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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 5

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, Chapters 4

0. **Collaboration and discussion.** Please list the names of all the students with whom you discussed these homework problems.
1. Kleppner & Kolenkow, Problem 4.4 [10 points]
2. Kleppner & Kolenkow, Problem 4.5 [10 points]
3. Kleppner & Kolenkow, Problem 4.7 [10 points]
4. Kleppner & Kolenkow, Problem 4.8 [10 points]
5. Kleppner & Kolenkow, Problem 4.9 [5 points]
6. Kleppner & Kolenkow, Problem 4.10 [10 points]
7. Kleppner & Kolenkow, Problem 4.13 [10 points]
8. Kleppner & Kolenkow, Problem 4.20 [10 points]
9. Kleppner & Kolenkow, Problem 4.28 [10 points]

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10. **Solar Energy.** [15 points]

There is considerable discussion today about switching over to renewable resources for our energy needs—wind, solar, tidal, biofuel—for both conservation and economics. In this problem you are to examine whether one of these solutions—Solar power—is a viable solution for Boston using estimation and order of magnitude approximations.

- (a) [5 pts] Estimate the average electrical power used by people in Boston, measured in Watts. There are roughly 6 million people in Boston.
- (b) [5 pts] Now estimate the amount of useable solar energy in the Boston area. First estimate the **incident flux** of radiation on the surface of the Earth, measured in W/m^2 . Then estimate how much of that flux can reasonably be captured over the course of the year, including the efficiency of solar panels (roughly 10%), the fact that the Sun is only up in the daytime, the inclination of the Sun in the sky, the scattering of sunlight by the atmosphere and clouds, etc. Some important numbers: the luminosity of the Sun (radiant power) is roughly 4×10^{26} W, the Sun-Earth distance is 1.5×10^{11} m = 1 Astronomical Unit, and the metro area of Boston is $11,000 \text{ km}^2$.
- (c) [5 pts] Based on part (b), what fraction of Boston's land area would need to be set aside for solar panels to provide electricity for everyone? Does this seem like a feasible approach? What are some of the practical impediments to doing this?
- (d) [5 pts] Redo the calculation but just for your dorm building. Could solar panels covering your dorm roof provide enough energy to power the whole building? What about for the case of a single family home (assume 4 residents)? Would simply covering every building top in solar panels provide sufficient electrical energy?
- (e) [5 pts] The World Resources Institute estimates that the total energy usage per capita in the United States is roughly 80,000 kiloWatt-hours per year (what is this in Watts?). What accounts for the difference between this number and your estimate in (a)? With this value, could solar panels meet all of the energy needs of Boston in the near future?