LECTURE 31: Potential energy functions

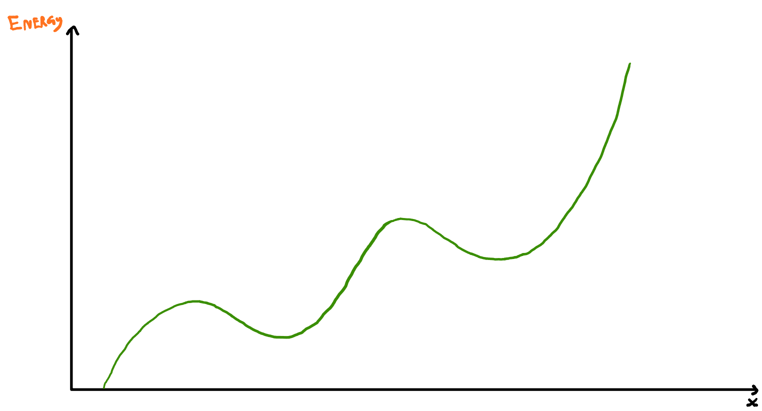
Select LEARNING OBJECTIVES:

i. Be able to analyze energy vs position graphs, identifying stable and unstable equilibrium locations, turning points, forbidden regions, and direction of forces and accelerations.
ii. Be able to construct an energy vs position graph including information about the total energy, gravitational potential energy, spring potential energy, and kinetic energy if applicable.

TEXTBOOK CHAPTERS:

- Giancoli (Physics Principles with Applications 7th) :: N/A
- Knight (College Physics : A strategic approach 3rd) :: N/A
- BoxSand :: Click here for video

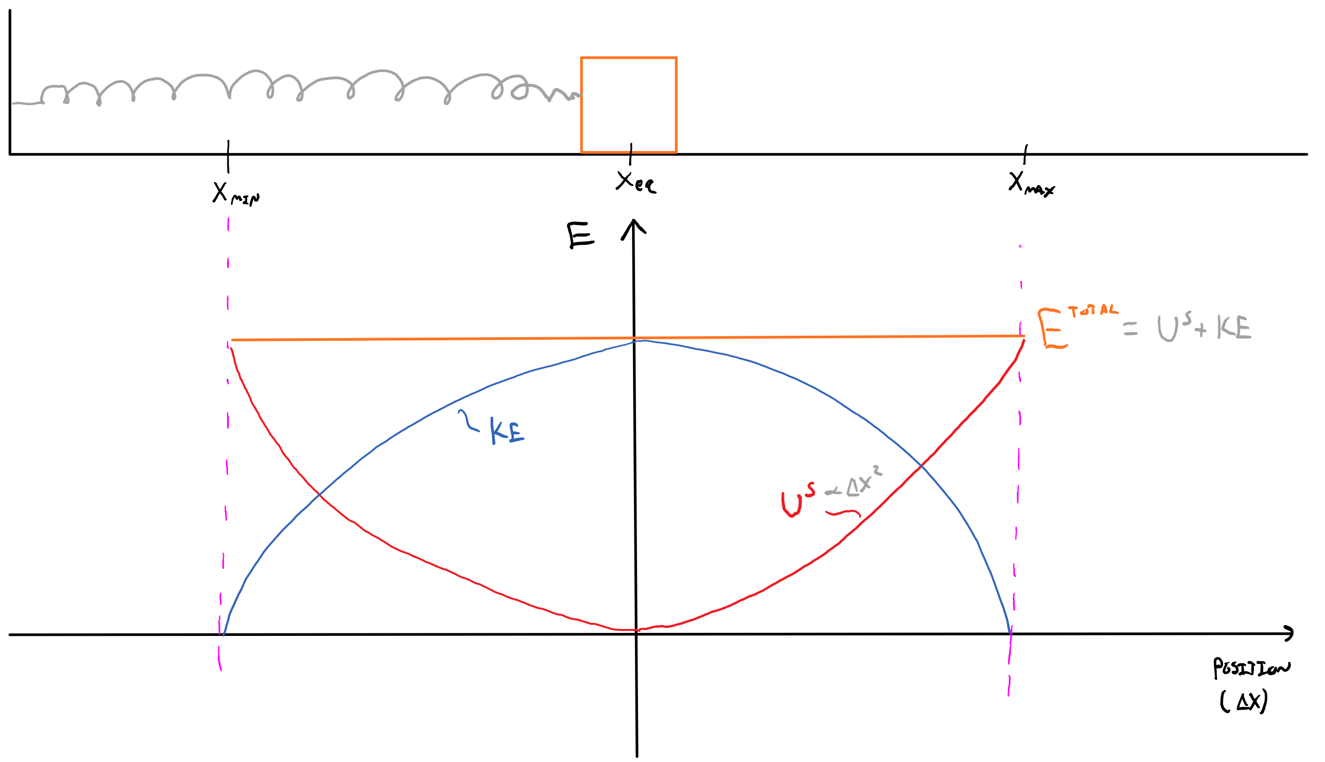
WARM UP: A ball slides down a ramp shown in green below. Draw the potential energy function for the ball over top of this ramp.



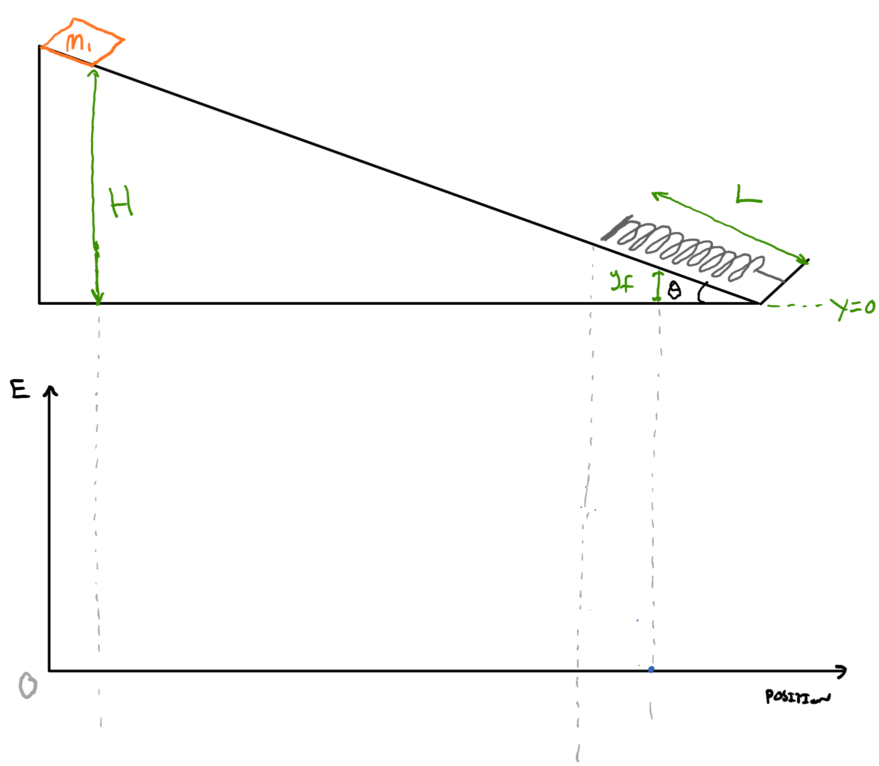
All of our hard work in studying the fundamentals of physics will now begin to pay off. We are about to study potential energy function in more depth and see how ubiquitous they are across almost all academic disciplines including but not limited to biology and chemistry. In fact, in upper level physics, we almost always work with potential energy function rather than forces.

In the previous lectures, we have constructed the potential energy functions for the spring potential energy and the gravitational potential energy. We found that U^s vs position was quadratic and U^g vs position was linear. Let's take a look at a case study and build an energy vs position plot for a mass oscillating on an ideal spring.

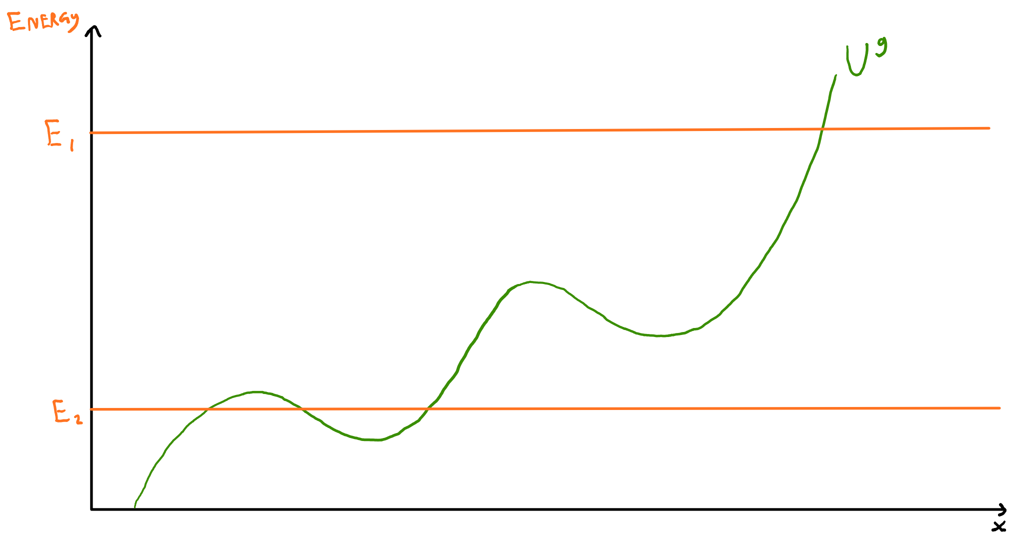
EXAMPLE: Construct an energy vs position graph for a block of mass m oscillating on a horizontal frictionless surface attached to an ideal spring as shown in the figure below.



PRACTICE: Starting from rest, a block of mass m slides down a frictionless incline where it encounters an ideal spring at the bottom as shown in the figure below. Construct an energy plot vs position along the length of the incline for the system.



PRACTICE: Consider a track that a ball can roll on. The gravitational potential energy as a function of horizontal distance looks exactly like the profile of the track as shown in the plot below. If the total energy is E2, identify stable and unstable equilibrium locations, turning point locations, and forbidden regions.



We spent the majority of this term talking about forces so it might seem like we are missing information if we are only given a potential energy function. However, information about force is not lost, it is just hidden within the potential energy function. Recall that we defined a potential energy function if there was internal conservative work…

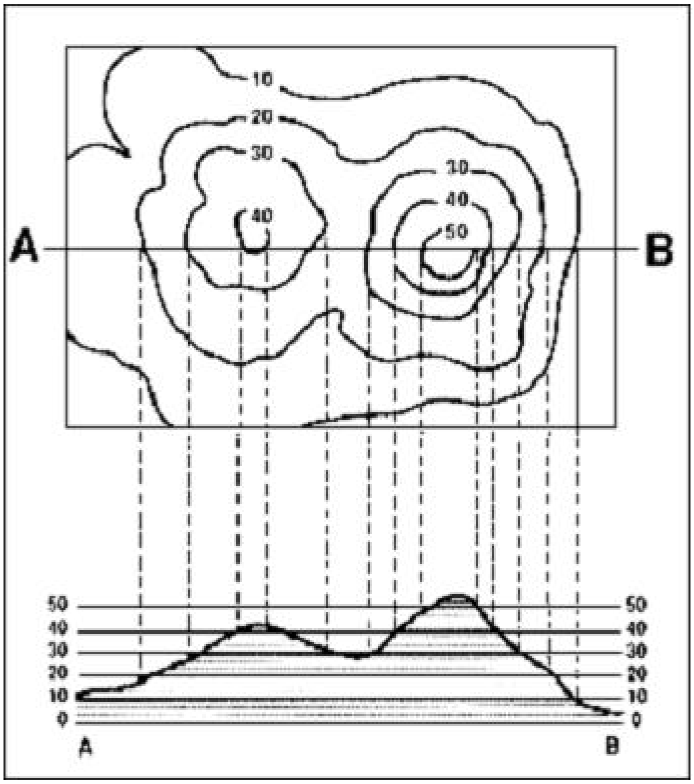
$$W^c_{INT} = \vec{F} \cdot \Delta\vec{r} = -\Delta U$$

It turns out we can get the force the following way…

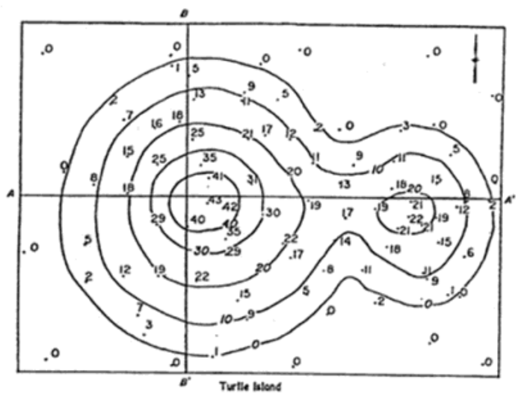
$$\vec{F} = \left\langle -\frac{\Delta U}{\Delta x}, -\frac{\Delta U}{\Delta y}, -\frac{\Delta U}{\Delta z} \right\rangle$$

Does this make sense? Check the first example problem of this lecture, if you look at the negative slope of the spring potential energy, does it give you the direction of the x-component of force?

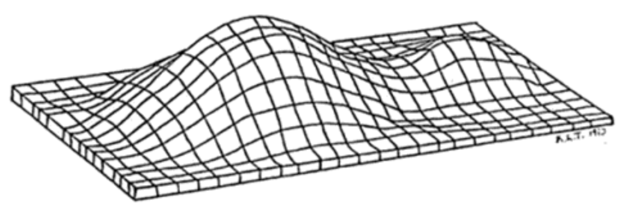
Topological Maps

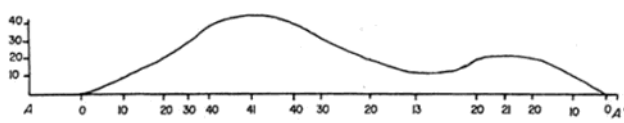


Contour Map of Turtle Island



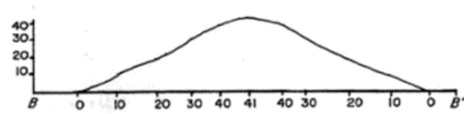
Three Dimensional Model of Turtle Island





TURTLE ISLAND

TOPOGRAPHIC PROFILE A - A'



TURTLE ISLAND

TOPOGRAPHIC PROFILE B - B'

Questions for discussion:

(1) Looking at a topological map, can you determine the direction of the force on a ball if it was placed at a random location?