Student ID Number: ________

# PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part D, August 21, 2018, 14:00–17:00

## Instructions

1. You may use a calculator and CRC Math tables or equivalent. No other tables or aids are allowed or required. You may **NOT** use programmable calculators to store formulae.

   (a) All of the problems will be graded and will be tabulated to generate a final score. Therefore, you should submit work for all of the problems.

   (b) For convenience in grading please write legibly, use only one side of each sheet of paper, and work different problems on separate sheets of paper. The sheets for each problem will be stapled together but separately from the other two problems.

   (c) Your assigned student **ID Number**, the **Problem Number**, and the **Page Number** should appear in the upper right hand corner of each sheet. Do **NOT** use your name anywhere on the Exam.

   (d) All work must be shown to receive full credit. Work must be clear and unambiguous. Be sure that you hand your completed work to the Proctor.

   (e) Each problem is worth 10 points.

   (f) Following the UF Honor Code, your work on this examination must reflect your own independent effort, and you must not have given, nor received, any unauthorized help or assistance. If you have any questions, ask the Proctor.

**University of Florida Honor Code:** We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment."*

**DO NOT OPEN EXAM UNTIL INSTRUCTED**

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D1. **(Tanner)** Consider a set of photons in a box in equilibrium at temperature $T$. Start with the photon's partition function

$$Z = \sum_{n=0}^{\infty} e^{-\beta n\hbar\omega}$$

where $\beta = 1/k_B T$ with $k_B$ Boltzman's constant and $\omega$ is the photon frequency. ($\hbar\omega$ is the photon energy.) We know that the number of photons is not constant and want to calculate the fluctuations in the number of photons at each frequency $\omega$.

(a) [**3 points**] The average number of photons with frequency $\omega$ is

$$\langle n \rangle = \frac{\sum_{n=0}^{\infty} n e^{-\beta n\hbar\omega}}{\sum_{n=0}^{\infty} e^{-\beta n\hbar\omega}}.$$

Write a corresponding expression for $\langle n^2 \rangle$.

(b) [**3 points**] Now show that

$$\langle n^2 \rangle - \langle n \rangle^2 = -\frac{1}{\hbar\omega}\frac{\partial \langle n \rangle}{\partial \beta}.$$

(c) [**4 points**] From the expression for the equilibrium $\langle n \rangle$ (the Bose-Einstein distribution function) use the result just found to find the relative fluctuations in the squared photon number:

$$\frac{\langle n^2 \rangle - \langle n \rangle^2}{\langle n^2 \rangle}.$$

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D2. **(Ray)** Parallel beam of light is going horizontally through the convergent lens with focal distance $f$. A thin glass plate of width $w$ and index of refraction $n$ is placed right after the lens perpendicular to the optical axis of a lens.

(a) [**6 points**] Calculate the change in position of a focal point. You can use small angle approximation $\sin\theta \approx \theta$.

(b) [**4 points**] If glass plate is tilted by small angle $\alpha$, what is the additional change in position of focal point in vertical and horizontal directions? For simplicity give answer only to the first order in $\alpha$.

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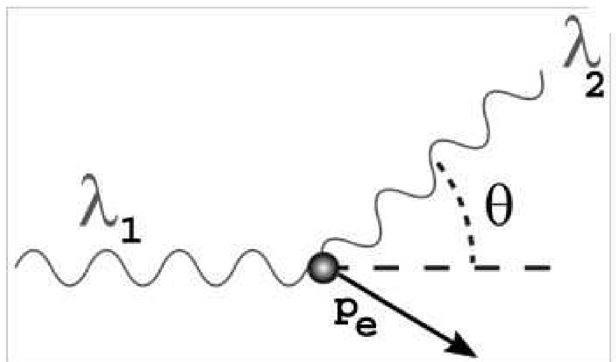
D3. **(Stewart)** In the Compton effect, an incoming photon of wavelength $\lambda_1$ scatters off a stationary charged particle (in the figure, an electron, $m_e = 0.511\ MeV/c^2$), with the final state being the scattered photon now having increased wavelength $\lambda_2$ and the scattered electron having momentum $p_e$ as shown in the diagram. In order to solve this problem, you need to derive the relativistic Compton equation (using conservation of energy and momentum), which relates the wavelength of the incoming photon to the wavelength of the outgoing photon and the momentum of the scattered particle.




(a) [**2 points**] Suppose $\lambda_1 = 0.00300$ nm. What is the energy (in units of MeV, 3 significant figures) of the incoming photon? ($hc = 1239.8\ eVnm$, $c = 3 \times 10^8\ m/s$)

(b) [**4 points**] If $\Theta = 45°$ what is $\lambda_2$ (units of nm, 3 significant figures)?

(c) [**4 points**] If the 0.00300 nm wavelength photon scatters off of a *proton* ($m_p = 938.2722\ MeV/c^2$) instead of an electron (consider how you have to alter Compton's equation), what is $\lambda_2$ (in units of nm, 3 significant figures)?