

Your name: _____

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Midterm Exam – PHYS 3306 Intermediate Physics

Prof. Bhattacharya



Duration: 45 minutes

Date: April 6, 2026

Total points: 12

You have 45 minutes to complete this exam. You may bring one page of notes, front and back. You may leave numerical answers in exact form (e.g., as fractions or roots) or use a calculator (no smartphone). Each question is worth **4 points**.

Question 1. (*4 points*)

A 2.0 mol sample of an ideal monatomic gas undergoes a reversible process forming a straight line on a T-S diagram from $S = 5.00 \text{ J/K}$, $T = 400.0 \text{ K}$ to $S = 20.0 \text{ J/K}$, $T = 200.0 \text{ K}$.

- (a) How much energy is absorbed as heat by the gas?
- (b) What is the change in the internal energy of the gas?
- (c) How much work is done by the gas?

Question 2. (*4 points*)

A large, open-top cylindrical water tank rests on the ground. The tank is filled with water (density ρ) to a total height H . A small circular hole is punctured in the side of the tank at a height h above the ground. Assume the cross-sectional area of the tank is vastly larger than the area of the small hole, meaning the water level at the top of the tank drops at a negligible speed. Also, assume both the top of the tank and the exiting water stream are exposed to atmospheric pressure (P_{atm}).

- (a) Exit Velocity: Using Bernoulli's equation, derive an algebraic expression for the speed v at which the water initially exits the hole. Express your answer strictly in terms of g (acceleration due to gravity), H , and h .
- (b) Impact Distance: Once the water exits the hole, it undergoes projectile motion. Derive an expression for the horizontal distance x from the base of the tank where the water stream strikes the ground. Express your answer strictly in terms of H and h .
- (c) Maximum Range: At what specific height h (in terms of H) should the hole be punctured to maximize the horizontal distance x the water travels?

Question 3. (4 points)

A 1.5 mol sample of an ideal monatomic gas is initially at State 1 with a pressure $P_1 = 1.0 \times 10^5$ Pa and a volume $V_1 = 0.020$ m³. The gas undergoes the following cyclic process:

1. **State 1** → **State 2**: The gas is heated at a constant volume (isochorically) until its pressure triples.
 2. **State 2** → **State 3**: The gas expands isothermally until its pressure returns to 1.0×10^5 Pa.
 3. **State 3** → **State 1**: The gas is compressed at a constant pressure (isobarically) back to its original volume.
- (a) Sketch a labeled P-V diagram for this complete cyclic process. Clearly indicate the direction of the cycle and label the states 1, 2, and 3.
- (b) What is the volume of the gas at State 3 (V_3)?
- (c) Calculate the net work done by the gas during one complete cycle.

Additional space for notes/calculation: