Chemistry 20A Midterm (I), October 22, Fall 2010

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Pro

2) 50 pts.: 45

3) 50 pts.: 33

4) 50 pts. 0

Total pts.: $\boxed{111}$

h = 6.626 x10^{-34} J s
R = 0.0821 L atm mol^{-1} K^{-1}
k_B = 1.38 x 10^{-23} J K^{-1}
c =2.998 x 10^8 ms^{-1}
e=1.6 x 10^{-19} C
ε_0=8.854 x 10^{-12} C^2 J^{-1} m^{-1}
m_e=9.1 x 10^{-31} kg=m_p/1836

$$\sqrt{2y^3+3y^2}$$

$$\int y\sqrt{2y+3}\,dx$$

$$\int \sqrt{u}\,du \qquad u = 2y+3 \qquad y = \frac{u-3}{2}$$

$$du = 2\,dy$$

$$\int \frac{1}{2}(u-3)(u)^{1/2}$$

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1. (*50 pts.*)

a) (*10 pts.*) What was experimentally proved by the Photoelectric effect and how?

b) (*20 pts.*) Give the name of the potential energy that holds the electron and protons together in atoms and molecules. Also write down this potential energy for C^{3+}.

c) (*20 pts.*) Make a reasonable accurate sketch of the energy density from a Blackbody radiation source as a function of wavelength for three different temperatures, $T_1 > T_2 > T_3$, where T_2 is temperature of the sun.

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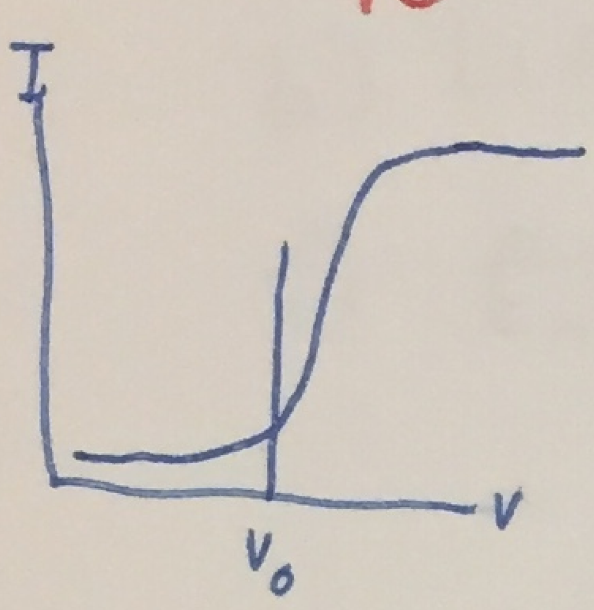
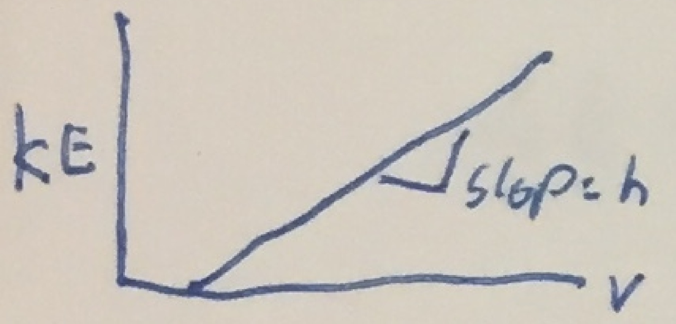
a) The photo electric effect proved the reality of wave-partical duality of energy. This was proved by shining light of ~~increasing~~ decreasing wave lengths on a piece of metal. ~~This cancel the~~ Classical mechanics suggested that the electrons ejected was directly proportional to intensity, and independent of ~~frequency~~ wavelength. This experiment proved that the wavelength is directly proportional to the eletrons ejected from the metal. Einstein's results are shown to the left. It also showed that the kinetic energy of an electron was directly related to its frequency by ~~the~~ Plancks constant as shown to the left





$E_{photon} = h\nu$

b) ~~Weak nuclear force~~. Coulomb Potential

$$V(r) = \frac{-Z_{eff} e^2}{4\pi\varepsilon_0 r} = \cancel{\frac{-3(-1.6\times10^{-19})^2}{4\pi\varepsilon_0}} = V(r)$$

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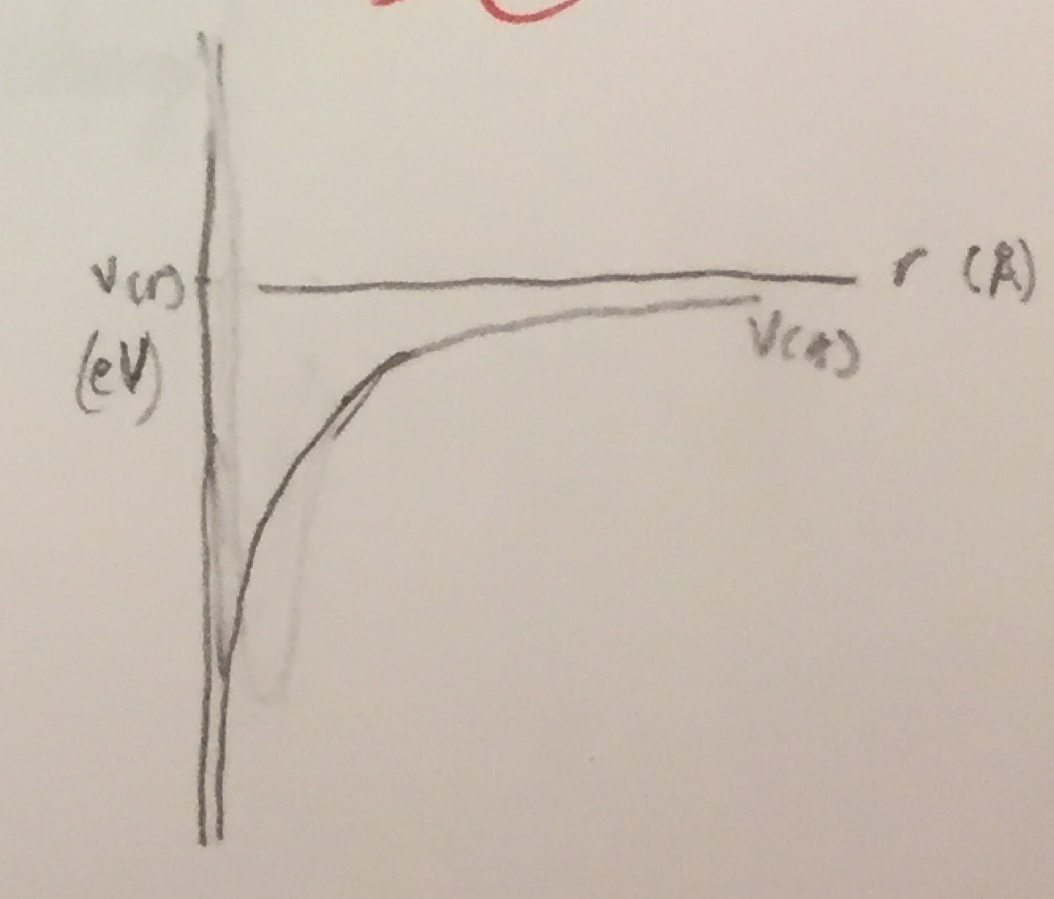
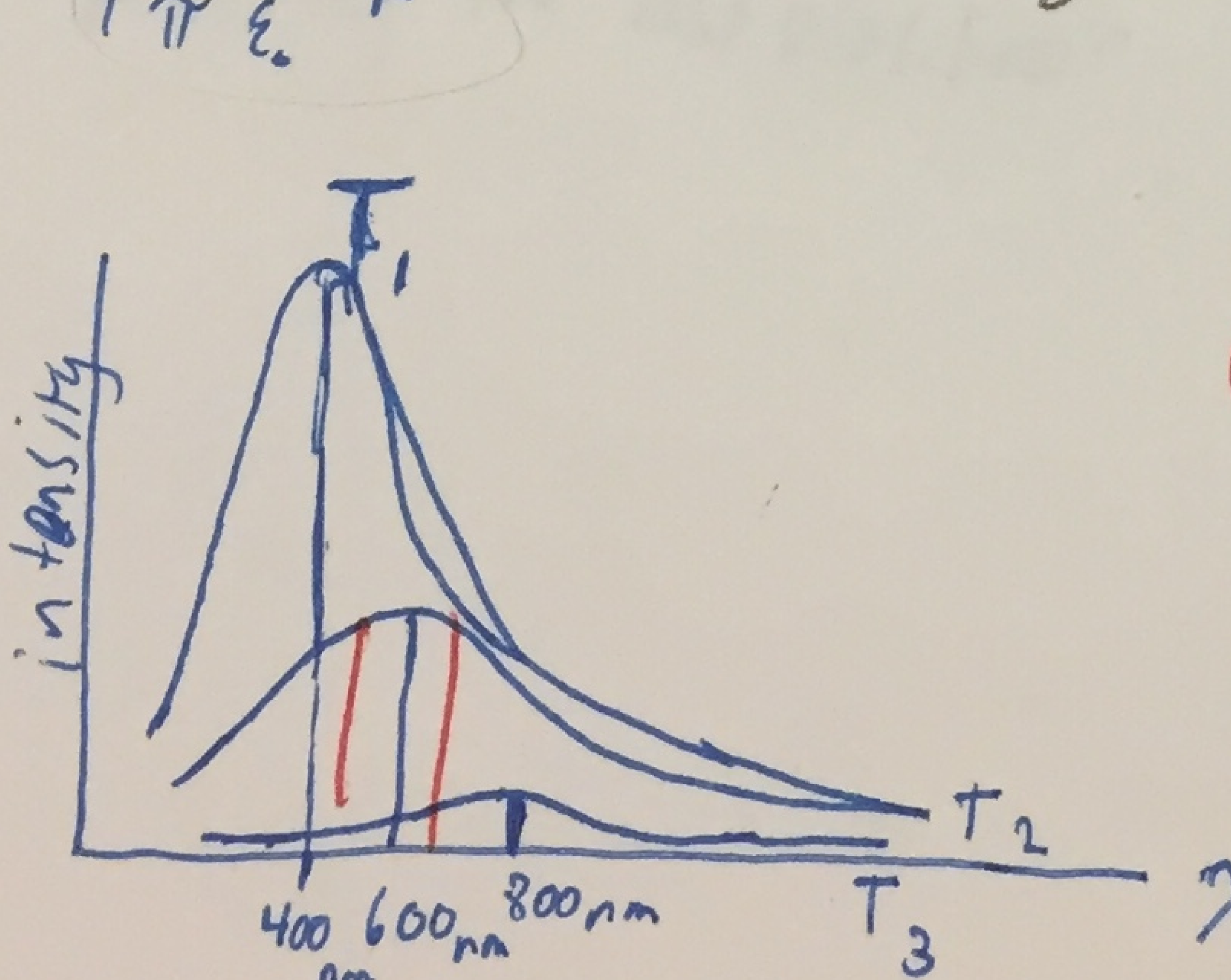


R 700
Y 600
G 500
V 400

c)



2. (*50 pts.*)

a) (*15 pts.*) Rank the following elements in terms of their first ionization energies: Li, C and F.

b) (*15 pts.*) Rank the same elements in terms of their electro-negativities.

c) (*20 pts.*) Finally estimate the effective charge of for the Be^+ for the L-shell electron. Assume that Be^+ is a one electron ion and use the Bohr Model to calculate the ionization energy of the L-shell electron using your estimated effective charge. Explain the reason for your choice of the effective charge.

$1s^2 2s^1$ $n=2$

a) Li < C < F 15

b) Li < C < F 15

c) $\cancel{E_n = h\nu\left(\left(\frac{1}{n}+\frac{1}{2}\right) - \left(\frac{1}{n_1}+\frac{1}{2}\right)\right)}$

$\cancel{h\nu\left(0 - \frac{3}{2}\right)}$

n = 2

$\Delta E = \frac{-Z^2}{\ }(-2.18\times10^{-18}J)\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$

$\Delta E = -(2)^2(-2.18\times10^{-18}J)$

$\Delta E = \cancel{6.54\times10^{-18}J}$ $\boxed{4.36\times10^{-18}J}$

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2 is the correct effective charge because a Be nucleus has 4 protons, but ~~one~~ two of the protons' ~~are~~ are attractive forces effectively canceled out by the ~~one~~ two remaining electrons in the inner shell. They are shielding the last electron from the full charge.

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$\nu = (3.29 \times 10^{15}) Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad n_2 > n_1$

3. (*50 pts.*)

a) (*10 pts.*) Sketch potential for an infinite square well potential (SQW) of length L

b) (*25 pts.*) Assume an electron is trapped in the SQW, L=6nm, calculate the frequencies for the first 4 lowest frequency transitions in the absorption spectrum.

c) (*15 pts.*) Sketch the absorption spectrum using these transitions and explain how the pattern of the lines differs from the Lyman-series in hydrogen and explain what caused the difference.

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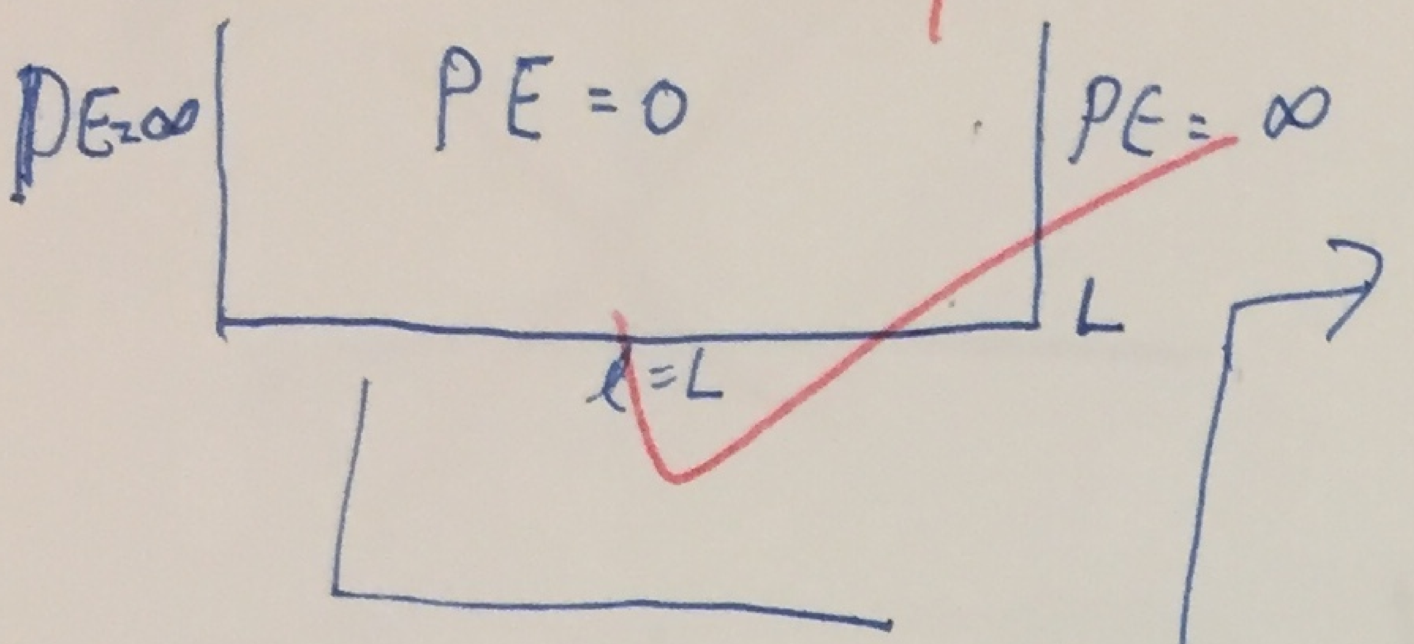
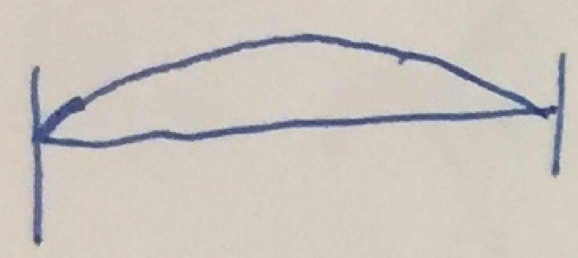
a)



b)



$L = 6nm$

$E = h\nu$

$\nu = \frac{E}{h} = \frac{c}{\lambda} = \frac{E}{h}$

$E_n = \frac{h^2 n^2}{8mL^2}$ $\quad E = \frac{ch}{\lambda}$ $\quad \lambda = \frac{ch}{E}$

$\lambda_1 = \frac{c\,8mL^2}{hn^2}$

$\lambda_1 = \frac{(3\times10^8 m/s)(8)(9.109\times10^{-31} kg)(6\times10^{-9} m)^2}{(6.626\times10^{-34} J\cdot s)(1)}$

$\lambda = \frac{1.188\times10^{-4}\ meters}{n^2}$

$\frac{1.188\times10^{-4}}{(1)}$

$\nu = \frac{c}{\lambda}$

$\lambda_1 = 1.188\times10^{-4}\left(\frac{1}{1^2}\right)$

$\lambda_1 = \cancel{8.4\times10^{-5}}\ 1.188\times10^{-4}$

$\lambda_2 = 1.188\times10^{-4}\left(\frac{1}{2^2}\right)$

$\lambda_2 = \cancel{1.680\times10^{-5}}$

$\lambda_2 = 2.969\times10^{-5}$

$\lambda_3 = 1.188\times10^{-4}\left(\frac{1}{3^2}\right)$

$\lambda_3 = 1.320\times10^{-5}$

$\lambda_4 = 1.188\times10^{-4}\left(\frac{1}{4^2}\right)$

$\lambda = 7.4\times10^{-6}$

$\boxed{\begin{aligned} \nu_1 &= 2.523\times10^{12}/sec \\ \nu_2 &= \frac{1.010\times10^{13}}{sec} \\ \nu_3 &= \frac{2.273\times10^{13}}{sec} \\ \nu_4 &= \frac{4.054\times10^{13}}{sec} \end{aligned}}$

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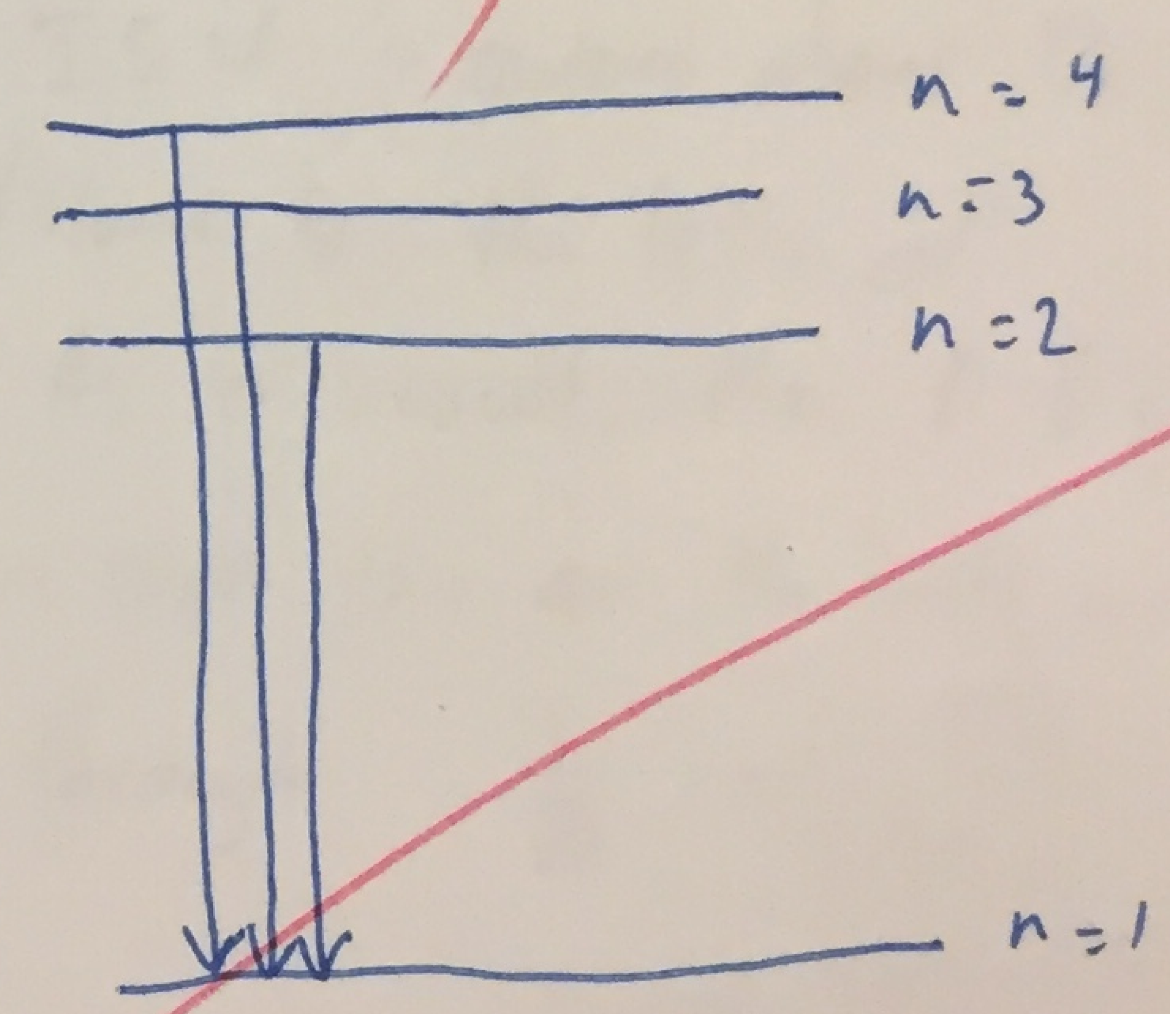
c)



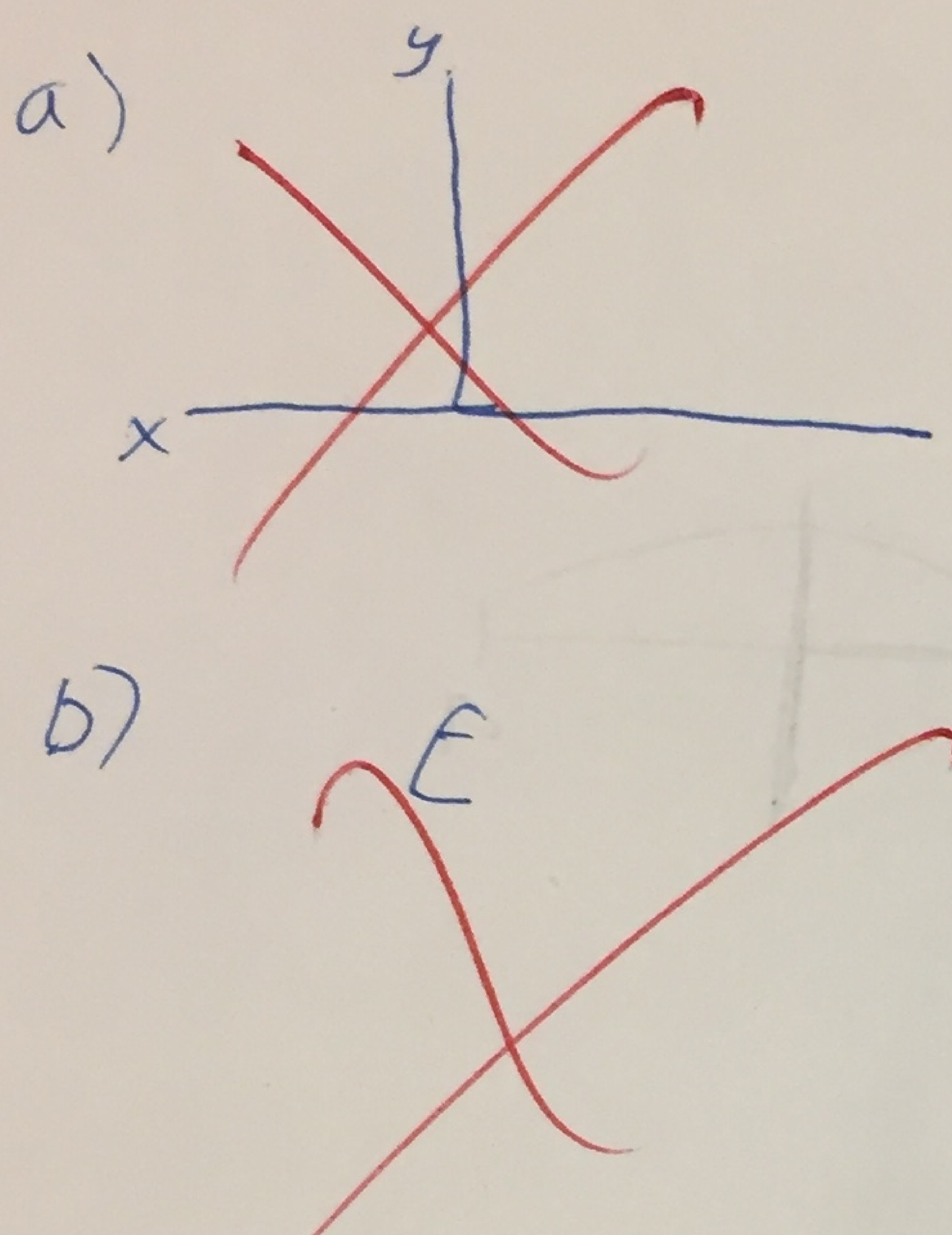
4. (*50 pts.*)

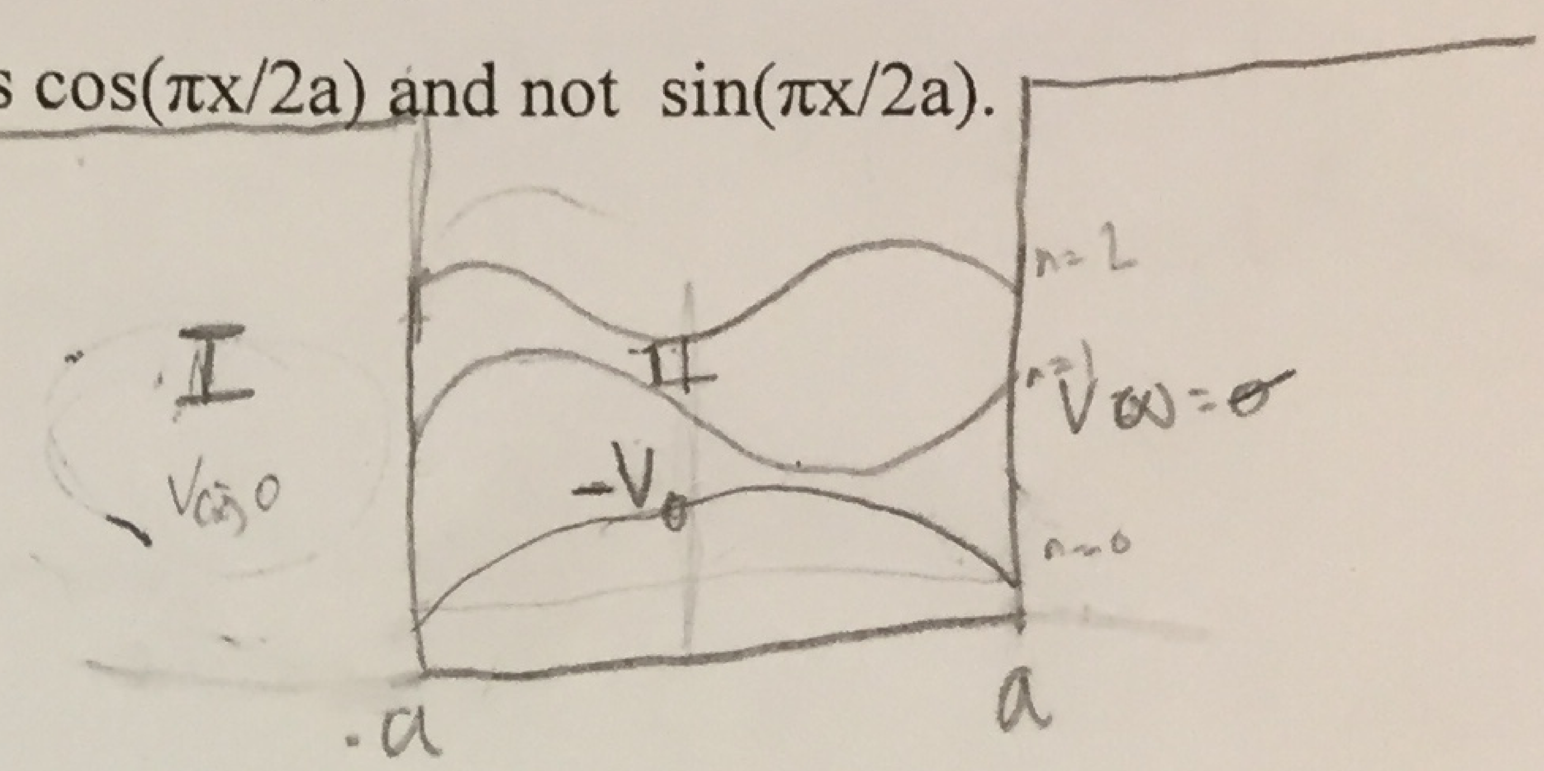
a) (*15 pts.*) Sketch the potential $V(x) = 0$ for $x \leq -a$ and $x \geq a$ and $-V_0$ elsewhere else!

b) (*20 pts.*) Assume the eigen function for the state with energy E, is approximately the infinite square well eigen function $\psi(x) = (1/\sqrt{a})\cos(\pi x/2a)$: sketch the eigen function in the region $-a \leq x \leq a$; use Schrödinger equation to calculate the energy E in terms of **m** and **a**. (Hint: plug the eigen function into Schrödinger)

c) (*15 pts.*) Explain why this eigen function is $\cos(\pi x/2a)$ and not $\sin(\pi x/2a)$.

a)





b) E

$L = 2a$

$$\frac{-h^2}{8\pi^2 m}\left(-\left(\frac{\pi}{2a}\right)^2\right)\psi_{(x)} + 0 = E\psi_{(x)}$$

$$\frac{h^2}{32ma^2} = E$$

c) This is because ~~when~~ the ISW is centered about 0, rather than $\frac{1}{2}L$. There is equal distance to the left of the origin and to the right. As a result, the $n=0$ state must have 0 nodes: when we sketch this on the well, we see that the function passes through $\frac{1}{\sqrt{a}}\cos\left(\frac{\pi(0)}{2a}\right)$.

$= \frac{1}{\sqrt{a}}\cos(0)$

$= \frac{1}{\sqrt{a}}(1)$

$= \frac{1}{\sqrt{a}}$

If the function used $\sin\left(\frac{\pi x}{2a}\right)$, the function would pass through 0, which would create a node at 0 given how the ISW is constrained