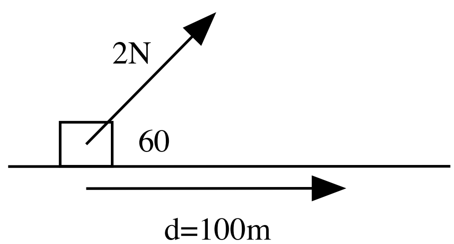
Exam 3
Physics 130

Short Answer Section. Please answer all of the questions.

1. A 20,000 kg locomotive engine has a velocity $v = 10\,\hat{j}$ m/s. What are its momentum and kinetic energy?

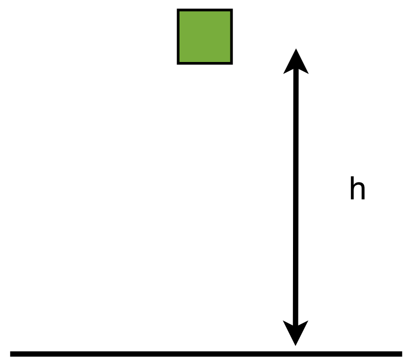
$$\vec{p} = 200{,}000\,\hat{j}$$
$$E = \frac{1}{2}mv^2 = 1\times 10^6\,J$$

2. A block of 5 kg is dragged across a frictionless floor as by a 2N Force for a distance of 100m shown below. What work is done on the block by the force? Assuming it started from rest, what is its final speed?



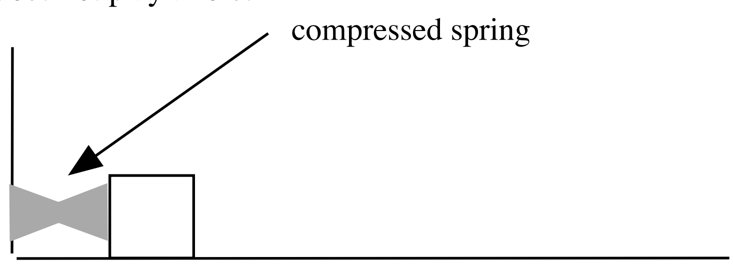
$$W = 2N\cdot 100N\cdot\cos 60 = 100J$$
$$\frac{1}{2}mv_f^2 - 0 = W$$
$$v_f = \sqrt{\frac{2W}{m}} = 6.32m/s$$

3. A block of mass m falls from a height h to the ground? Using energy methods, find an expression for the block's velocity just before it hits the ground. How much work did gravity do on the block in this process?



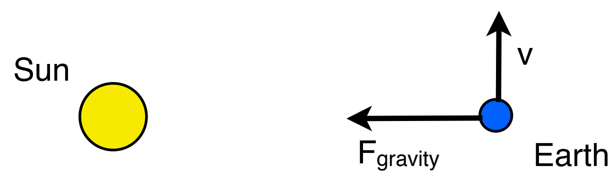
$$\frac{1}{2}mv^2 = mgh$$
$$v = \sqrt{2gh}$$
$$W = mgh$$

4. A spring with spring constant k=2000N/m is initially compressed by distance 0.1m. How much energy is stored in this spring? What final kinetic energy would the mass (m=2 kg) have after the spring expands back to its original shape, pushing it along, and what velocity would the mass have? Hint: Use conservation of energy for this problem. The surface is perfectly flat and frictionless so gravity does not play a role.



$$U = \frac{1}{2}kx^2 = 10J$$
$$KE_f = 10J$$
$$\frac{1}{2}mv_f^2 = KE_f$$
$$v_f = \sqrt{\frac{2KE_f}{m}} = 3.16m/s$$

5. The earth moves in a nearly perfect circle around the sun at a fairly constant speed, so it can be approximated by uniform circular motion. How much work does the sun's gravitational force do on the earth and why?



No work is done by the inward force in uniform circular motion.

6. A 20,000 mass has a velocity of $\vec{v}_1 = 10\hat{i}\ m/s$. It collides and sticks to a mass of 10,000 kg that was initially at rest. What is the final velocity of the composite system? Hint: This is a conservation of momentum problem. *(number corrected)*

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1' + m_2\vec{v}_2'$$

$$m_1\vec{v}_1 + 0 = (m_1 + m_2)\vec{v}'$$

$$\vec{v}' = \frac{m_1\vec{v}_1}{(m_1 + m_2)} = 6.67\hat{i}\ m/s$$

7. A potential energy is given by

$$U = -b\,x^2$$

What force can be associated with this potential?

$$U = -b\,x^2$$

$$F = -\frac{dU}{dx} = 2bx$$

8. Is it possible to write a potential energy for the forces involved in an automobile crash? Why or why not?

No--it's not conservative.

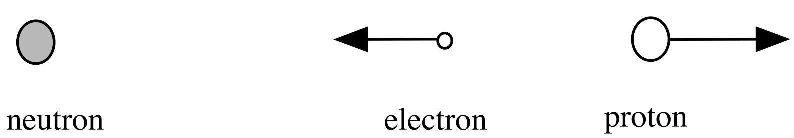
9. When a player serves a tennis ball, the ball goes from rest to 30m/s in approximately 0.1 s. If the ball has a mass of 0.200 kg, what change in momentum and average force does it experience?

$$\Delta p = 0.2kg \cdot 30m/s = 6kgm/s$$
$$F = \frac{\Delta p}{\Delta t} = \frac{6kgm/s}{0.1s} = 60N$$

Problems: Please work 2 problems.

1. A free neutron will decay into an electron and a proton in about 15 minutes. Consider a neutron at rest before the decay. After the decay, the electron has a velocity to the left $\vec{v}_e{}' = -5\times10^7 m/s\,\hat{i}$ Take the masses to be:

$$m_n = 1.68\times10^{-27} kg$$
$$m_p = 1.67\times10^{-27} kg$$
$$m_e = 9.11\times10^{-31} kg$$



a) What are the initial momentum and kinetic energy of the neutron

$$\vec{p}_N = 0kgm/s$$
$$E_N = 0J$$

b) What is the final momentum of the electron-proton system? What is final velocity of the proton?

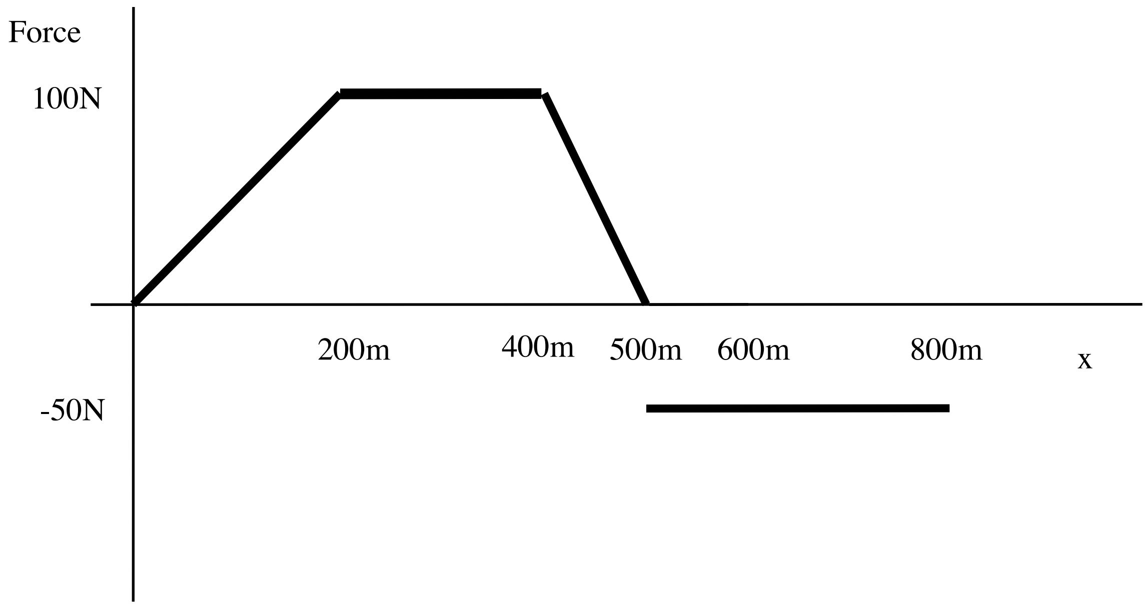
$$\vec{p}_f = 0kgm/s$$
$$= m_e\vec{v}_e{}' + m_p\vec{v}_p{}'$$
$$\vec{v}_p{}' = \frac{m_e\vec{v}_e{}'}{m_p} = 2.72\times10^4 m/s\,\hat{i}$$

c) What is the final kinetic energy of the electron proton system? What was the change in the kinetic energy in this decay?

$$KE_f = \frac{1}{2}m_e v_e'^2 + \frac{1}{2}m_p v_p'^2 = 1.14\times10^{-15}\,J = \Delta KE$$

Note: The energy for this decay comes from the difference in masses between the initial and final states. The mass of the neutron is slightly larger than the mass of the electron plus the mass of the proton. The mass that "disappears" turns into kinetic energy via Einstein's famous formula $E = mc^2$. We have ignored the presence of a third light particle as well to simply this problem. Neutrons in nuclei can also decay under certain circumstances

2. A mass of 10 kg is subjected to the forces shown below. These are the only forces that act on the mass.



a) How much work is done on the mass between 0m and 200 m?

$$W = \frac{1}{2} \cdot 200m \cdot 100N = 10{,}000J$$

b) How much work is done on the mass between 200 and 400 m?

$$W = 200m \cdot 100N = 20{,}000J$$

c) How much work is done on the mass between 400 and 500 m?

$$W = \frac{1}{2} \cdot 100m \cdot 100N = 5{,}000J$$

d) How much work is done on the mass between 500 m and 800 m?

$$W = 300m \cdot -50N = -15{,}000J$$

e) What total work was done on the mass?

$$W = 10{,}000J + 20{,}000J + 5{,}000J - 15{,}000J = 20{,}000J$$

f) Assuming the mass started from rest, what would be its final kinetic energy and velocity?

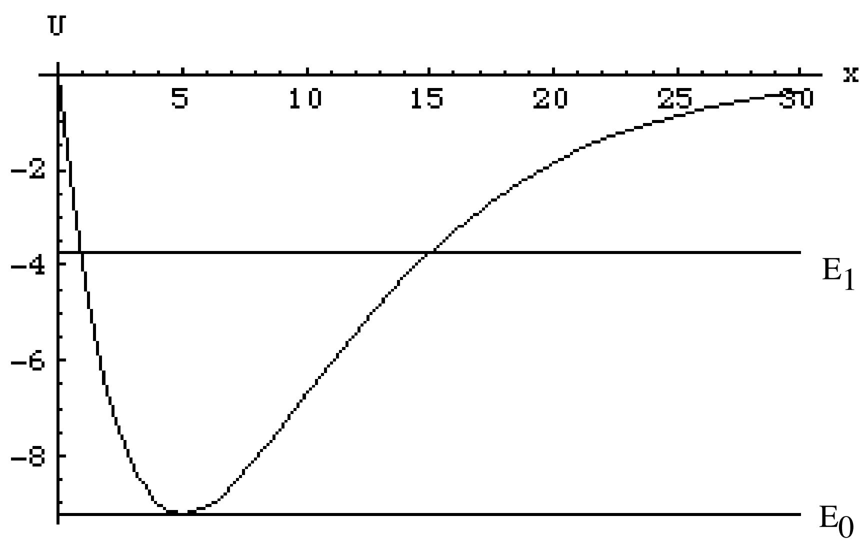
$$\frac{1}{2}mv^2 = KE_f - 0$$

$$v = \sqrt{\frac{2KE_f}{m}} = 63.25 m/s$$

g) At what x position would the mass have its maximum kinetic energy and velocity?

At 500m

3 Consider the potential shown below. The vertical axis is in Joules and the horizontal axis is in meters. The total energies shown are E_0=-9.19J and E_1=-3.734J. E_0 is the minimum energy that the system can have. For this problem, you can estimate values from the graph



a) What motion can a mass have when it has total energy E_0=-9.19J. What x values can it have?

At rest at at approximately x=5.

b) What motion can a mass have when it has total energy E_1=-3.734J. What are the turning points?

Oscillates between approximately x=1 and x=15

c) What is the maximum kinetic energy that a mass can have if the energy is E_1

9.19-3.743=5.447J

d) Where is the force positive, negative and zero? How do you know this?

Force is positive for x<5, negative for x>5, and zero at x=5.

Useful Formulas

Conversions:

1 mile = 1.6 km
1 foot = 0.3048 m
1 inch = 2.54 cm
1 mile = 5280 ft.

Constants:

g = 9.8 m/s^2 = 32 ft/s^2

Misc. Equations:

Volume of a sphere = (4/3) πr^3

Volume of a cylinder = $\pi r^2 L$

Area of a circle = πr^2

Volume of a rect. obj. = L x W x D

Area of a triangle =(1/2)*base*height

sin θ = opp/hyp
cos θ = adj/hyp
tan θ = opp/adj

<u>Derivative of a Polynomial.</u>

$$\frac{d}{dx}(a\,x^n) = n\,a\,x^{n-1}$$

Example:

$$\frac{d}{dx}(a\,x^3) = 3\,a\,x^2$$

<u>Integral of a polynomial.</u>

$$\int a\,x^n dx = \frac{a\,x^{n+1}}{n+1}$$

Example:

$$\int b\,x^3 d\,x = \frac{b\,x^4}{4}$$