

**Homework IX**  
**Easy exercises for a general review before the test**  
*due November 10<sup>th</sup> 2006*

1) **Black body radiation**

The human body temperature is  $T = 310\text{K}$  and typical area  $A = 2\text{m}^2$ . A typical daily diet is based on 2000kCal with  $1\text{kCal} = 4184\text{J}$ . Stefan's constant is  $\sigma = 5.670 \times 10^{-8} \text{W m}^{-2} \text{K}^{-4}$ .

- a) Modeling a naked human body as a black body radiator, calculate the radiated power
- b) How does this compares to the metabolism rate corresponding to a normal diet?

2) **Photoelectric effect**

a) In a photoelectric effect experiment, a sample of aluminum is exposed to UV radiation of wavelength  $\lambda = 206\text{nm}$ . The stopping potential is measured to be

$V_{\text{stop}} = 1.92\text{V}$ . What is the work function  $\Phi_{\text{Al}}$  of aluminum? ( $1\text{eV} = 1.602 \times 10^{-19}\text{J}$ ,  $h = 6.63 \times 10^{-34}\text{J}\cdot\text{s}$ ,  $c = 299792458\text{m}\cdot\text{s}^{-1}$ )

b) The work function of sodium is  $\Phi_{\text{Na}} = 2.28\text{eV}$ . What is the threshold frequency? What is the corresponding wavelength? What part of the visible spectrum does it belong to?

3) **De Broglie's wavelength**

A bacteria of size  $0.5\mu\text{m}$  has a mass  $m = 10^{-16}\text{kg}$ . It moves a distance comparable to its length in one second. What is the de Broglie wavelength of the bacteria? How does that compares to the size of a hydrogen atom?

4) **Heisenberg's uncertainty relations**

a) The subatomic particle called the  $\Delta(1232)$  is an excited state of the proton and has a life time  $\Delta\tau \approx 10^{-23}\text{s}$ . What is in electron-Volt the uncertainty on its energy?

b) A proton ( $m_p = 938\text{MeV}/c^2$ ) is confined in the volume of a nucleus  $5\text{fm}$  across. Assuming it moves only in one dimension, estimate the proton minimum kinetic energy. How would you change your result when considering a more realistic three dimensional nucleus?

5) **Potential well**

Consider potential wells that can be parameterized as  $V(x) = a|x|^\alpha$  with  $-\infty < x < \infty$  and  $-\infty < \alpha < \infty$ . Using the Heisenberg uncertainty relation for position and momentum, find an expression for the approximative energy of the fundamental state of a particle of mass  $m$  in this potential. Is this approximation working for all values of  $\alpha$ ?

6) **Wave functions**

We consider particle of mass  $m$  in a potential well  $V(x)$  such that  $V(x)=\infty$  for  $x \leq 0$ ,  $V(x)=0$  for  $0 < x < a$  and  $x > 2a$ ,  $v(x)=-V_0$  for  $a \leq x \leq 2a$ . For given values of  $a$  and  $V_0$  there are only 4 bound states. Assume the ground state as an energy greater than but close to  $-V_0$  and the most excited state has an energy less than but close to zero.

a) Assimilating the 4 bound states to the 4 first state of the infinite square well of width  $a$ , express an approximative relation between  $a$  and  $V_0$  for the number of bound states to be 4. (In the infinite square well, the possible energies are

$$E_n = n^2 \frac{\pi^2 \hbar^2}{2ma^2} )$$

b) Discuss the solution to the time independent Schrodinger equation in each region and draw a representations the wave functions and probability densities for the four states.

7) **Tunneling**

A 1000kg car moves toward a bump in the road. The bump is  $H=0.1\text{m}$  high and  $0.5\text{m}$  long. The gravitational acceleration is  $g=10\text{m}\cdot\text{s}^{-2}$ . The car, in neutral, is going much slower than what would be necessary for it to pass over the bump. Give a rough estimate (non zero) of the probability the car has to tunnel to the other side of the bump.