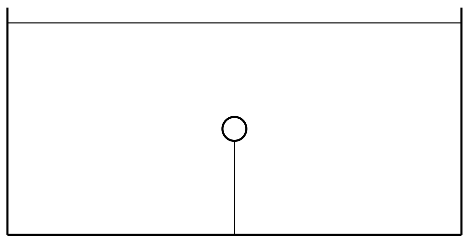
Exam 3; Phys 185 Name ________________

**Note:** As I walk around, you can ask me for help; for example, to supply an equation or a number you have forgotten down, or to give you algebra aid. If you do, however, I will write down what help I provided on your exam, and grade your answer accordingly.

**1. (20 points)** Explain why heat flows from hot to cold but not the other way around.

**2. (40 points)** You take a table tennis ball with mass 0.0027 kg, and attach it to the bottom of a tub of water with a thread. The radius of the ball is 0.020 m, and the depth of the ball is 0.26 m. The density of water is 1000 $kg/m^3$. The volume of a sphere is $\frac{4}{3}\pi r^3$.

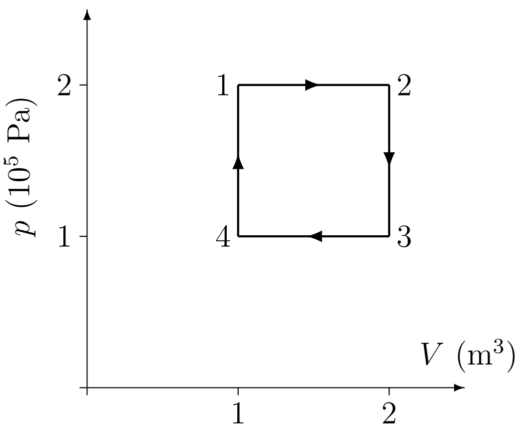


(a) Find the tension in the thread.

(b) You fail to use waterproof glue, and the thread comes unattached to the ball. How long does it take for the ball to rise to the surface, assuming there is no drag force on the ball?

(c) More realistically, the drag force in the water is large, and the ball will reach terminal speed almost instantly. With $D = \frac{1}{2}C_D\rho Av^2$, where $C_D = 0.52$ and $A$ is the cross-sectional area of the ball, calculate how long it will take the ball to rise to the surface.

**3. (50 points)** You have a monatomic ideal gas with an initial pressure of $2.0 \times 10^5$ Pa and volume of 1.0 $m^3$ (state 1). You then put it through the cycle shown in the $p$–$V$ graph.




(a) For the process taking the gas from state 1 to state 2, find $\Delta E_{th}$ (the change in thermal energy), $Q$ (the heat added to the gas), and $W$ (the work done *by* the gas).

(b) Find $\Delta E_{th}$, $Q$, and $W$ for the process $2 \rightarrow 3$.

(c) Find $\Delta E_{th}$, $Q$, and $W$ for the process $3 \to 4$.

(d) Find $\Delta E_{th}$, $Q$, and $W$ for the process $4 \to 1$.

(e) Find the *total* $\Delta E_{th}$, $Q$, and $W$ values for the full cycle. Are these as you would expect?

(f) The cycle is a heat engine. If you total the positive $Q$'s from the steps in the cycle, you will get $Q_H$, the amount of heat input to the gas over a cycle. If you total the negative $Q$'s, you will get $-Q_C$, the discarded exhaust heat. Find $Q_H$, $Q_C$ and $W$ for this cycle as a heat engine.

(g) Find the efficiency of this heat engine.

**4. (30 points)** A person with surface area of 2.0 $m^2$ and a skin temperature of 34°C stands naked in a room where the air is 22°C but the walls are 16°C.

(a) The thickness of the "dead air" layer next to the skin is 0.004 m, with thermal conductivity 0.025 W/m·K. What is the rate of this person's heat loss due to conduction?

(b) If skin's emissivity is 0.95, what is the *net* radiative heat loss to the walls? (Stefan-Boltzmann constant: $5.67 \times 10^{-8}$ W/$m^2$·$K^4$.)

(c) When at rest, this person has a power consumption of 100 W to keep their metabolism going. How much total power do they need from their food to stay alive?

**5. (30 points)** As in your lab exam, you have a cart with mass $m$ on a horizontal track. Assume friction, weight, and the normal force are the only forces acting on the cart. You let the cart go and watch it slow down. Your motion detector gives you $x_i$ and $v_i$ at time $t_i$, $x_f$ and $v_f$ at time $t_f$, and the constant acceleration $a$ between times $t_i$ and $t_f$.

(a) Write down an equation for $W_f$, the work done by friction in this interval.

(b) If $\Delta K$ is the change in kinetic energy between $t_i$ and $t_f$, mathematically show that $\Delta K = W_f$ or that $\Delta K \neq W_f$. (*Hint:* For 1D motion with constant acceleration, $v_f^2 = v_i^2 + 2a(x_f - x_i)$.)

**6. (30 points)** You have two identical-looking cylinders, with the same mass $m$ and radius $r$. Cylinder 1 has a moment of inertia $I_1 = mr^2$, while cylinder 2 has $I_2 = kmr^2$, with $k$ an unknown constant. You let them go from rest from the exact same height on an inclined plane, and let them roll without slipping. When they reach the bottom of the incline, you measure their center-of-mass speeds, finding $v_1 = 0.94\, v_2$. What is $k$?