MCM: The Mathematical Contest in Modeling
ICM: The Interdisciplinary Contest in Modeling
2011 MCM Problems

PROBLEM A: Snowboard Course

Determine the shape of a snowboard course (currently known as a “halfpipe”) to maximize the production of “vertical air” by a skilled snowboarder.
"Vertical air" is the maximum vertical distance above the edge of the halfpipe.
Tailor the shape to optimize other possible requirements, such as maximum twist in the air.
What tradeoffs may be required to develop a “practical” course?

PROBLEM B: Repeater Coordination

The VHF radio spectrum involves line-of-sight transmission and reception. This limitation can be overcome by “repeaters,” which pick up weak signals, amplify them, and retransmit them on a different frequency. Thus, using a repeater, low-power users (such as mobile stations) can communicate with one another in situations where direct user-to-user contact would not be possible. However, repeaters can interfere with one another unless they are far enough apart or transmit on sufficiently separated frequencies.

In addition to geographical separation, the “continuous tone-coded squelch system” (CTCSS), sometimes nicknamed “private line” (PL), technology can be used to mitigate interference problems. This system associates to each repeater a separate subaudible tone that is transmitted by all users who wish to communicate through that repeater. The repeater responds only to received signals with its specific PL tone. With this system, two nearby repeaters can share the same frequency pair (for receive and transmit); so more repeaters (and hence more users) can be accommodated in a particular area.

For a circular flat area of radius 40 miles radius, determine the minimum number of repeaters necessary to accommodate 1,000 simultaneous users. Assume that the spectrum available is 145 to 148 MHz, the transmitter frequency in a repeater is either 600 kHz above or 600 kHz below the receiver frequency, and there are 54 different PL tones available.

How does your solution change if there are 10,000 users?

Discuss the case where there might be defects in line-of-sight propagation caused by mountainous areas.

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How environmentally and economically sound are electric vehicles? Is their widespread use feasible and practical?

Here are some issues to consider, but, of course, there are many more, and you will not be able to consider all the issues in your model(s):

- Would the widespread use of electric vehicles actually save fossil fuels or would we merely be trading one use of fossil fuel for another given that electricity is currently mostly produced by burning fossil fuels? What conditions would need to be put in place to maximize the savings through use of electric vehicles?
- Consider how much the amount of electricity generated by alternatives such as wind and solar would need to climb during the twenty-first century to make the widespread use of electric vehicles feasible and environmentally beneficial. Assess whether or not the needed growth of these alternate sources of electricity is likely and possible.
- Would charging batteries at off-peak times be beneficial and increase the feasibility of widespread use of electric vehicles? How quickly would batteries need to charge to maximize the efficiency and practicality of electric vehicles? How would progress in these areas change the equation regarding the environmental savings and practicality of widespread use of electric vehicles?
- What method of basic transportation is most efficient? Is the efficiency of different methods dependent of the nation or region in which it is used?
- Pollution caused directly by electric vehicles is low, but are there hidden sources of pollutants associated with electric vehicles? Gasoline and diesel fuel burned in internal combustion engines for transportation account for nitrites of oxygen, vehicle-born monoxide and carbon dioxide pollution but are these bi-products something we really should worry about? What are the short and long term effects of these substances on the climate and our health?
- How would the pollution caused by the increasing need to dispose of increasing numbers of large batteries effect the comparison between the environmental effects of electric vehicles versus the effects of fossil fuel-burning vehicles?
- You also should consider economic and human issues such as the convenience of electric vehicles. Can batteries be recharged or replaced fast enough to meet most transportation needs or would their ranges be limited? Would electric vehicles have only a limited role in transportation, good only for short hauls (commuters or light vehicles on short trips) or could they practically be used for heavier and longer-range transportation and shipping? Should governments give subsidies to developers of electric vehicle technologies and if so, why, how much, and in what form?

Requirements:

- Model the environmental, social, economic, and health impacts of the widespread use of electric vehicles and detail the key factors that governments and vehicle manufacturers should consider when determining if and how to support the development and use of electric vehicles. What data do you have to validate your model(s)?
- Use your model(s) to estimate how much oil (fossil fuels) the world would save by widely using electric vehicles.
- Provide a model of the amount and type of electricity generation that would be needed to support your recommendations regarding the amount and type of electric vehicle use that will produce the largest number of benefits to the environment, society, business, and individuals.
- Write a **20-page** report (not including the summary sheet) to present your model and your analysis of the key issues associated with the electric vehicle and electricity generation. Be sure to include the roles that governments should play to insure safe, efficient, effective transportation. Discuss if the introduction of widespread use of electric vehicles is a worthwhile endeavor and an important part of an overall strategy to address global energy needs in the face of dwindling fossil fuel supplies.

References:

Getting reliable global data on controversial issues like this one can be difficult. As a start on global energy information we provide this link:
http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html

A concise summary of energy generation and usage in the US is found here:
http://www.eia.gov/totalenergy/data/annual/index.cfm

More global data in spreadsheet form are found here:
http://www.eia.doe.gov/iea/

Good luck and have fun modeling!