2005-2006 EE Ph.D. Qualifying Exam
Question area: *Engineering Physics*
Examiner: *Jelena Vuckovic*

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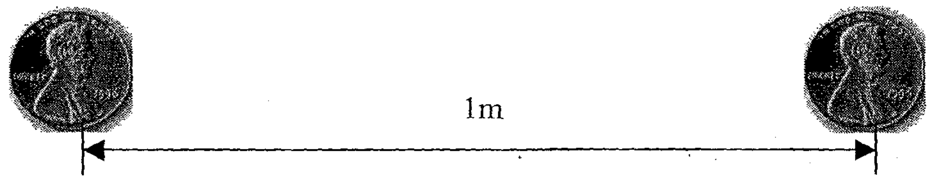
1. We know that the magnitudes of the negative charge of an electron and the positive charge of a proton are equal. Suppose, however, that these magnitudes differ from each other by 0.0001%. With what force would two copper cents placed 1m apart then act on each other? Is this force larger or smaller than the force of gravity acting on a cent at the surface of the Earth?

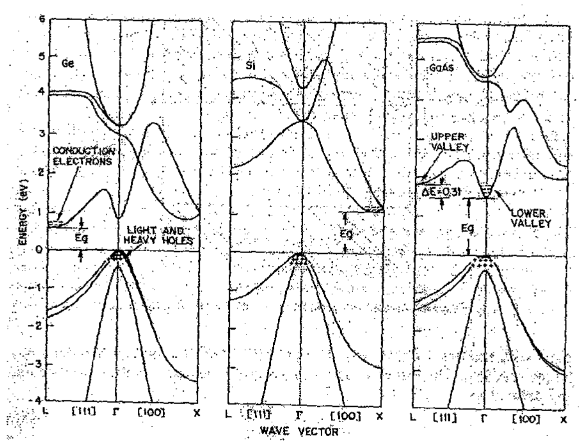


Hints:

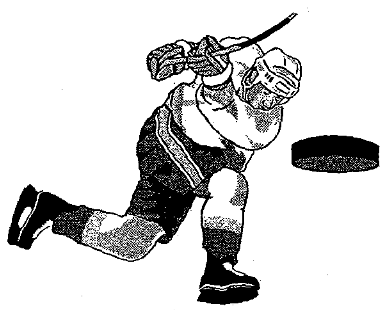
- Give order of magnitude answers.
- You may assume that a cent is made of copper only, and has the mass of 2.5g.
- You can use the attached periodic table of elements.
- Some useful constants: the dielectric constant of vacuum is $\varepsilon_0=8.85 \cdot 10^{-12}$F/m, the charge of an electron is $e=-1.6 \cdot 10^{-19}$C, and the mass of a proton is $m_p=1.67 \cdot 10^{-27}$kg.

2. When studying semiconductors, we plot their energy band diagrams, as shown in the figure on the right for Ge, Si and GaAs.

   Explain what these diagrams mean and how they are calculated. How would the states (wavefunctions) of electrons differ at various points of these band diagrams? What about the probability distributions of electrons throughout such materials?



3. Why is ice slippery?



2008-2009 EE Ph.D. Qualifying Exam
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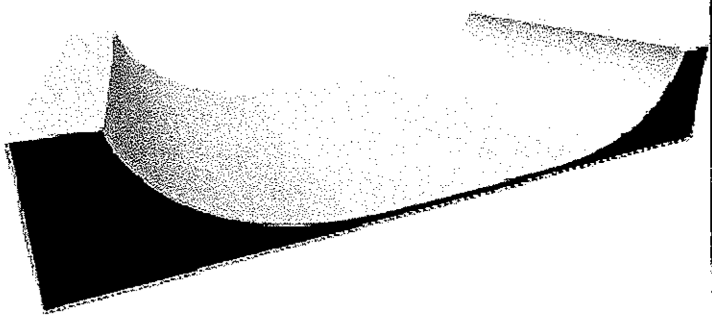
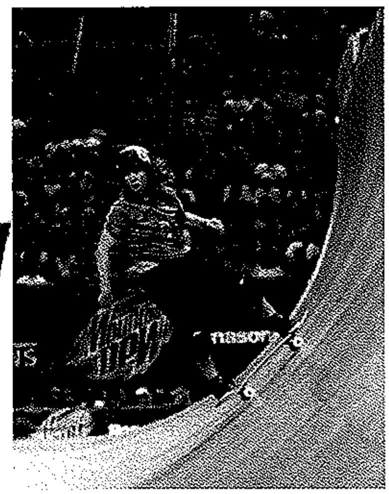
Please give order of magnitude answers to all of the questions below, and make any approximations you believe are reasonable.

1. [7 pts]
   Skateboarding or snowboarding on a half-pipe (ramp), as shown in the figures below is a very popular sport (half-pipe snowboarding is now even a Winter Olympics sport).
   Suppose the half-pipe is 10m high and 20m wide, and the skateboarder's weight is 70kg (the skateboarder releases him/herself from the top of the half-pipe).
   a) What is the maximum velocity that the skateboarder has at any point of the half-pipe?
   b) What is the approximate skateboarder's oscillation period?
   c) Under your assumptions, how would your answers to (a) and (b) change if the skateboarder is lighter or heavier?

(Figures from Wikipedia)

2. [3pts]
   What area of Nevada would you have to cover with solar cells in order to provide all energy needed for the US?
   The solar flux is 340 Wm^{-2} at the surface of the Earth, and the current energy consumption in the US is 3.35TW. State all your assumptions.

2009-2010 EE Ph.D. Qualifying Exam
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1. Assume that there is a lossless oscillating system whose physical property a oscillates over time with angular frequency ω. For example, you can assume that this system represents electromagnetic field in a resonator. (However, you can also think about a mass on a spring, or another oscillating system of your choice, if it is simpler for you.)

a) Write the equation that describes the behavior of a over time. What is its solution?

b) If the system is not lossless, how does the property a vary in time? How do you have to modify the equation from the part (a) to account for losses?

c) Now assume that such a lossless oscillator is coupled to another, identical lossless oscillator. Would the system still oscillate harmonically? If yes, at what frequency?

d) Could you write equations which describe the behavior of such a coupled system?

2009-2010 EE Ph.D. Qualifying Exam
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2011-2012 EE Ph.D. Qualifying Exam
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Clearly state any assumptions you make while solving the problems. Good luck!

1. Multiple slit interference

Consider a setup consisting of two parallel screens, separated by distance d.
The first screen has very narrow slits on it, while the second screen is used for imaging. The separation between the slits (s) is much smaller than the distance between the screens (d).
Figures 1a and 1b show the first screen with 2 and 3 slits, respectively. A monochromatic light source is used to illuminate the first screen from the back, as shown in the figures.

a) How would the projected image (intensity distribution) on the second screen look for 2 slits on the first screen?

b) What about the intensity distribution on the second screen in case of 3 slits on the first screen? How is it different from the result in (a)?

c) How would the image on the second screen look for N slits on the first screen, where N is an arbitrary positive integer? (Same as in parts (a) and (b), assume that the separation between neighboring slits is s.)

d) Do you expect the central point (O) of the second screen to be bright or dark for an arbitrary N? Why?

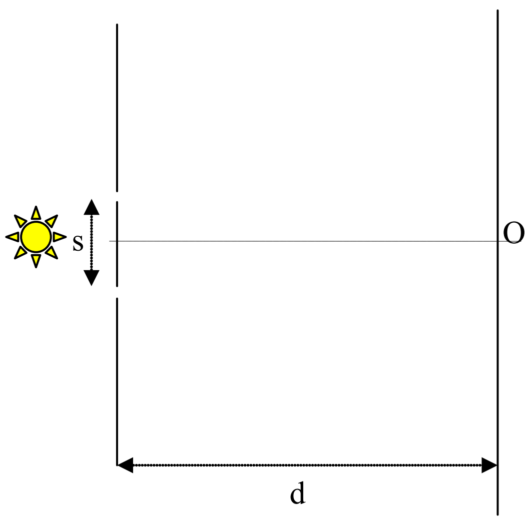

Figure 1a

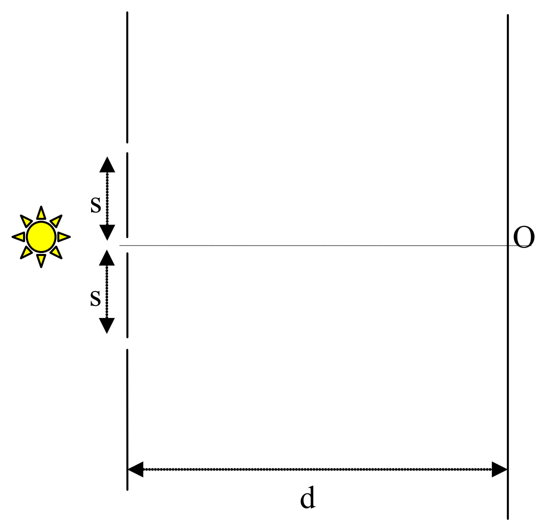

Figure 1b

2. Quantum box

Suppose there is a tiny, quantum box with dimension L, and a particle with mass m confined inside of it. What can you tell about the momentum of this particle?

2012-2013 EE Ph.D. Qualifying Exam
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Clearly state any assumptions you make while solving the problems. Good luck!

1. Electron source

Suppose you need to generate an electron beam for your experiment.

You have access to the following equipment:

- a source of ultraviolet radiation (e.g., a UV lamp with radiation spectrum covering 200nm-400nm wavelength range);
- a high voltage source (DC);
- a strong magnet (generating DC magnetic fields of up to 4T);
- a metal evaporator, that you can use to coat substrates with gold, platinum, or aluminium;
- a variety of substrates (e.g., quartz and glass microscope slides and silicon wafers);
- a sensitive screen detecting electrons, which you can use to characterize the profile of the electron beam

(a) Explain how you would generate an electron beam using the available equipment.

(b) What would you do to focus the electron beam, so that the spot on the detector screen is as small as possible?

Hint: The following parameters can be useful for your analysis:

- the workfunctions of gold, platinum, and aluminium are 5.1eV, 6.35eV, and 4.08eV, respectively;
- electron mass $m=9.1 \cdot 10^{-31}$kg; electron charge $e=-1.6 \cdot 10^{-19}$ C;
- Planck's constant $h=6.626 \cdot 10^{-34}$Js

2. Coffee cooling

Explain the process by which a hot cup of coffee cools.