Student ID Number: ________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part D, August 18, 2021, 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. (a) [**4 points**] The heat of melting (latent heat) of ice is about 300 J/g. At one atmosphere, ice (of course) melts at 273 K. One gram of water has a volume of 1 cm^3 , while one gram of ice has a volume of about 1.1 cm^3 . If the pressure is increased by 1 MPa = 10^6 N/m^2, by approximately how much will the melting point of ice change? (Make sure to state whether the change you calculated represents an increase or decrease in the melting point.)

(b) [**3 points**] An electrically operated heat pump delivers 1200 J per second to the interior of a house at 300 K. It takes heat from the exterior of the house at a temperature of 250 K. What is the minimum possible electrical power consumption of the heat pump?

(c) [**3 points**] Two identical plates of copper are brought into thermal contact. Initially, one is at 100°C and the other at 0°C. The plates exchange heat only with each other. What is the total change in entropy from the initial contact until the two blocks are in thermal equilibrium with each other? (You may assume that the heat capacity of each block, c, is constant over this temperature range, and you may neglect volume changes.)

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D2. A single proton collides head-on (i.e. along one dimension) with another proton traveling at the same speed in the opposite direction, and produces an additional proton and antiproton ($p + p \to p + p + p + \bar{p}$).

(a) **[3 points]** In this center-of-mass reference frame, what is the minimum kinetic energy (i.e. threshold kinetic energy) required of each initial proton to produce the extra proton and antiproton in terms of the proton rest mass energy? (The antiproton has the same mass as the proton.)

(b) **[2 points]** What is the minimum speed of each proton, as a fraction of the speed of light, required of the reaction in this center-of-mass frame?

(c) **[2 points]** What is the speed of one proton in the reference frame of the other proton, as a fraction of the speed of light?

(d) **[3 points]** Now consider a fixed-target collision where a single proton collides head-on with another proton at rest and produces an additional proton and antiproton. In this reference frame, what is the minimum kinetic energy required of the incident proton in terms of the proton rest mass energy?

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D3. For this question consider the Earth and Sun as spherical black bodies with surface temperatures T_E, T_S and radii R_E, R_S respectively. The Earth, not being an ideal black body, reflects a fraction α of the energy falling upon it (this is called the albedo and is due to clouds reflecting incoming radiation), and radiates a fraction $\epsilon < 1$ of the "ideal" black body radiation into space (i.e. it traps a fraction $1 - \epsilon$ where ϵ is the emissivity. This is known as the greenhouse effect). For this question, assume that the Earth has no internal sources of energy.

(a) [**1 points**] The Stefan-Boltzman law states that an ideal black body radiates energy in proportion to its area and the fourth power of its temperature. What are the units of the proportionality constant σ (also known as the Stefan–Boltzmann constant)?

(b) [**1 points**] What is the total power P_S radiated by the Sun?

(c) [**2 points**] If the Earth-Sun distance is d, how much of the Sun's radiated power is absorbed by the Earth?

(d) [**2 points**] What is the total power radiated by the Earth?

(e) [**2 points**] What is the equilibrium temperature of the Earth's surface T_E in terms of the Sun's surface temperature T_S, α, ϵ, and any other relevant constants?

(f) [**2 points**] The Moon can also be considered a spherical black body at the same distance from the Sun as the Earth, i.e. the average Moon-Sun distance is also d, its albedo and emissivity are $\alpha_M = 0.15$ and $\epsilon_M = 0.9$ respectively, and the albedo, emissivity and average surface temperature of the Earth are $\alpha = 0.30$, $\epsilon = 0.9$, and $T_E = 15^\circ\,\mathrm{C}$, what is the average surface temperature of the moon T_M? Express your answer in terms of the Earth's surface temperature T_E, α, α_M, ϵ, ϵ_M, and any other relevant constants, *as well as* provide a numerical value in degrees C.