UCI ENGR 80 project description. Design of a simple Trebuchet.

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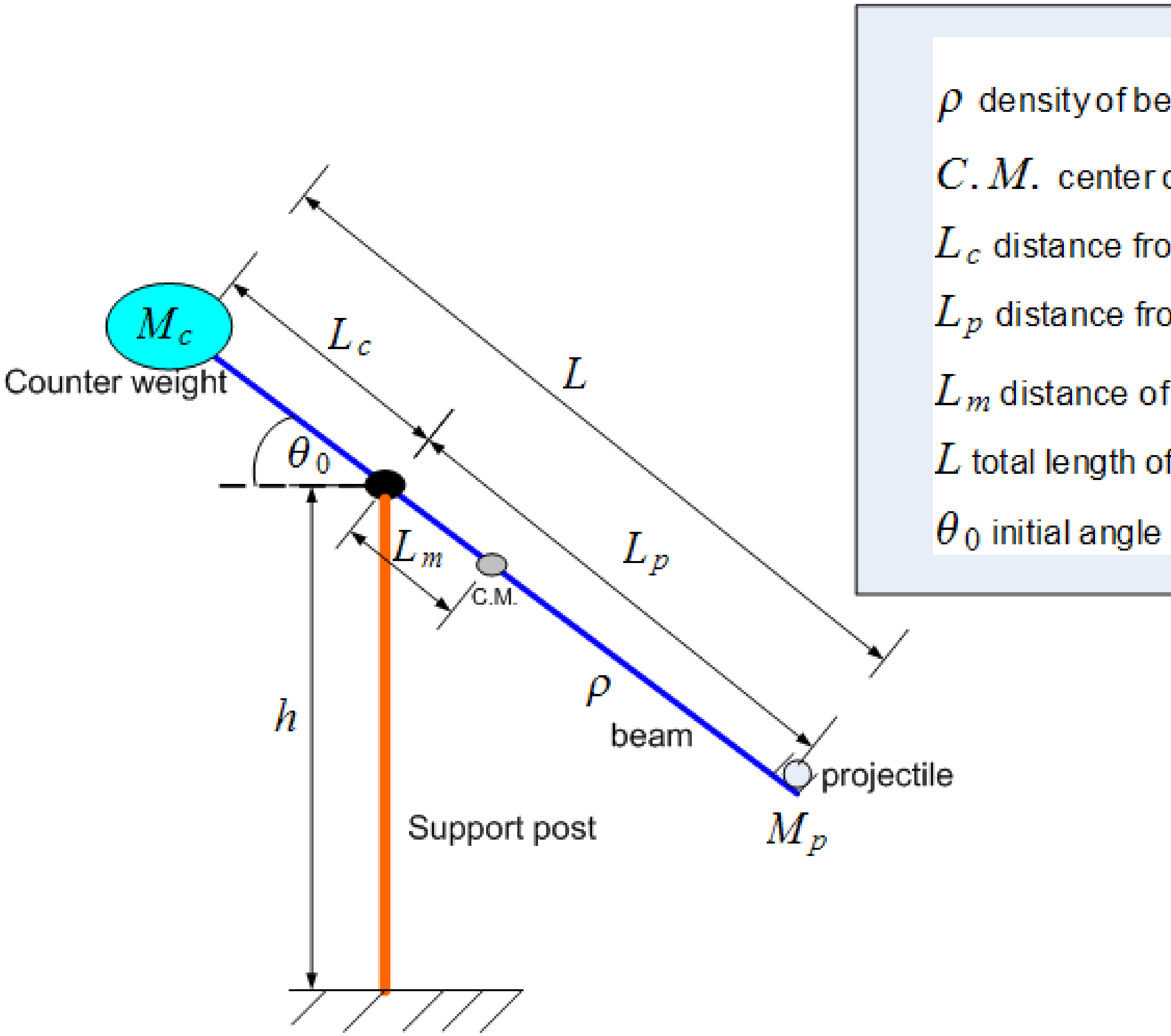
1 Introduction

The objective of this project is to design the most efficient Trebuchet by modifying 2 parameters in order to obtain the maximum projectile range.

Trebuchet is a mechanical device used to throw a projectile of mass M_p by converting the potential energy stored in the device (as a result of raising a heavy mass M_c to some height) into kinetic energy used to propel the projectile mass.

The following diagram illustrates the model of the Trebuchet to use. This is the initial configuration.



Trebuchet configuration at time t=0

The following are the system parameters

1. ρ density of beam per unit length
2. $C.M.$ center of mass of beam
3. M_p mass of projectile object.
4. M_c mass of the counter weight object.
5. L_c distance from pivot to center of counter object.
6. L_p distance from pivot to center of projectile object.
7. L_m distance of $c.m.$ from pivot.
8. L total length of beam.
9. θ_0 initial angle from horizontal that M_c is raised to.
10. h the height of the base support column.

The following are the known input values: $\rho = 1kg/m$, $L = 10m, M_p = 5kg, M_c = 100kg, h = 12m$

Your goal is to select design values for L_c and θ_0 which will result in maximum horizontal range for the projectile when it is ejected from its holding cup at the end of the beam.

Notice that as you change L_c , this will obviously change the center of mass of the beam and the L_p as well. This means that you need to remember to recalculate all the moments of inertias for M_p, M_c and the beam around the pivot each time you make design changes.

The projectile will be ejected when the reaction (the normal force) it makes with the beam becomes zero. Hence your goal is to determine at what angle this will occur and the speed of the projectile at that instance. This angle will be called the separation angle α_s. Once you obtain the speed of the projectile at ejection time, you will be able to calculate the range of the projectile.

1.1 Range of allowed values

You allowed to vary the parameter L_c from 5% to 45% of the total length of the beam. For the initial angle θ_0 you are allowed to vary this angle from 5^0 up to 85^0.

2 Assumptions

All the energy is conserved. This means we can assume that all the potential energy is converted to kinetic energy. You can ignore friction, damping, and wind effect.

Assume the projectile has only normal reaction with the beam. Hence the projectile will be ejected from the holding cup when the normal force becomes zero between the projectile and the beam.

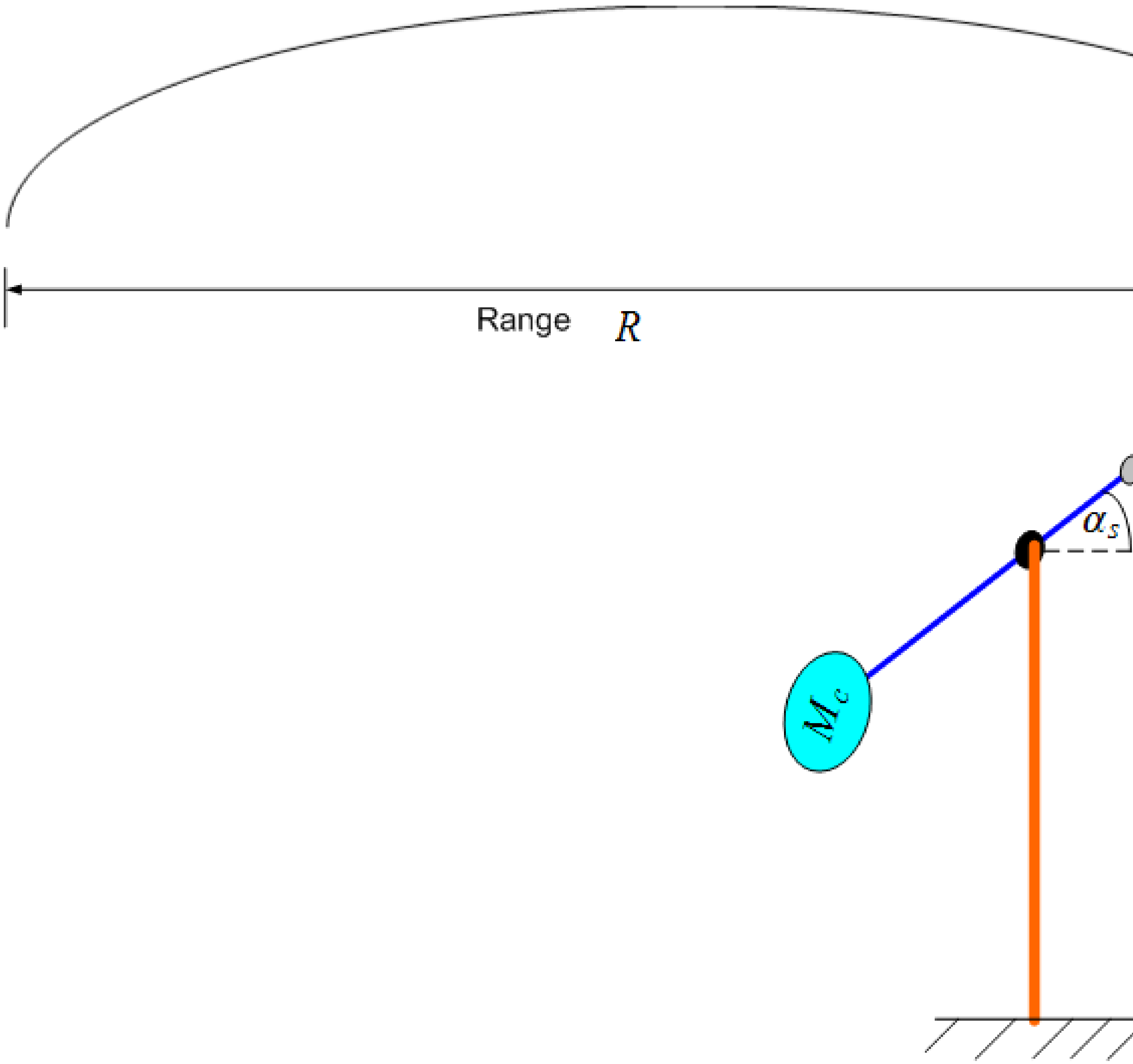
3 Output and results

Derive the equations of motion and obtain an analytical expression for the separation speed of the projectile. Use this expression to obtain the horizontal range.

Obtain the optimum value for θ_0, L_c which will result in a maximum horizontal range. This can be done by writing a function which will calculate R (the horizontal range) for different values of θ_0, L_c and by plotting the result and seeing where the maximum is.

Plot the horizontal range as a function of θ_0 and L_c in a 3D plot showing where the maximum range occurs.

Plot the horizontal range as a function of the separation angle α_s. The separation is the angle at which the projectile will be ejected with speed v as illustrated in the following diagram.



Trebuchet configuration at time of separa