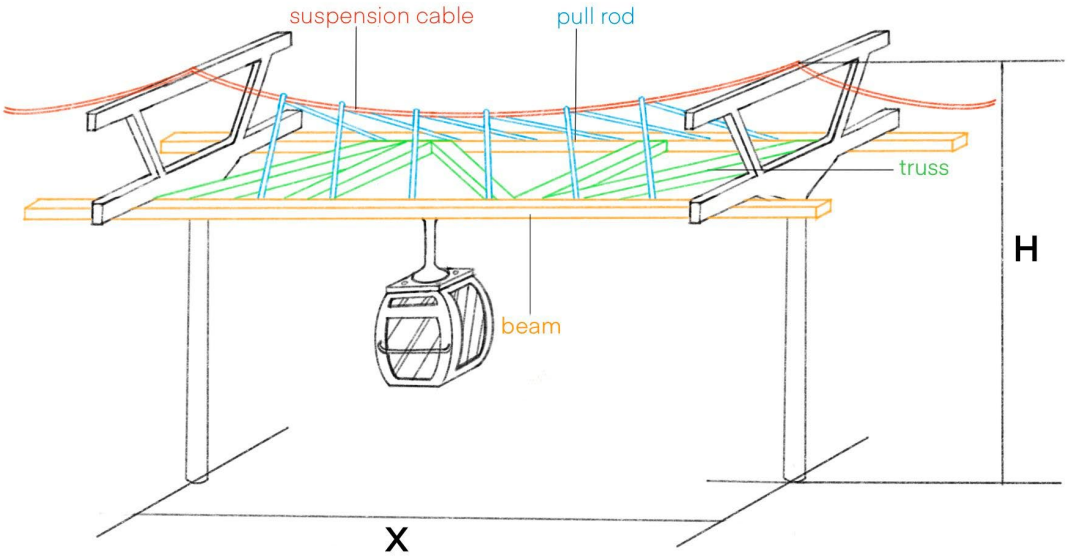
2020 MCM-SJTU

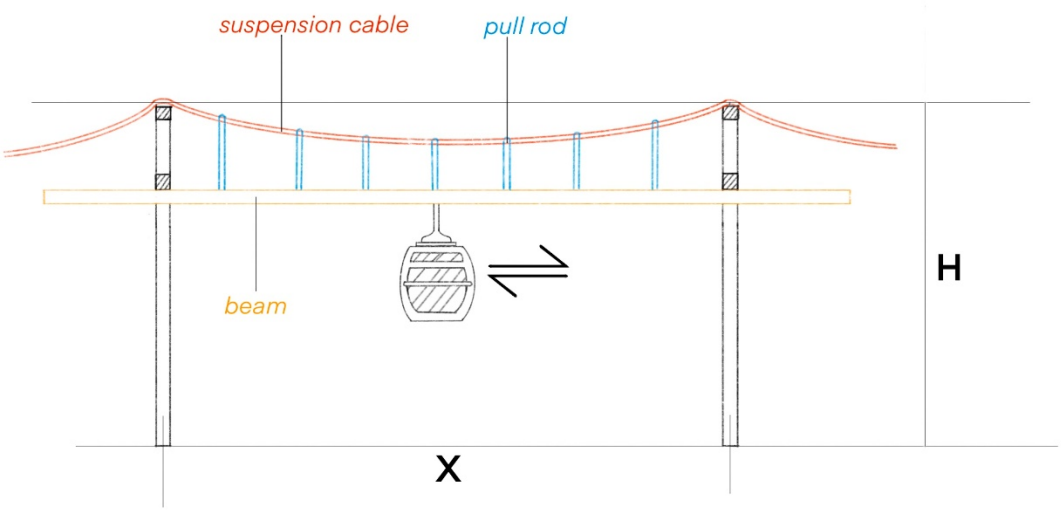
Problem A: Lightweight Suspension Transportation System

As a possible new traffic form in the future, lightweight suspended traffic system is basically a railway track supported in the air by pile foundation, and the lightweight trailer is suspended on the track to run. The limited load of the trailer body is 1t, and the running speed is less than 60km/ h. If the trailer does not work regularly, it will be pulled away from the main track to the bypass track by engineering vehicles. The approximate size of a trailer is 1.5*1.5*1.8 m (length, width and height). There are multiple ways to design such tracks: the first one is truss, the second one is cable-stayed bridge form of truss, and the third one is three-wire form of suspension cable. The truss can also be constructed using box girder design. Such lightweight suspended traffic system has many benefits such as avoiding road surface occupation, adapting all-terrain environments, and operating point-to-point as a network system. It also has great economic advantages.

(Details can be found at https://mp.weixin.qq.com/s/XUbDABygfwdr9jqbFw3KwA)

in order to promote the development of this system, a small-scale testbed is designed to simulate the original system as a suspension bridge structure (the canyon span is *X* m and the suspension cable height is *H* m), which is used to test the operation of the span of 50m, 50~100m, 100m. The schematic structure of the suspension bridge can be shown as the following pictures (from different points of view). This sample structure has two beams with the corresponding truss, and one suspension cable.





Note: There can also be two suspension cables in the structure shown above. Each suspension cable bears a truss by pull rods. What's more, please be noticed that each railway track is a single truss. The two tracks are two independent parallel truss structures, which are connected together by bars to enhance the stability. The description above is similar to the first picture of real products.

Your tasks are as follows:

Task 1: Analyze the limit status of the suspension cable according to the restriction of elastic deformation. You can simplify the structure of the beam under a given static load range (limit the weight to *W* t), and optimize the cost of the suspension cable and tie rod (given the unit mass price of the suspension cable and rod).

Task 2: Based on your model in Task 1, (we assume that the motion of the trailer is

"uniform acceleration - uniform velocity - uniform deceleration", or you may analyze the situation of the trailer in other motion conditions by yourself), compute the speed limit (or re-analyze the cost of suspension cables and bars).

Note: In Task 1 & 2, if necessary, the structure can be simplified as one beam without truss.

Task 3: According to Task 2, consider more environmental factors (mainly wind load), a small vibration of the trailer may occur, which will affect the ride comfort of the occupant. Analyze the vibration of the trailer, and give an improvement plan to reduce the vibration (such as improving a parameter).

Task 4: In a given situation (such as a trailer getting stuck in the middle of the bridge during operation), discuss the rescue scheme based on this traffic system (only rescued by this system) and discuss its effectiveness.

Tips:

- *Beam: It is similar to a pillar which is put in horizontal. It mainly bears lateral force and shear force. The main deformation is bending.*
- *Box Girder: It is nearly a hollow beam. The main characteristics are the same to those of the beam.*
- *Bar: It is a slim pole. It mainly bears axial pull force and push force. The main deformation is in the axial direction.*
- *Truss: It is a group of bars which are connected at the ends of them with hinge joints.*
- *Suspension Cable/Pull Rod: They only bear axial pull force with the main deformation in the axial direction.*

Note: The MCM/ICM Contest now have a 25 page limit. The 25 page limit applies to the entire submission including the Summary Sheet, Solution, Reference List, Table of Contents, Notes, Appendices, Code and any problem specific requirements.

This problem is motivated by Prof. Yue Hu (yuehu@sjtu.edu.cn) from Department of Electrical Engineering at Shanghai Jiao Tong University, designed and scribed by Mr. Xinhao Zheng (void_zxh@sjtu.edu.cn) from Team 015 of SJTU MCM Group, who also won the Finalist Award in MCM 2020 (Problem A). Prof. Xiaofeng Gao (gao-xf@cs.sjtu.edu.cn) from Department of Computer Science and Engineering at Shanghai Jiao Tong University modified and finalized this problem. Mr. Tongxin Ren (rentongxin@sjtu.edu.cn, outstanding winner of MCM2018 Problem C) and Mr. Dejun Kong (kdjkdjkdj99@sjtu.edu.cn) helped proof reading and made some corrections.