Q1. (12 pts total, 3 pts for each sub-question)

Two relativistic rockets travel toward each other. As seen from Earth, rocket A, of proper length 500m, travels with a speed 0.8c. Rocket B, of proper length 1000m, has a speed of 0.6c. The speed of light is defined as "c" in this question.

a) What is the speed of the rockets relative to each other?

b) A Earth based observer sets his stopwatch to zero when the noses of the rockets pass each other. What will the stopwatch read when the tails of the rockets pass each other?

c) The Captain of rocket A, sitting at the nose of his rocket, sets his stopwatch to zero when the noses pass each other. What will his stopwatch read when the captain passes the tail of rocket B?

d) The captain of rocket B sets his stopwatch to zero when the noses pass each other. What will his stop watch read when the tails pass each others.

Q2. (12 pts total, 3 pts for each sub-question)

A 40W incandescent light bulb radiates from a tungsten filament a 3300K. We assume it radiates like a black body and the electric power is entirely converted into radiation.

a) What is the wave-length λ_m at the maximum of the radiation spectral distribution?

b) With corresponding frequency ν_m from above as an approximation of the average frequency, estimate how many photons are emitted by the light bulb per second.

c) You are looking at the light bulb from a distance of 5m, how many photons enter your eyes per second? (the diameter of people pupil is about 5mm)

d) The light bulb is now mounted in a lamp that redirect all the light along one direction. Estimate the force exerted by the light on the lamp?

Q3. (11 pts total)

a) In a photoelectric effect experiment, a sample of aluminum is exposed to UV radiation of wavelength λ=206nm . The stopping potential is measured to be V_{Stop}=1.92V . What is the work function Φ_{Al} of aluminum? (1eV=1.602×10^{-19} J , h=6.63×10^{-34} $J{\cdot}s$, c=299792458$m{\cdot}s^{-1}$) **(3 pts)**

b) The work function of sodium is Φ_{Na}=2.28 eV . What is the threshold frequency? What is the corresponding wavelength? What part of the visible spectrum does it belong to? **(4 pts)**

c) A bacteria of size 0.5 μm has a mass m=10^{-16} 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 pts)**

Q4. (8 pts total)

Compute the angle between angular momentum **L** and spin vector **S** in (a) the $d_{5/2}$ and (b) the $d_{3/2}$ states of atomic hydrogen.

Q5. (7 pts total)

Consider a gas of electrons and a gas of photons. Which has more states available at T = 1 K? Explain why?

Q6. (10 pts total)

A 1 mA beam of electrons moving at 3×10^6 m/s enters a region with a sharply defined boundary in which the electron speeds are reduced to 1×10^6 m/s by a difference in potential. Find the transmitted and reflected currents.

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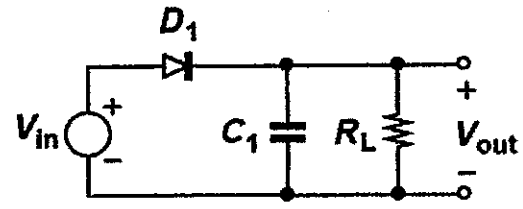
Q7. (10 pts total)

Find the eigen energy of a system with Hamiltonian $H=\frac{p^2}{2m}+U(x)$, where the potential $U(x)$ is defined as follows.

$$U(x)=\begin{cases}\frac{1}{2}m\omega^2x^2 & x>0\\ \infty & x\le 0\end{cases}$$

Q8. (10 pts total)

For a rectifier with a filter capacitor (see the circuit below), the input V_{in} is a sinusoid with a peak value V_p, and assume the diode to be ideal. The period of the input sinusoid is T and $C_1 R_L >> T$.



(a) please draw and explain waveforms (voltage versus time) of the input signal V_{in}, and output signal V_{out}

(b) please draw and explain waveforms (current versus time) of the diode (D_1) current, and resistor (R_L) current

Q9. (15 pts total)

(A) On a p-type body, please draw the cross-section view of a CMOS integrated circuit. (Hint, PMOS and NMOS need to be included. PMOS to be formed on n-well) (Contact electrodes need to be specified)

(B) For a CMOS inverter. Assuming a bias voltage V_{DD}, and PMOS and NMOS are matched. Please draw the voltage transfer characteristic of the CMOS inverter.

(C) In (B), please specify the regions where (1) NMOS in saturation, PMOS in triode region (2) NMOS and PMOS in saturation (3) PMOS in saturation, NMOS in triode region

Q10. (5 pts total)

What is the main difference of "Conductors, Insulators, and Semiconductors"?

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