Student ID Number: ___________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part D, 6 January 2006, 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. Each problem is worth 10 points.
7. 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. **Space ninja:** At the end of a spacewalk, a ninja astronaut finds herself at a distance of 20 m from the space station, but drifting away from the station at a velocity of 2 m/s. Sensing trouble, she tries to think of the best way to return to the space station. In her possession, she has a 10-kg ninja grappling hook attached to a 45-m silk rope of negligible mass. The astronaut's mass is 40 kg.

(a) (4 points) From her training days as an astronaut she remembers the textbook example of Lt Col Stumblebum who, being in a similar situation, managed to save himself by throwing stuff in a direction opposite to the space station. Given that she is able to throw the hook with a maximum speed of 5 m/s *with respect to herself*, will she be able to save herself by pulling off the Stumblebum trick?

(b) (6 points) From her training days as a ninja she remembers the main purpose of the grappling hook and now considers the possibility of throwing the hook (with the same maximum speed of 5 m/s) *towards* the space station, getting it hooked and then slowly pulling herself by the rope towards the station. The danger here is that the rope may be too short. Will she be able to pull off this space-ninja stunt?

D2. Here (as elsewhere in the context of thermodynamics) the c's are the molar specific heats at constant pressure and constant volume and R is the gas constant.

(a) (4 points) For a non-ideal system, $c_p - c_v = Tv\beta^2/\kappa$, where $\beta = v^{-1}\partial v/\partial T|_P$ is the volume thermal expansion coefficient, and $\kappa = -v^{-1}\partial v/\partial P|_T$ is the isothermal compressibility. Please derive this result.

Hint: You can start with the entropy $S(P, T)$ or $S(v, T)$ and arrive at the following equation: $C_p\, dT - Tv\beta dP = C_v\, dT + (T\beta/\kappa)dv$.

(b) (2 points) Show that for an ideal gas, $c_p - c_v = R$.

(c) (1 point) For a quasi-static adiabatic process of an ideal gas, assuming the adiabatic index $\gamma = c_p/c_v$ to be a constant, show that $TV^{\gamma-1} =$ constant.

(d) (1 point) At about 100 ms after detonation of a uranium fission bomb, the "ball of fire" consists of a sphere of gas with a radius of about 50 ft and a temperature of 300,000 K. Making very rough assumptions, estimate at what radius its temperature would be 3000 K.

(e) (2 points) Assuming helium to be an ideal monatomic gas, we begin at 300 K and a pressure of 1 atmosphere. The gas is then compressed quasi-statically and adiabatically to a pressure of 5 atmospheres. What is the final temperature of the helium gas?

D3. (Useful constants: $\sigma = 5.6703 \times 10^{-8}$ W/m^{2}K^4, $hc = 1239.8$ eV nm.)

(a) (3 points) In 1905 Einstein published his famous paper explaining the photoelectric effect. In the table are given photoelectric work functions Φ for several elements.

Element	Φ (eV)
Na	2.28
Mg	3.68
Al	4.08
Ag	4.73
Ni	5.01
Pt	6.35

What color of light has the *longest* wavelength λ that would *still be energetic enough* to eject electrons from Na? Show how you get your answer.

Color	λ (nm)
Violet	400
Indigo	445
Blue	475
Green	510
Yellow	570
Orange	590
Red	650

(b) (3 points) A blackbody radiates a broad spectrum of photon energies following Planck's law, which is peaked at λ_{max}. The blackbody that people observe most often is our sun, surface temperature 5800 K, which has λ_{max} around 500 nm (*i.e.*, close to green.) What would the surface temperature (to two significant figures) of a star have to be so that its λ_{max} matched the work function for the element Al, *i.e.*, 4.08 eV?

(c) (4 points) Neptune can be treated as a perfect blackbody, with a surface temperature of only 59 K. If Neptune is 49,500 km in diameter, what is the total power radiated by this cold planet, to three significant figures?