1. Estimate the mass of the Earth. (10%)

2. For a potential $U(\vec{r}) = \vec{r} \cdot \hat{z}$, find $\vec{F}$ at (1,0,1). Here $\hat{z}$ is the unit vector along the z-axis. $U$ is in J and $r$ is in m. (10%)

3. Why does the pattern form at the bottom of a pail? (5%)

4. The figure shows the force-displacement curve of a spring. Explain the physical meaning of the shaded area. (5%)
5. Poincaré theorem states that a finite system can evolve to any state after a sufficient long time. Consider a container with one mole of gas molecule A and one mole of gas B. Initially, both gases mix uniformly in the container. At room temperature the relaxation time $\tau$ of the gases is about $10^{-10}$ s. Estimate the time it takes for the case to happen that molecules A all are in one half of the container and molecules B all are in the other half of the container. The age of the universe is about 20 billion years. (10%)

6. An ideal gas undergoes free expansion. After the expansion, (a) does the temperature $T$ of the gas increase, decrease, or remain same? (b) how about the entropy? (10%)

7. We give the same charge to a metal sphere of radius $R$ and a metal cone of radius $R$ and height $2R$. The shaded regions in the figure are of equal area. Which region has the greatest surface charge density? Why? (10%)

8. Two straight rods with 60 cm long and 2.0 mm apart in a current balance carry currents of 18 A each in opposite direction. What mass must be placed on the upper rod to balance the magnetic force of repulsion? (10%)
9. Two flat planes of glass are laid on top of one another. The upper plane is slightly raised due to the insertion of a thin piece of paper at one end and an air wedge is thus formed. Light of wavelength 500 nm is normally incident on the glass from above and interference fringes are observed by reflection with 2.5 fringes per cm. Calculate the angle of the wedge. (10 %)

10. What is the minimum height of a plane mirror in which a standing woman can see her entire body reflected? Why? (10 %)

11. A 60° prism has a refraction index of 1.64 for blue light and 1.61 for red light. Calculate the difference in the angle of emergence from the opposite face of the prism for a beam of red and a beam of blue light that are both incident at an angle of 60°. (10 %)