Week 5 Challenge Homework

Free Body Diagrams and Newton's 2nd Law

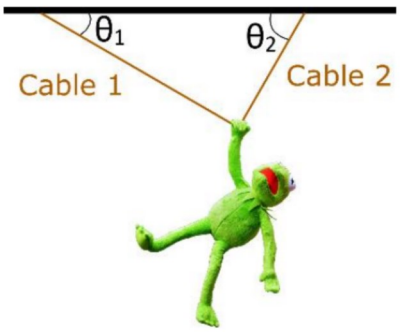
Submit a digital copy (PDF, jpg, etc.) to gradescope.com. Please use the Gradescope interface to associate each page of your submission with the corresponding question number! It makes grading much easier.

Every page should be labeled on the top left with the question number and there should be only be one solution per page. If a solution takes more than one page, be sure to label that it is a continuation of the previous page's solution. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

You will be asked to apply sense-making in some problems. Use the list below as a reference to the different sense-making techniques. More information about sense-making can be found on the BoxSand menu under Math Tools => Sense-making.

- *Sign:* Check the **sign** of each quantity makes sense.
- *Dimensionality:* Check the **dimensionality** and units of each quantity makes sense.
- *Order of Magnitude:* Check the **order of magnitude** of the final answer and other important quantities is within a a factor of 10 of what you think it should be.
- *Graphical Analysis:* Use a **graph** to see if the behavior of a solution makes sense.
- *Proportionality:* Using a symbolic solution, check the behavior of the answer when you change a given quantity on which it is dependent. Does the answer vary **proportionally** to what you expect?
- *Special Cases:* Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in sin(x).
- *Self-consistency:* Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values:* Compare given or derived quantities with common well **known values**.
- *Related Quantities:* Compare the relative magnitude of two **related quantities**.

Question 1:

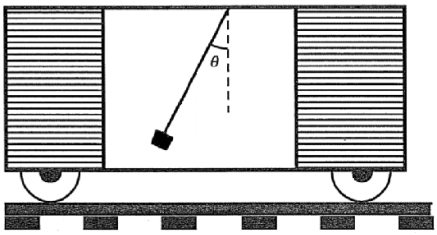


A chandelier with mass m is attached to the ceiling of a large concert hall by two cables. Cable 1 has tension T_1 and makes an angle of θ_1 with the ceiling. Cable 2 has tension T_2 and makes an angle of θ_2 with the ceiling.

(a) Find an expression for T_1, the tension in cable 1, that does not depend on T_2. Express your answer in terms of some, or all of the variables m, θ_1, θ_2, and the magnitude of the acceleration due to gravity g.

(b) Use the *Special Cases* sense-making technique to check your expression in part (a). Specifically how does the tension change as m, θ_1, θ_2, and g change to extreme values?

Question 2:



A rope is loosely fastened, (i.e. it can swing back and forth) to the ceiling of a railway car. When a block of unknown mass is hung from the rope and the car maintains a constant acceleration, the rope is oriented at an angle of 6° as shown in the figure. All of the following questions refer to the time when the car is accelerating and the rope is maintaining a constant angle with respect to the vertical.

(a) What must the direction of the acceleration of the car be? Explain.

(b) What is the direction of the velocity? Explain.

(c) Find the acceleration of the railway car (hint: find a symbolic expression for the magnitude of the acceleration before plugging in numbers) (hint 2: when you don't know what the value of a quantity is, give it a name / variable).

(d) Use the *Proportionality* sense-making technique to check your symbolic expression for the acceleration in part (c). Does the acceleration increase or decrease as the angle increases? Explain what you would expect the relationship between acceleration and angle to be and why, then compare to the relationship your expression shows.