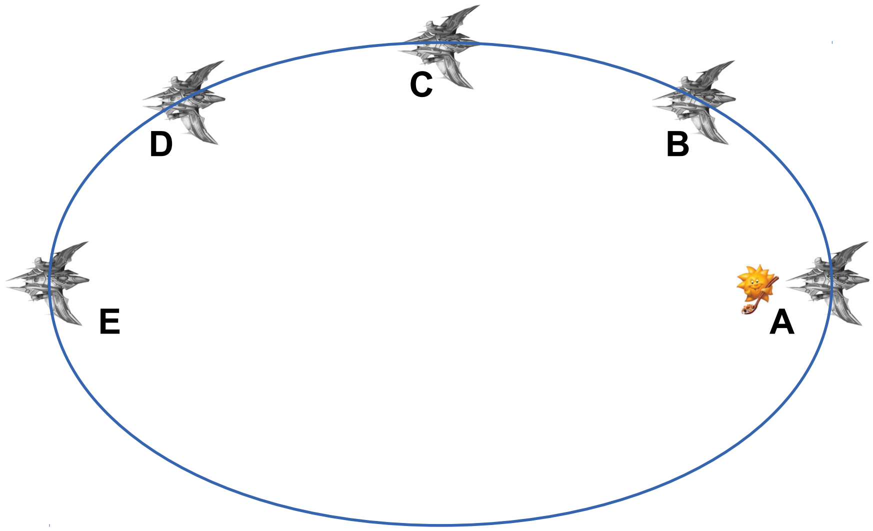
Physics 2211 – Summer GPS Week 8

Problem #1

The diagram shows the path of a spacecraft orbiting a star. You will be asked to rank order various quantities in terms of their values at the locations marked on the path, with the largest first. You can use the symbols "<" and "=". For example, if you were asked to rank order the locations in terms of their distance from the star: "A <B <C <D <E"



(a) Rank order the locations on the path in terms of the spacecraft's **kinetic energy** at each location, starting with the location where the kinetic energy is the largest.

(b) Consider the system of the spacecraft plus the star. **Which of the following statements are correct?**

A. As the kinetic energy of the system increases, the gravitational potential energy of the system decreases.

B. As the spacecraft slows down, the kinetic energy of the system decreases.

C. As the spacecraft slows down, energy is lost from the system.

D. External work must be done on the system to speed up the spacecraft.

E. As the spacecraft's kinetic energy increases, the gravitational potential energy of the system also increases.

F. Along this path the gravitational potential energy of the system is never zero.

G. The sum of the kinetic energy of the system plus the gravitational potential energy of the system is a positive number.

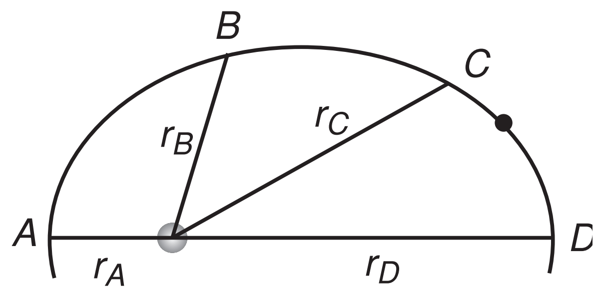
H. The gravitational potential energy of the system is inversely proportional to the square of the distance between the spacecraft and star.

I. The sum of the kinetic energy of the system plus the gravitational potential energy of the system is the same at every location along this path.

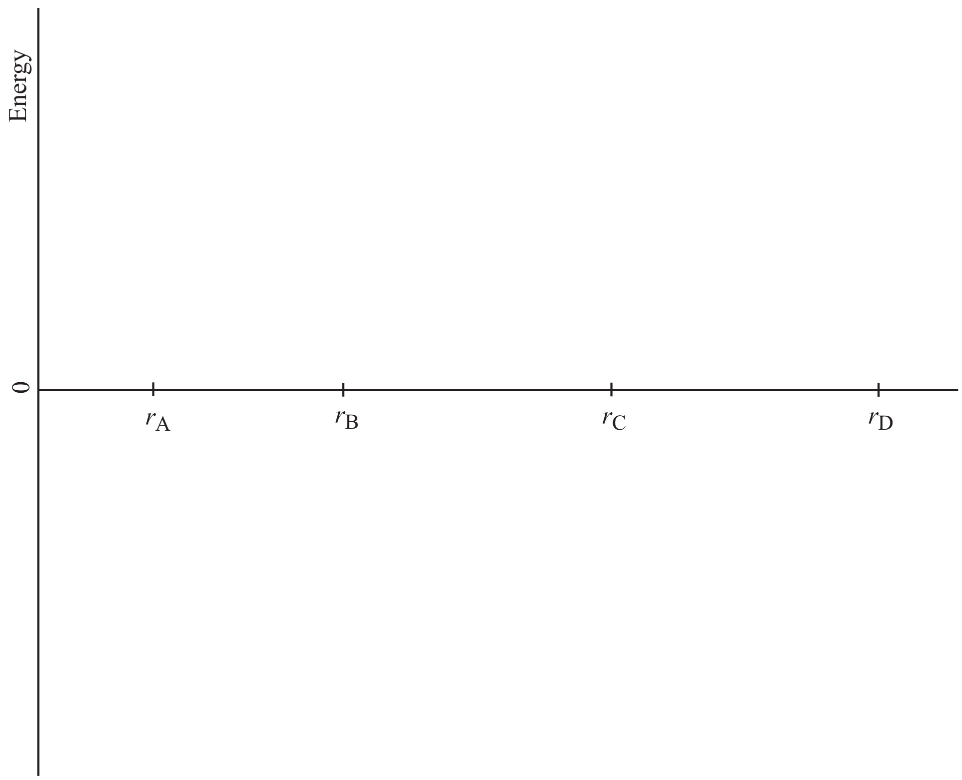
J. At every location along the spacecraft's path the gravitational potential energy of the system is negative.

Problem #2

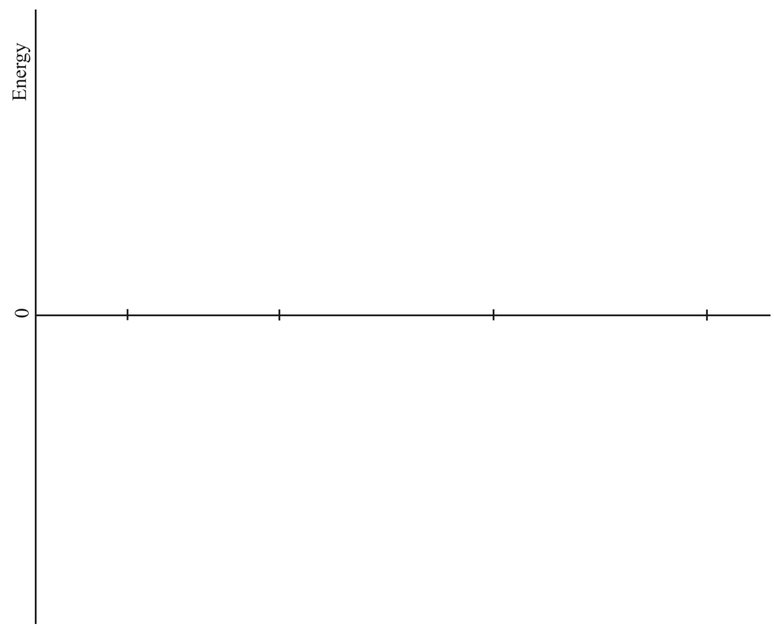
Here is a portion of the elliptical orbit of an asteroid moving around the sun from A to B to C to D.



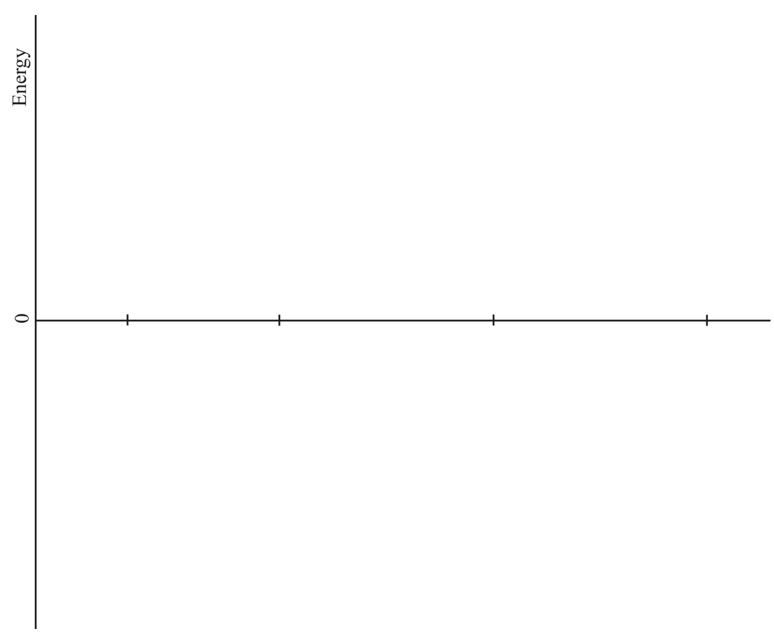
(a) For the system consisting of the Sun plus the asteroid, graph the gravitational potential energy U, the kinetic energy K, and the sum $K + U$ (total energy), as a function of the separation distance between Sun and asteroid. ***Label each curve.*** Along the r axis are shown the various distances between Sun and asteroid.



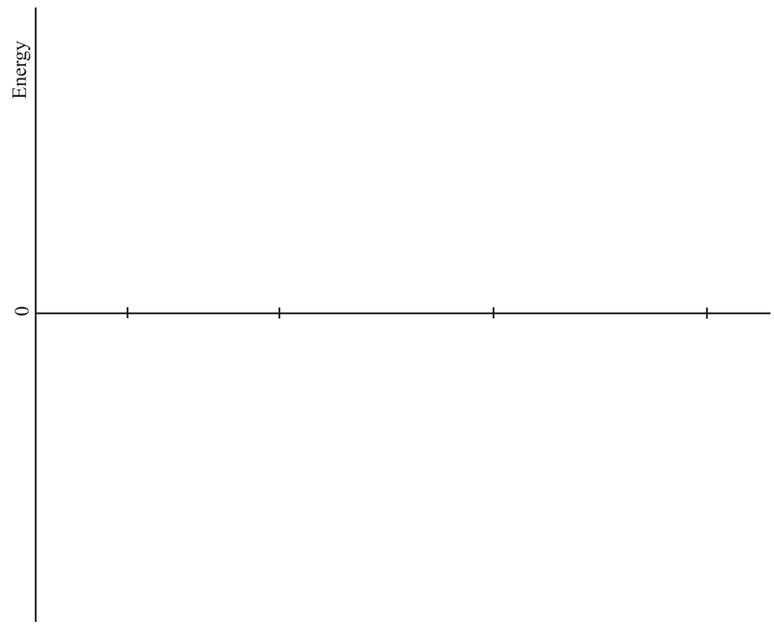
(b) A spacecraft leaves the surface of a planet at exactly the escape speed. For the system consisting of a planet and a spacecraft, graph the gravitational potential energy U, the kinetic energy K, and the sum $K + U$, as a function of the separation distance between planet and the spacecraft. ***Label each curve.***



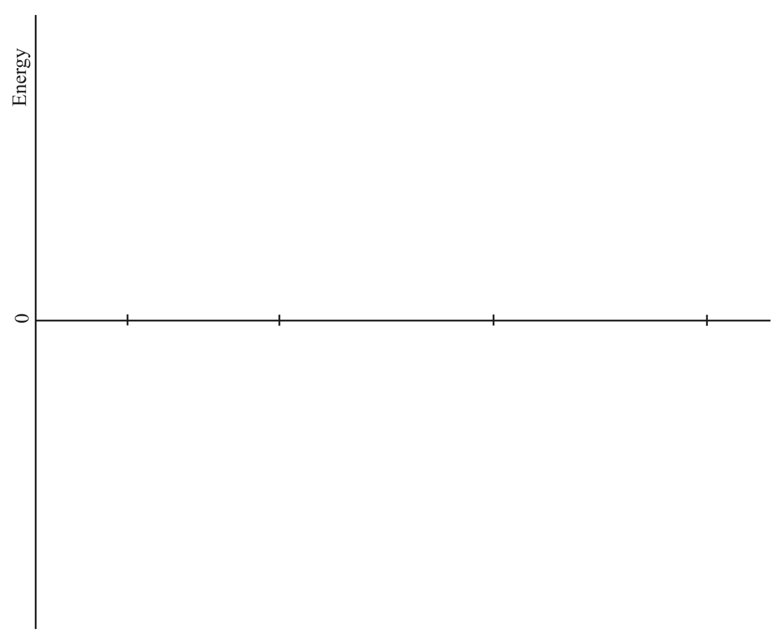
(c) A spacecraft leaves the surface of a planet with a velocity that is twice the escape speed. For the system consisting of a planet and a spacecraft, graph the gravitational potential energy U, the kinetic energy K, and the sum $K + U$, as a function of the separation distance between planet and the spacecraft. ***Label each curve.***



(d) Two charged particle with opposite charge and identical mass are released from rest a distance R from each other. For the system consisting of the two charges, graph the electric potential energy U, the kinetic energy K, and the sum $K + U$, as a function of the separation distance between the two charges. ***Label each curve.***



(e) Two charged particle with identical charge and mass are released from rest a distance R from each other. For the system consisting of the two charges, graph the electric potential energy U, the kinetic energy K, and the sum $K + U$, as a function of the separation distance between the two charges. ***Label each curve.***



Problem #3

During the spring semester at MIT, residents of the parallel buildings of the East Campus Dorms battle one another with large sling-shots made from surgical hose mounted to window frames. Water balloons (with a mass of about 0.5 kg) are placed in a pouch attached to the hose, which is then stretched nearly the width of the room (about 3.5 meters). If the hose obeys Hooke's Law, with a spring constant of 100 N/m, how fast is the balloon traveling when it leaves the dorm room window?

Problem #4

A spring with stiffness k_s and relaxed length L_0 stands vertically on a table. You hold a mass M just barely touching the top of the spring.

(a) You very slowly let the mass down onto the spring a certain distance, and when you let go, the mass doesn't move. How much did the spring compress? Hint: Use Newton's 2nd law.

(b) In part (a) you very slowly let the mass down onto the spring a certain distance, and when you let go, the mass doesn't move. Choose the block to be the system and use the energy principle to determine the work done by the Earth, the spring and your hand. Hint: the spring force is not constant.

(c) In part (a) you very slowly let the mass down onto the spring a certain distance, and when you let go, the mass doesn't move. Choose the block+spring+Earth to be the system and use the energy principle to determine the work done by your hand.

(d) Now you again hold the mass just barely touching the top of the spring, and then let go. Choose the block to be the system and use the energy principle to calculate the speed of the block when the spring has the same compression you found in part (a).

(e) Now you again hold the mass just barely touching the top of the spring, and then let go. Choose the block+spring+Earth to be the system and use the energy principle to calculate the speed of the block when the spring has the same compression you found in part (a).

(f) Compare your answers in parts (b) and (c), and the answers in parts (d) and (e). What does that tell you about your choices when you have an energy principle problem?

Problem #5

After watching "The Big Lebowski" for the first time this summer, you and a friend get into an argument about how much ice to add when making the perfect white russian cocktail. You both agree that, for optimum taste, the cocktail should be enjoyed at 10 degrees Celsius. The two ingredients for the cocktail, cream and a "vodka & kahlua" mix, both leave the fridge at 15 degrees Celsius. Ice from a standard freezer is at a temperature of -10 degrees Celsius. If typical white russian calls for 0.06 L of cream and 0.14 L of the "vodka & kahlua" mix, how much ice is needed to bring the drink down to its optimum temperature?

Ice: density = 0.91 kg/L, C = 4.18 J/(Cg)
Mix: density = 0.8 kg/L, C = 2.44 J/(Cg)
Cream: density = 1 kg/L, C = 3.77 J/(Cg)

Problem #6

During 3 hours one winter afternoon, when the outside temperature was 11° C, a house heated by electricity was kept at 25° C with the expenditure of 58 kwh (kilowatt·hours) of electric energy.

(a) What was the average energy leakage in joules per second (watts) through the walls of the house to the environment (the outside air and ground)?

(b) The rate at which energy is transferred between two systems due to a temperature difference is often proportional to their temperature difference. Assuming this to hold in this case, if the house temperature had been kept at 28° C (82.4° F), how many kwh of electricity would have been consumed?

Problem #7

Consider a system consisting of two particles connected by a spring of negligible mass:
$m_1 = 5$ kg, vector $\vec{v}_1 = \langle 5,\ -10,\ 15\rangle$ m/s
$m_2 = 10$ kg, vector $\vec{v}_2 = \langle -10,\ 0,\ -5\rangle$ m/s

(a) What is the total momentum $\vec{p}_{total}$ of this system?

(b) What is $\vec{V}_{CM}$, the velocity of the center of mass of this system?

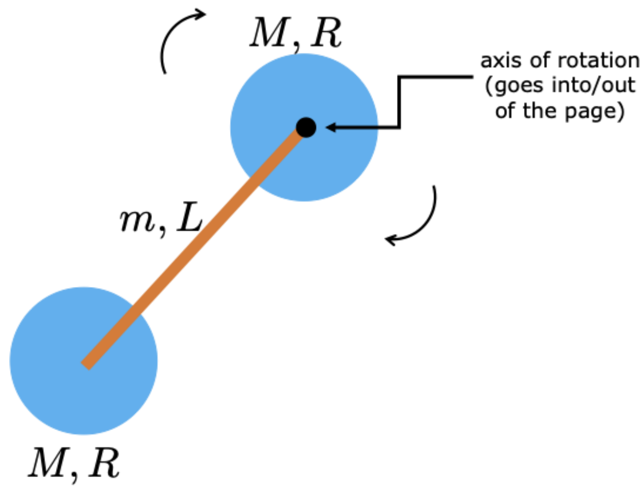
(c) What is K_{trans}, the translational kinetic energy of this system?

(d) What is K_{total}, the total kinetic energy of this system?

(e) What is K_{rel}, the kinetic energy of this system relative to the center of mass?

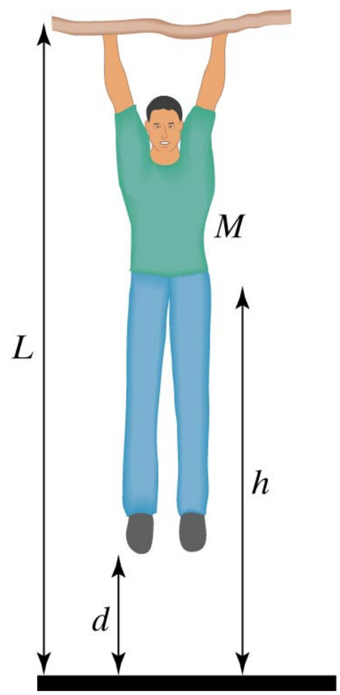
Problem #8

A barbell is made up of two solid spheres of mass M and radius R whose centers are attached to the ends of a thin rod that has mass m and length L. The entire thing rotates about an axis that goes through the center of sphere 1. Determine the total moment of inertia of the barbell about this axis of rotation. Hint: remember the parallel axis theorem.



Problem #9

You hang by your hands from a tree limb that is a height $L = 6$ m above the ground, with your center of mass a height $h = 5$ m above the ground and your feet a height $d = 4$ m above the ground, as shown in the figure (not to scale). You then let yourself fall. You absorb the shock by bending your knees, ending up momentarily at rest in a crouched position with your center of mass a height $b = 0.25$ m above the ground. Your mass is $M = 110$ kg. Hint: this problem is like the lemur problem from the homework, but backwards.



(a) Starting from the energy principle, find your speed just before your feet touch the ground.

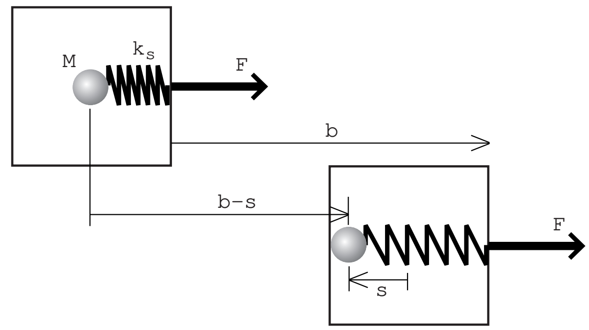
(b) Starting from the energy principle (point particle model) and assuming that the contact force of the ground on your feet is constant, find the magnitude of the contact force during your landing.

(c) What is the (real) work done by the contact force?

(d) Starting from the energy principle (real model), find the change in your internal energy during landing.

Problem #10

A thin box in outer space contains a large ball of clay of mass M, connected to an initially relaxed spring of stiffness k_s. The mass of the box is negligible compared to M. The apparatus is initally at rest. Then a force of constant magnitude F is applied to the box. When the box has moved a distance b, the clay makes contact with the left side of the box and sticks there, with the spring stretched an amount s. See the diagram for distances.



(a) Immediately after the clay sticks to the box, how fast is the box moving?

(b) What is the increase in thermal energy of the clay?