Student ID Number: ________

PRELIMINARY EXAMINATION
Department of Physics
University of Florida
Part C, January 4, 2020, 9:00–12:00

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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C1. We reel a thin wire around a disk with radius $r = 0.1\,\mathrm{m}$ negligible mass, which is fixed at its center and is free to rotate (see image). The plane of the disk is vertical. We hang a small mass of $m = 100\,\mathrm{g}$ on the free end of the wire. A massless rod of length $R = 0.2\,\mathrm{m}$ is glued on the disc along the radial direction from the center, and a small mass M is placed at the end of the rod.

Initially, the small mass m is supported from underneath, and the system is stationary in the position shown in the image. After we remove the support under mass m, it descends, while the other mass M rises such that the rod, which was initially vertical, moves up and reaches as high as 60° angle from vertical. The disk experiences weak friction, and the system eventually stops such that the mass M will be at an angle ϕ from vertical.

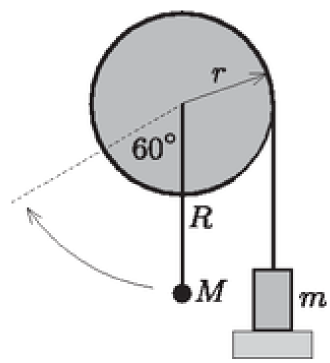

Figure 1: Illustration.

(a) [**3 points**] What is the mass M of the body fixed on the rod?

(b) [**3 points**] What is the angle ϕ?

(c) [**4 points**] Moving the system slightly out of equilibrium, what will be the period of the resulting oscillation? *(Hint: the period of harmonic oscillation is $T = 2\pi\sqrt{I/k}$ for I moment of inertia and $\tau = k\alpha$, where τ is torque and α is the angular displacement.)*

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C2. A block of mass m slides on a horizontal surface. The surface is treated with special lubricant such that the block experiences viscous drag described by

$$\vec{f_d} = -\alpha\sqrt{v}\hat{v} \quad (\alpha > 0),$$

where $\vec{v}$ is the velocity of the block.

(a) [**3 points**] The block started to move with a speed of v_o at $t = 0$. Calculate the speed of the block at a later time t

(b) [**3 points**] How long does the block travel until it stops?

(c) [**4 points**] Now the surface is inclined to make an angle θ with the horizontal surface. If the block is released from the rest, what will the terminal speed of the block. Assume that the inclined surface is infinitely long.

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C3. A reversible cyclic heat engine operates between high temperature T_h and low temperature T_l reservoirs as shown in the schematic. The heat flows in each cycle are indicated by Q_h and Q_l respectively and the work done per cycle is W.

(a) **[2 points]** Write an expression for the First Law of Thermodynamics using the symbols in the figure.

(b) **[1 point]** One statement of the Second Law of Thermodynamics is that no heat engine working between two different temperatures is more efficient than a Carnot engine. Write an expression for the Carnot efficiency η_C as a function of the reservoir temperatures T_h and T_l.

(c) **[1 point]** Reconfigure the energy flows in a revised sketch showing consistency with the First Law of Thermodynamics but a violation of the Second Law.

(d) **[2 points]** Calculate and compare the **total** entropy changes associated with the Carnot engine of the schematic and the situation where the engine is removed and heat Q is transferred directly from the high to low temperature baths.

(e) **[1 point]** If dissipation is present and the now irreversible engine has an efficiency $\eta < \eta_C$, comment on how the entropy changes associated solely with the engine are affected.

(f) **[3 points]** A start-up company claims to have developed an engine that in one hour takes in 1.10×10^8 Joules at 400 K, rejects 5.0×10^7 Joules at 200 K, and delivers 16.7 kW hours of work. Explain whether this engine obeys the First and Second Laws of Thermodynamics? Is it a good idea to invest in the development of this engine? If so, why, if not, why not?

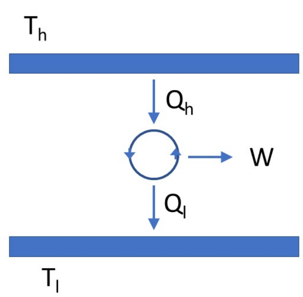

Figure 2: Schematic of heat engine