Student ID Number: __________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part C, January, 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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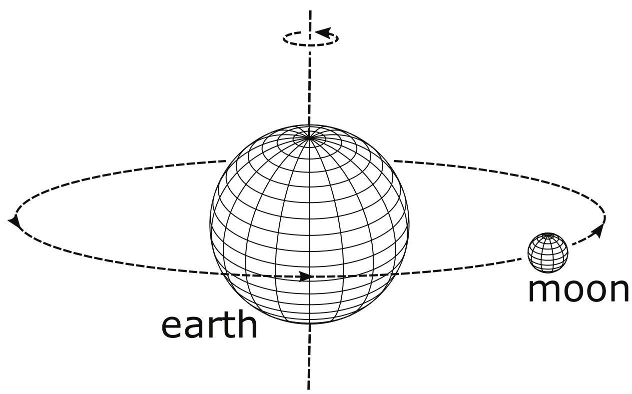
C1. **(Hamlin)** The average length of a day is increasing by about 1.7 ms per century (due to tidal effects from the moon). In this problem, you will estimate how much the earth moon distance changes in one century using the highly simplified model of the earth-moon system shown in the figure below (which is not to scale).



You may make the following approximations:

- The earth and moon rotate about a common axis in the same direction.[1]
- The earth is a sphere of uniform density.
- The moon's orbit around the earth is circular.
- The ratio of the earth's mass to that of the moon is large enough that you may consider the center of mass of the system to be at the center of the earth.

The following values may also be helpful:

Quantity	**Value**
M: mass of earth	6×10^{24} kg
R: radius of earth	6.4×10^{6} m
m: mass of moon	7.3×10^{22} kg
r: earth moon distance	3.75×10^{8} m
T: period of moon's orbit around earth	27.3 days

(a) [**4 points**] Taking the earth as the center of rotation, and treating the moon as a point mass, write an expression for the angular momentum of the moon in terms of only m, M, r, and the gravitational constant G.

(b) [**6 points**] After 1 century by how many meters will the earth moon distance change? Give your answer in meters. Is the distance increasing or decreasing?

[1] In reality, the plane of the moon's orbit is tilted from the earth's equatorial plane by almost 30°, but we will ignore this fact for the purpose of simplifying the problem.

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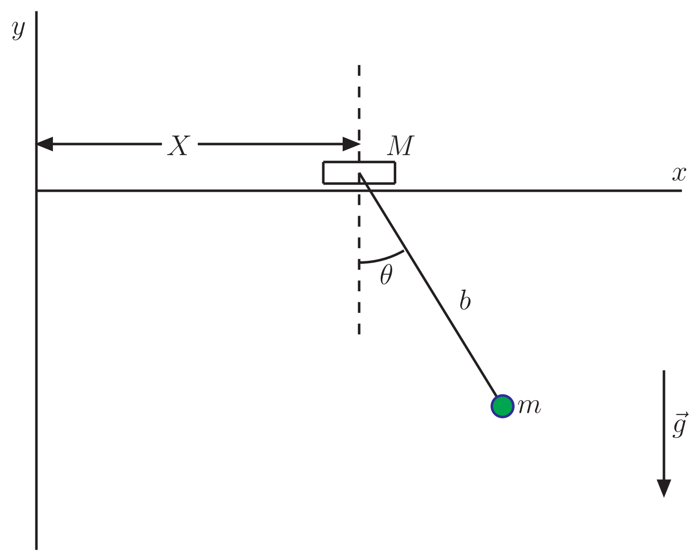
C2. **(Matchev)** A plane pendulum of length b has a bob of mass m. The pendulum is suspended from the center of a cart of mass M which can move on a frictionless, horizontal table. You may ignore the vertical dimension (height) of the cart. Gravity $\vec{g}$ is also present.



(a) [**1 point**] Using $\{X, \theta\}$ as your generalized coordinates, find expressions for the rectangular coordinates (x_m, y_m) of the bob and (x_M, y_M) of the cart.

(b) [**3 points**] Find the kinetic energy and the potential energy of the system, and finally, construct its Lagrangian.

(c) [**2 points**] Derive the Euler-Lagrange equations of motion for the pendulum+cart system.

(d) [**2 points**] Identify all conserved quantities for this system.

(e) [**2 points**] Find the frequency of small amplitude oscillations of the pendulum bob (you may use the approximation $\sin\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ). Check the validity of your answer in the limit $M \gg m$.

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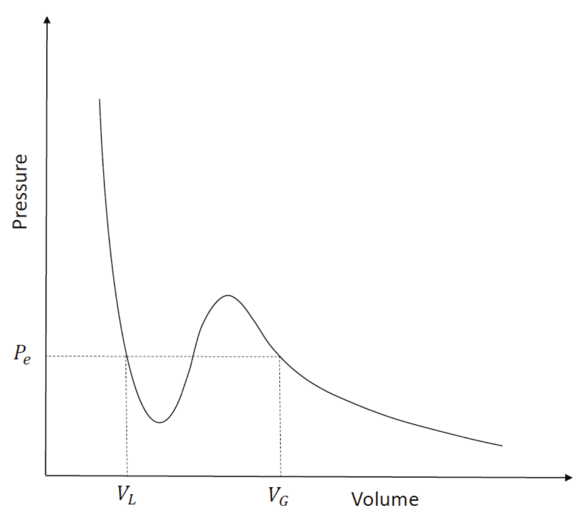
C3. **(Lee)** An elastic band is a thermodynamic system and can be described by the following equation of state:

$$f = aT\left\{\frac{L}{L_o} - \frac{L_o^2}{L^2}\right\},$$

where a is a positive constant, f is the tension applied, and L_o is the original length. This system is very similar to an ideal gas which is described by the ideal gas equation. Considering the physical nature of tension applied, one can construct a differential relation based on the first law of thermodynamics equivalent to $dU = TdS - pdV$ for an ideal gas: $dU = TdS + fdL$. Here, U, S, p, and V represent internal energy, entropy, pressure, and volume, respectively.



(a) [**2 points**] For an ideal gas,

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p.$$

This thermodynamic relation directly leads to the fact that the internal energy of an ideal gas is a function of temperature only. Apply a similar method to prove that the internal energy of an elastic band is not a function of length (a function of T only).

(b) [**3 points**] The elastic band is *isothermally* at T_o and *reversibly* stretched to $2L_o$ from its original length. Calculate the change in heat, ΔQ.

(c) **[3 points]** The rubber band is released *adiabatically* but *freely* from $2L_o$ at T_o back to the original length. What is the change in entropy in this process?

(d) **[2 points]** Do you expect to see temperature change during the process described in (c)? Provide your physical reasoning to justify your answer.