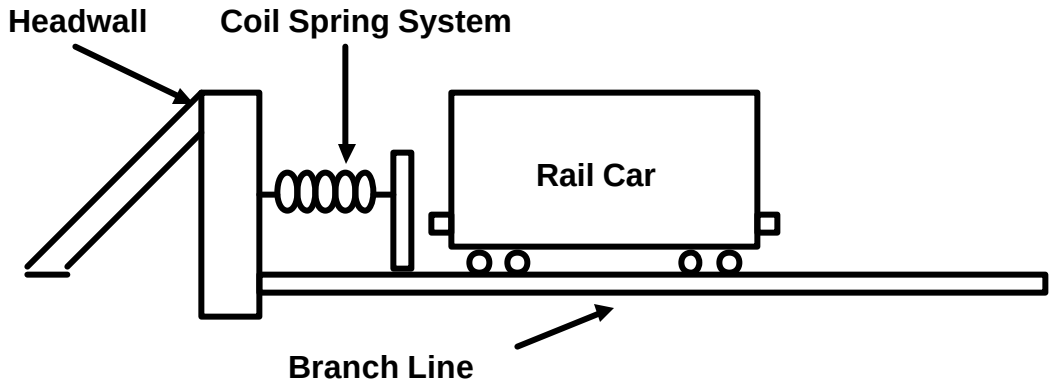
Railway Headwall Design

SITUATION: You are still in the process of preparing to deploy to the country of Igotit and based on your earlier successful performances the battalion operations officer gives you another project which will require you to use your knowledge of spring-mass systems.

MISSION: Preparation of the ore mining site near Igotitville includes constructing a railway branch line from an existing rail system approximately two miles away from the site. At the end of the branch line a safety bumper must be placed as a precaution to prevent rail cars from running off the track in case an accidental separation of the rail cars occurs. The basic design of the safety bumper (seen below) includes a fixed headwall with a coil spring connected to a bumper wall. The intent of the design is to absorb the shock of the car impacting the bumper using this flexible system versus a rigid system that could possibly damage the couplings on the rail cars.



For this particular case, you can assume the headwall design is sufficient to withstand a force greater than the design criteria for the coil spring. As a result, the primary focus for research needs to center on the design of the coil spring system. Your research will center on a comparison of two courses of action. Course of action one (COA 1) will utilize a single coil spring, whereas course of action two (COA 2) will utilize two coil springs side-by-side. As a starting point, you will need to design the spring system to withstand rail cars weighing a total of _____ (**wt**) tons without compressing the spring(s) more than _____ (**p**) percent of the springs' original length. Additionally, for COA 1 plan on using a spring length of _____ (**l1**) feet and for COA 2 plan on using a spring length of _____ (**l2**) feet. Assume the maximum velocity of the rail car upon impact will be _____(**v0**) miles per hour.

The cost associated with this system depends upon the spring required to meet the established criteria. It can be approximated by multiplying the spring constant times the length of the spring. You can assume that the cost of the headwall is fixed and will not factor into the cost of the spring system.

As part of your analysis look into these two cases for each course of action:

Case 1: Assume the rail car is moving along a frictionless surface.

Case 2: Assume the friction force between the rail car and the track is proportional to the downward force exerted by the rail car and has a proportionality constant of _____(**u**) .

Consider applying the principle of work and energy which states: "**the net increase in the kinetic energy of a particle in a displacement from position 1 to position 2 is equal to the work done on the particle by the external forces during the displacement**." Mathematically this can be represented as:

$\mathbf{T_F - T_I = W}$, where 1. $\mathbf{T}$ ≡ Kinetic energy in the system = $\mathbf{0.5\ m\ v^2}$,

$\mathbf{T_I}$ ≡ Initial kinetic energy

$\mathbf{T_F}$ ≡ Final kinetic energy

2. $\mathbf{W}$ ≡ Total work done on the particle during movement

$= \int \mathbf{F_r\, dx} + \int \mathbf{F_s\, dx}$,

3. $\mathbf{F_r}$ ≡ Friction force between the rail car and the track,
4. $\mathbf{F_s}$ ≡ Spring force exerted against the rail car.

As a guide for your research, you should address the list of questions below to help you in your comparison and recommendation.

<u>Course of Action 1</u>:

a. What are the spring constants for each of the two cases above?
b. What are the differential equations that model the motion for each case?
c. What are the equations of motion of the spring system for each case?
d. Determine how long the equations of motion would actually be valid for this situation.
e. Plot the position versus velocity of the rail car for the time the equation is valid.
f. For Case 2, hold the spring constant fixed and investigate how changing the proportionality constant of friction would affect the system's motion.
g. What is the maximum compression of the spring using your model (i.e. determine the percent maximum compression of the spring)? Is this value within the design parameters?

<u>Course of Action 2</u>: Answer the same questions above (a through g) for Course of Action 2.

<u>Comparison of Courses of Action</u>:

h. What are the advantages and disadvantages of each of the systems?
i. What are your recommendations for the design of the system and why? Be sure to consider cost, safety, and durability of the two systems.

REQUIREMENT: Present the results of your findings in a memorandum to your battalion operations officer. Attach all your work and detailed analysis as enclosures to the memorandum.

BONUS: (30) If we assume each spring exerts a frictional damping force that is proportional to the square of the rail car's velocity and that damping coefficient is _____ (**dc**), determine when the car will stop using numerical methods for COA 1, Case 2. Do not recompute the spring constant you found for this case.