = \frac{1}{4};\ \frac{V^2}{c^2} = \frac{3}{4};\ V/c = 0.87$

$E_{TOT} = \gamma M_o c^2$

$= \underbrace{(\gamma-1)M_o c^2}_{Kinetic} + \underbrace{M_o c^2}_{Rest}$

$\boxed{p = \frac{E}{c} =}$

$p = \gamma M_o V$

$= \gamma\frac{M_o c^2}{c}\frac{V}{c}$

$=$