Student ID Number: ________

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part C, August 21, 2018, 09:00–12:00

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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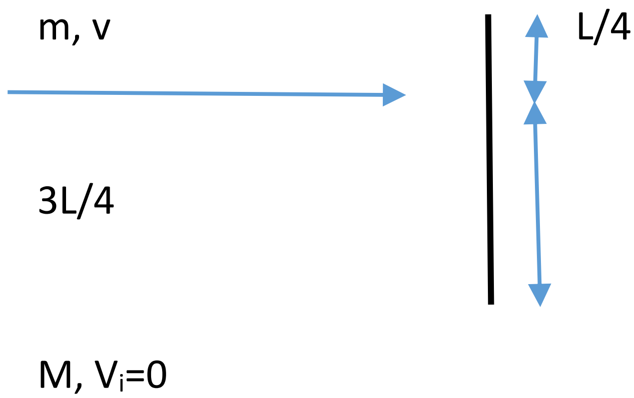
C1. **(Yelton)** A stationary uniform stick of length L and mass M is on frictionless ice. It is hit, at right angles, by a bullet skimming over the ice, which hits at $L/4$ from one end. The bullet has high speed v, and mass, $m \ll M$ (so m can be ignored in any equation when it is added to M), and embeds itself in the stick putting it in motion.



(a) [**6 points**] How much kinetic energy is "lost" in this inelastic collision?

(b) [**4 points**] Immediately after the collision, how fast is the bullet (by now, embedded in the moving stick), moving?

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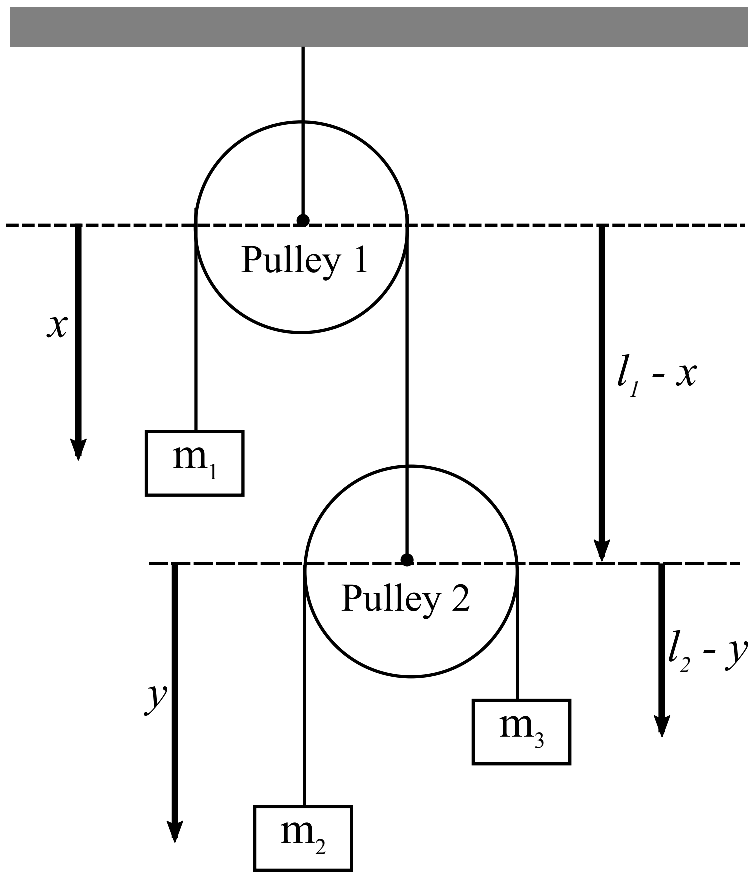
C2. **(Whiting)** Consider a double Atwood machine as shown in the figure. Assume both pulleys are massless.



(a) [**3 points**] Using the generalized coordinates shown, construct expressions for the kinetic and potential energies of the system.

(b) [**4 points**] Write down the Lagrangian and hence obtain the (separated) equations of motion for the two generalized coordinates.

(c) [**3 points**] Find the conditions such that each pulley 1 and pulley 2 do not separately rotate, and hence the conditions such that neither rotates.

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C3. **(Stanton)** The density of states in k-space in two dimensions, is:

$$D(k)dk = \frac{A}{2\pi} k dk.$$

"Ripplons" are the "quantum" of the small harmonic oscillations on the two-dimensional *surface* of a fluid. (Similar to the "photon" being the quantum of the electromagnetic field). They have a *dispersion relation* $\omega(k) = \alpha k^{3/2}$, where $\alpha = (\gamma_s/\rho)^{1/2}$, ρ is the fluid density, and γ_s is the surface tension (a constant). The ripplons are *spinless* and they move in a two-dimensional area A, with wave vector $\mathbf{k}$. This problem is similar to that of Black Body Radiation, except now we are working in a two-dimensional space and dispersion relation has $\omega(k) = \alpha k^{3/2}$ instead of $\omega(k) = ck$ for photons in the black body problem.

(a) [**3 points**] Find the average energy (at temperature T) in a *single ripplon mode* of frequency ω. You may ignore any zero point energy.

(b) [**3 points**] Find the high temperature limit of that average energy, for $k_B T$? hω. Explain why this is reasonable – that is, why it is consistent with what you expect from classical physics.

(c) [**4 points**] Find the total contribution of *all the modes* to the surface energy (energy per unit surface area) of the fluid, at temperature T. Express your answers in terms of a dimensionless integral. That is, the integral must not be a function of any system parameters (T, α, etc.). Hence, *obtain the dependence of the total energy on temperature.* You do not need to evaluate the integral.