<table>
<tr><td>PHYSICS 262 Fall 2011
Exam 3 (problems 1-4)</td><td>SIGNATURE:_______________________.
Banner ID:__________________________.</td></tr>
<tr><td colspan="2">INSTRUCTIONS:
This is a take-home exam that is due <u>at the beginning</u> of class, 12PM, Monday December 5th. You may use any source of information except another person. Please fill in your Banner ID and clearly indicate your answers Please sign this exam above, signifying you followed the UNM Honor Code, and return this exam with neatly filled out answer sheets attached Monday at noon.</td></tr>
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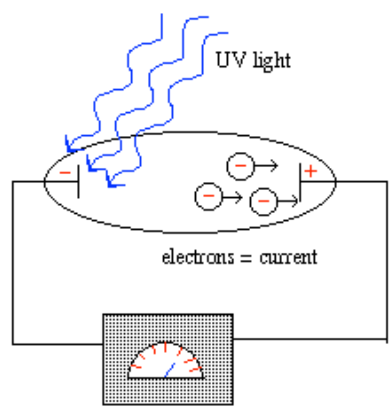
1. (20 pts)
A) Emcore Corporation in Albuquerque has a long history of providing solar cells for space missions. They made the solar cells for the recently launched Mars Curiosity Rover. By what fraction is the performance of solar cells on Mars reduced compared to on Earth?

B) Is Mars a greenhouse-effect planet? The average surface temperature of Mars is 226 K. Calculate the equilibrium blackbody temperature of Mars. Assume Mars and the Sun are perfect blackbodies.
For uniformity sake, use the following parameters:

Blackbody temperature of the Sun: T_{Sun} =5800 K
Radius of the Sun: R_{sun} =6.96x10^{8} m
Distance of Mars from the Sun: D_{Mars} =2.28x10^{11} m
Radius of Mars: R_{Mars}=3.40x10^{6} m

(hint: Wikipedia shows how to do this for the Earth).

2. (15 pts)
We wish to use the photoelectric effect to convert light to electrical power. A photoelectric effect test cell similar to the one shown on the right is constructed with Al metal (work function of ϕ=4.0 eV) for the photoelectric cathode. Monochromatic light of wavelength 248 nm and an intensity of 100 mW cm^{-2} is used to test this new type of solar cell. The light falls on an Al photoelectric cathode of area 1 cm^{-2}.



A (5) Assuming every photon is converted to an electron, how much electrical current flows in this device?

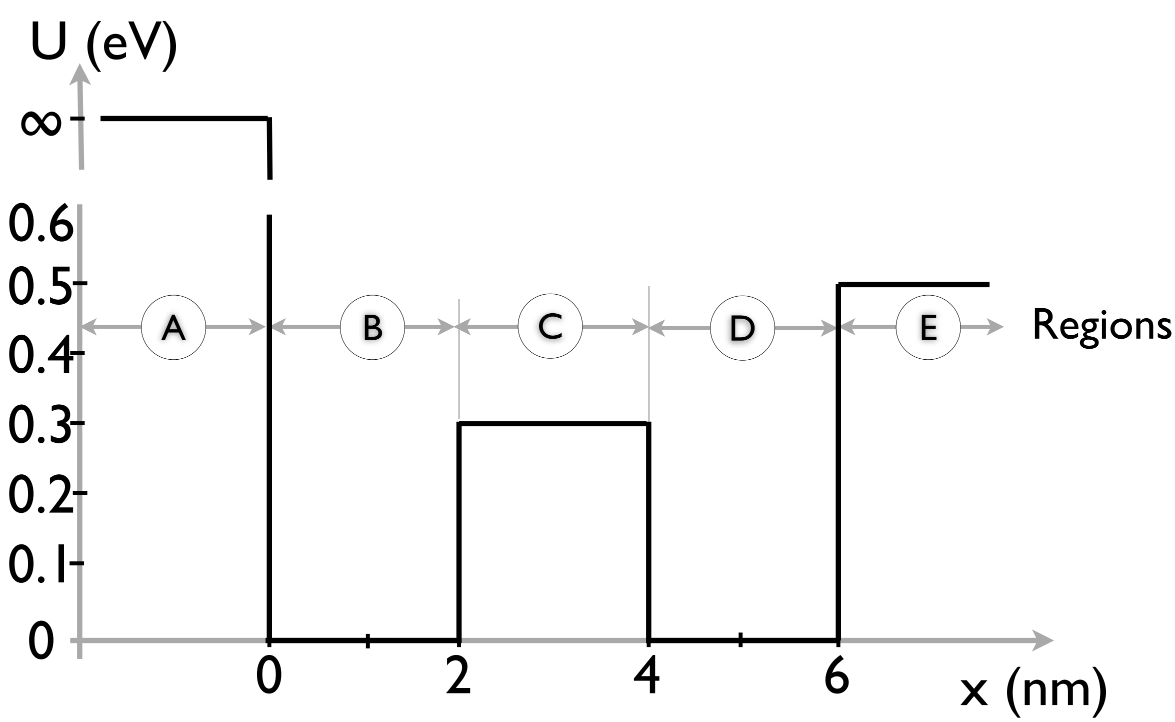
B (10) How much electrical power may be extracted from this device?

3. (25 pts)
A particle is measured in one IRF to have a kinetic energy of 1 GeV and a momentum of 3 GeV/c, and is measured in another IRF to have a momentum of 4 GeV/c.

Fill in the table below:

	IRF 1	**IRF 2**
Momentum (eV/c)	3 GeV/c	4 GeV/c
Kinetic Energy (eV)	1 GeV	
Mass (eV/c²)		
Total Energy (eV)		
Speed (c)		
Wavelength (m)		

4. (40 pts)
Consider a quantum mechanical particle-in-a-box problem with the potential energy shown below:



4 (continued) For each region, assume the wavefunction has energy of either 0.2 eV or 0.6 eV and complete the following table. For "Description of the wavefunction," choose from the following:

0) Zero: $\psi(x) = 0$
1) Standing wave: $\psi(x) = A\sin(kx) + B\cos(kx)$
2) Free particle plane wave propagating in the +x direction: $\psi(x) = A\exp(ikx)$
3) Free particle plane wave propagating in the -x direction: $\psi(x) = B\exp(-ikx)$
4) Free particle plane waves propagating in both directions: $\psi(x) = A\exp(ikx) + B\exp(-ikx)$
5) Exponentially decaying tunneling wavefunction: $\psi(x) = A\exp(-\kappa x)$
6) Exponentially growing tunneling wavefunction: $\psi(x) = B\exp(\kappa x)$
7) Both expponentially decaying and growing tunneling wavefunctions: $\psi(x) = A\exp(-\kappa x) + B\exp(\kappa x) = A\cosh(\kappa x) + B\sinh(\kappa x)$

Hint: Check your answers using http://phet.colorado.edu/en/simulation/quantum-tunneling OR http://phet.colorado.edu/en/simulation/bound-states

Region	**Expression for *k***		**Description of wavefunction**	
	E=0.2 eV	**E=0.6 eV**	**E=0.2 eV**	**E=0.6 eV**
A				
B				
C				
D				
E				

1.A) SUN PUTS OUT POWER

$$P_{SUN} = A_{SUN}\sigma T_s^4 = 4\pi R_s^2 \sigma T_s^4$$

AT D_{EARTH} THIS <u>INTENSITY</u> IS $\dfrac{P_{SUN}}{4\pi D_E^2} = \dfrac{4\pi R_s^2 \sigma T_s^4}{4\pi D_E^2}$

$$I_E = 1.38\times10^3 \frac{W}{m^2}$$

RATIO $\dfrac{I_{MARS}}{I_{EARTH}} = \left(\dfrac{D_{MARS}}{D_{EARTH}}\right)^2 = 43\%$

SOLAR CELLS ON MARS ARE $\boxed{43\%}$ AS EFFECTIVE AS ON EARTH

B. MARS INTERCEPTS/ABSORBS $\dfrac{\pi R_m^2}{4\pi D_m^2}$ FRACTION OF SUNS POWER

THIS MUST BE RE-RADIATED AS BLACKBODY RADIATION

$$\therefore A_m\sigma T_m^4 = 4\pi R_m^2\sigma T_m^4 = \frac{\pi R_m^2}{4\pi D_m^2}\cdot 4\pi R_s^2\sigma T_s^4$$

$$T_m = \sqrt[4]{\frac{R_s^2 T_s^4}{4D_m^2}} = \sqrt{\frac{R_s}{2D_m}}\,T_s = \boxed{227K}$$

MARS HAS AN ATMOSPHERE OF CO_2 BUT IT IS TOO THIN TO CONTRIBUTE TO GREENHOUSE EFFECT

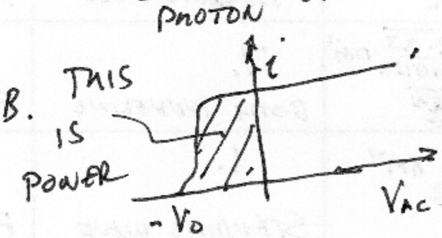
2.A. PHOTON FLUX AT $100\frac{mW}{cm^2} = 0.1\frac{W}{cm^2}$ of 248 nm Photons

$$= 0.1\frac{W}{cm^2} = \frac{0.1J}{s\cdot cm^2}\cdot\frac{1eV}{1.6\times10^{-19}J}\cdot\frac{248nm}{1240eV\,nm}\ \text{Photons}$$

$$= 1.25\times10^{17}\frac{\text{PHOTONS}}{s\cdot cm^2}$$

$\dfrac{1\ \text{electron}}{\text{photon}}$ GIVES CURRENT DENSITY OF $0.02\,\dfrac{\text{Amps}}{cm^2}$, $\boxed{I = 0.02A}$

B.



$$hf = \phi + eV_0$$

$$5eV = 4eV + eV_0$$

$$eV_0 = 1eV$$

$$V_0 = 1V$$

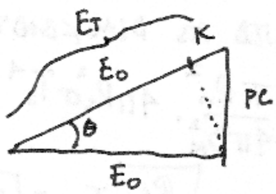
ELECTRICAL POWER $= I\cdot V_0 = 0.02W$

INPUT POWER $= 0.1W$

EFFICIENCY $= 20\%$

3.

	IRF 1	IRF 2
Momentum (eV/c)	3 GeV/*c*	4 GeV/*c*
Kinetic Energy (eV)	1 GeV $=(\gamma-1)E_0$	$4(\sqrt{2}-1)=1.66\,\text{GeV}$
Mass (eV/c²)	$(E_0+K)^2=E_0^2+(pc)^2$; $E_0=4\,\frac{GeV}{c^2}$	$E_0=4\,\frac{GeV}{c^2}$ SAME FOR ANY IRF
Total Energy (eV)	$E_T=E_0+K=5\,\text{GeV}$	$E_T=\gamma E_0=4\sqrt{2}\,\text{GeV}$
Speed (c)	$\gamma=\frac{5}{4}$ $\frac{v}{c}=\frac{pc}{E_T}=\frac{3}{5}$; $v=\frac{3}{5}c$	$\gamma=\sqrt{2}$ $\frac{v}{c}=\frac{1}{\sqrt{2}}$ $v=\frac{c}{\sqrt{2}}$
Wavelength (m)	$\frac{hc}{pc}=4.13\times10^{-16}\,m$	$\frac{hc}{pc}=3.1\times10^{-16}\,m$



$$\sin\theta=\frac{v}{c}=\frac{pc}{E_T}=\frac{\gamma m_0 v c}{\gamma m_0 c^2}$$

4.

Region	Expression for *k*		Description of wavefunction	
	E=0.2 eV	**E=0.6 eV**	**E=0.2 eV**	**E=0.6 eV**
A	k doesn't exist 0 okay	k doesn't exist 0 okay	0 $\psi=0$	0 $\psi=0$
B	$k=\sqrt{2/\cancel{(0.0762)}(0.2)}$ $=\sqrt{\frac{2mE}{\hbar^2}}\,nm^{-1}$	$k=\sqrt{\frac{2\cdot0.6}{0.0762}}\,nm^{-1}$ $=\sqrt{\frac{2mE}{\hbar^2}}$	1. STANDING WAVE	4. FREE PLANE WAVES
C	$k=\sqrt{\frac{-2\cdot0.1}{0.0762}}$ $\boxed{\text{IMAGINARY}}$ $=\sqrt{\frac{2m}{\hbar^2}(E-U)}\,nm^{-1}$	$k=\sqrt{\frac{2\cdot0.3}{0.0762}}\,nm^{-1}$ $=\sqrt{\frac{2m(E-U)}{\hbar^2}}$	7. BOTH TUNNELING	4. FREE PLANE WAVES
D	$k=\sqrt{\frac{2\cdot0.2}{0.0762}}\,nm^{-1}$	$k=\sqrt{\frac{2\cdot0.6}{0.0762}}\,nm^{-1}$ $=\sqrt{\frac{2mE}{\hbar^2}}$	1. STANDING WAVE	4. FREE PLANE WAVES
E	$k=\sqrt{\frac{-2\cdot0.4}{0.0762}}$ $\boxed{\text{IMAGINARY}}$ $=\sqrt{\frac{2m(E-U)}{\hbar^2}}\,nm^{-1}$	$k=\sqrt{\frac{2\cdot0.1}{0.0762}}\,nm^{-1}$ $=\sqrt{\frac{2m(E-U)}{\hbar^2}}$	5. DECAYING $\to K$	4. FREE PLANE WAVES

$k=\sqrt{\frac{2m}{\hbar^2}(E-U)}$ $\quad\quad$ $\frac{\hbar^2}{m}=0.0762\,eV\,nm^2$