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8.012 Physics I: Classical Mechanics
Fall 2008

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.012: Physics (Mechanics) I

Fall Term 2008

PROBLEM SET 2

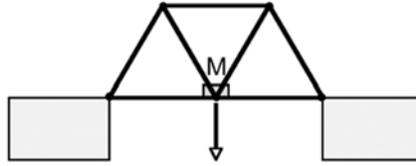
Collaboration policy: You are encouraged to freely discuss homework problems with other 8.012 students and teaching staff. However, **you must write up your solutions completely on your own**—do not simply copy solutions from other students. You are **forbidden from consulting solutions from previous years or from the web**. Violations of this policy may result in disciplinary action.

Reading: Kleppner & Kolenkow, Chapter 2

0. **Collaboration and discussion.** Please list the names of all the students with whom you discussed these homework problems.
1. Kleppner & Kolenkow, Problem 2.1 (5 points) **NOTE**– The mass starts from rest.
2. Kleppner & Kolenkow, Problem 2.3 (5 points)
3. Kleppner & Kolenkow, Problem 2.5 (5 points)
4. Kleppner & Kolenkow, Problem 2.7 (10 points)
5. Kleppner & Kolenkow, Problem 2.9 (10 points)
6. Kleppner & Kolenkow, Problem 2.11 (10 points)
7. Kleppner & Kolenkow, Problem 2.12 (5 points)
8. Kleppner & Kolenkow, Problem 2.15 (10 points)
9. Kleppner & Kolenkow, Problem 2.17 (10 points) **NOTE**– The constraints should be $\tan \theta > \mu$ in (b) and $\tan \theta < \mu$ in (c)
10. Kleppner & Kolenkow, Problem 2.24 (10 points)

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11. **Bridge Building.** (10 points)



A mass M (perhaps a car) sits at the center of a bridge made up of three equilateral triangles of beams. Assume that these seven beams are effectively massless, and that they are connected to each other by hinges at the very ends (so forces only act at the ends of each beam). The supports at either end of the bridge only provide vertical forces to hold the bridge the car up. Assume constant gravitational acceleration \vec{g} acts downward.

- (10 points) Find the forces on each hinge point of each beam (both magnitude and direction) and specify whether these forces are compressive or tensile (i.e., do they push the beam in or stretch it out?). It is helpful to draw force diagrams for each beam to work out where each force originates.
- (10 points EXTRA CREDIT CHALLENGE) Find the forces on $2n+1$ beams making up an n -triangle bridge (i.e., generalize your result above).

12. **Order of Magnitude Estimates.** (10 points)

Last week we introduced dimensional analysis as a means of estimating the functional forms of physical quantities from basic principles. This week you are going to make order of magnitude estimates of some physical quantities. Try to make these estimates without using a calculator! One of the important skills of a physicist or engineer is to be able to calculate on the spot.

- (2 points) The entire population of Earth lines up, holding each others hands with arms outstretched. How many times would this human chain wrap around the Earth? The Earth's radius is roughly 6×10^6 m.
- (2 points) Astronomers typically measure the angular motion of nearby stars in units of arcseconds/year, where an arcsecond is $1/3600$ th of a degree. If we were to project the angular motion onto the Moon (a distance of 4×10^8 m), what speed would that correspond to? Is this speed closest to that of a snail, an Olympic runner or a jet plane?
- (3 points) Crumple zones in cars are designed to reduce the acceleration in a collision with a stationary object. Estimate a relation between the size of the crumple zone, the initial speed of the car, and the acceleration on the car's occupants using dimensional analysis. For a collision at 30 miles per hour, what is the minimum crumple zone size needed to keep accelerations below (a fatal) acceleration of $20g$. How does this size compare to the length of a typical car?
- (3 points) The nearest star to the Sun is about 4 lightyears away. Knowing that the speed of light is 3×10^8 m/s, and that the typical mass of a star is roughly 10^{30} kg, estimate the mass density of stars (kg/m^3) in the vicinity of the Sun. How does this compare with the density of air?