October 20

Get Whiteboards

I will teach 0175 next semester
WF from 2:00-3:40 and M 2:00-2:50

The class is listed with course id number 33982

It should be open to everyone, so if you want a spot, I suggest registering as early as possible…

Go Over Quiz

A Plutonium-240 with a rest mass of 240.054 u fissions when it absorbs a neutron. For this problem, the three fission fragments are two equal fragments: Silver-120 nuclei with rest mass 119.919 u and charge 47e, and a free neutron. (In addition to the two main fission fragments there are typically one or more free neutrons in the final state; in your analysis make the simplifying assumption that the one free neutron has the same kinetic energy as the absorbed neutron.)

The unit u is a unified atomic mass unit where 1 u = 1.66054e-27 kg (approximately the mass of one nucleon) and e is the charge on a proton, e = 1.60218e-19 coulomb. $1/(4\pi\varepsilon_0) = 8.98755\times10^9 \mathrm{N\cdot m^2/C^2}$, $c = 2.99792\times10^8$ m/s.

Keep at least 6 significant figures in your intermediate calculations.

(a) Calculate the final speed *v*, when the Silver-120 nuclei have moved very far apart (due to their mutual electric repulsion)

(b) Using energy considerations, calculate the distance between centers of the Silver-120 nuclei just after fission, when they are momentarily at rest.

GATHER:
$M_{Pl\text{-}240}$ = 240.054 u; $M_{Ag\text{-}120}$= 119.919 u; 1 u = 1.66054e-27 kg;
$Q_{Ag\text{-}120}$ = 47 *e*; *e* = 1.60218e-19 coulomb

It is ok to use the nonrelativistic formulas, but must check that the calculated *v* is indeed small compared to *c*. (The large kinetic energies of these palladium nuclei are eventually dissipated into thermal energy of the surrounding material. In a nuclear reactor this hot material boils water and drives an electric generator.)

ORGANIZE:
Chose a system: all the particles (no external work)
Identify initial and final states (there are three choices):

1. The Pl-240 nucleus + free neutron before it fissions
2. Just after fission when the two silver nuclei are close together and momentarily at rest + free neutron.
3. The silver nuclei are very far away from each other, traveling at high speeds + free neutron

ANALYZE:

The analysis can be thought of as a diamond.

- Write a compact statement of the energy principle for your system and choice of initial and final states.
- Expand to include all the possible energy terms.
- Rewrite with appropriate subscripts for the situation.
- Contract by evaluating specific terms.
- Solve for the unknown quantity of interest.

$$E_f = E_i + W_{\text{ext}}$$

$$\left(m_{1f}c^2 + K_{1f}\right) + \left(m_{2f}c^2 + K_{2f}\right) + \ldots + U_{12f} + \ldots = \left(m_{1i}c^2 + K_{1i}\right) + \left(m_{2i}c^2 + K_{2i}\right) + \ldots + U_{12i} + \ldots + W_{\text{ext}}$$

Rewrite with appropriate subscripts for the particular situation.

Cross out any terms that are zero;

write specific potential energy terms.

Solve for unknown.

Plug in numbers.

For a)

Initial State: State 1

Final State: State 3

Draw appropriate diagrams

Identify appropriate Fundamental Principle: Energy Principle

$$\left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \left(m_n c^2 + K_{n,f}\right) + U_f = \left(m_{\text{Pl}}c^2 + K_{\text{Pl},i}\right) + \left(m_n c^2 + K_{n,i}\right) + U_i + W_{\text{ext}}$$

$$2\left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \left(m_n c^2 + K_{n,f}\right) + \cancel{U_f} = \left(m_{\text{Pl}}c^2 + \cancel{K_{\text{Pl},i}}\right) + \left(m_n c^2 + K_{n,i}\right) + \cancel{U_i} + \cancel{W_{\text{ext}}}$$

$$2\left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \cancel{\left(m_n c^2 + K_{n,f}\right)} = \left(m_{\text{Pl}}c^2\right) + \cancel{\left(m_n c^2 + K_{n,i}\right)}$$

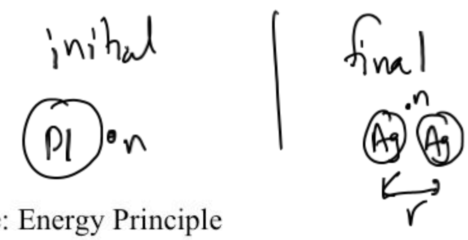
$$2K_{\text{Ag},f} = 2\frac{1}{2}m_{\text{Ag}}v^2 = m_{\text{Pl}}c^2 - 2m_{\text{Ag}}c^2$$

$$v = \sqrt{\frac{m_{\text{Pl}}c^2 - 2m_{\text{Ag}}c^2}{m_{\text{Ag}}}}$$

$$= \sqrt{\frac{(240.054\ \text{u} - 2\times 119.919\ \text{u})c^2}{119.919\ \text{u}}}$$

$$= \sqrt{0.0018\times c^2} = 0.042\ c = 1.3\times 10^7\ \text{m/s}.$$

For b)
Initial State: State 1
Final State: State 2
Draw appropriate diagrams
Identify appropriate Fundamental Principle: Energy Principle



$$\left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \left(m_{\text{Ag}}c^2 + K_{\text{Ag},f}\right) + \left(m_n c^2 + K_{n,f}\right) + U_f = \left(m_{\text{Pl}}c^2 + K_{\text{Pl},i}\right) + \left(m_n c^2 + K_{n,i}\right) + U_i + W_{\text{e}}$$

$$2\left(m_{\text{Ag}}c^2 + \cancel{K_{\text{Ag},f}}\right) + \left(m_n c^2 + K_{n,f}\right) + U_f = \left(m_{\text{Pl}}c^2 + \cancel{K_{\text{Pl},i}}\right) + \left(m_n c^2 + K_{n,i}\right) + \cancel{U_i} + \cancel{W_{\text{ext}}}$$

$$2\left(m_{\text{Ag}}c^2\right) + \cancel{\left(m_n c^2 + K_{n,f}\right)} + U_f = \left(m_{\text{Pl}}c^2\right) + \cancel{\left(m_n c^2 + K_{n,i}\right)}$$

$$U_f = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{r} = m_{\text{Pl}}c^2 - 2m_{\text{Ag}}c^2$$

$$r = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{\left(m_{\text{Pl}} - 2m_{\text{Ag}}\right)c^2}$$

$$= 8.98755\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\frac{\left(47\times1.60218\times10^{-19}\ \text{C}\right)^2}{(240.054 - 2\times119.919)\times1.66054\times10^{-27}\ \text{kg}\times\left(2.99792\times10^8\ \text{m/s}\right)^2}$$

$$= 1.58\times10^{-14}\ \text{m}.$$

LEARN:

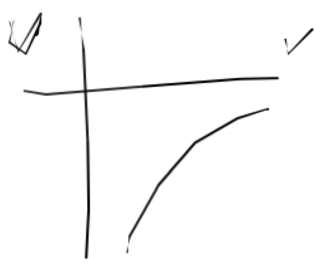
Do the units make sense?

Did the speed of each silver nucleus turn out to be small enough that $\frac{1}{2}mv^2$ or $\frac{p^2}{2m}$ was an adequate approximation for the kinetic energy of one of the palladium nuclei?

Is the final speed a high speed? (High speed goes with lots of heating of the metal, which can run electric generators.)

Are the nuclei at a reasonable separation?

Potential Energy and Force

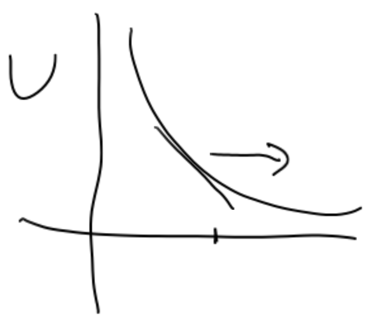


$$F_r = -\frac{dU}{dr}$$

Force = − slope

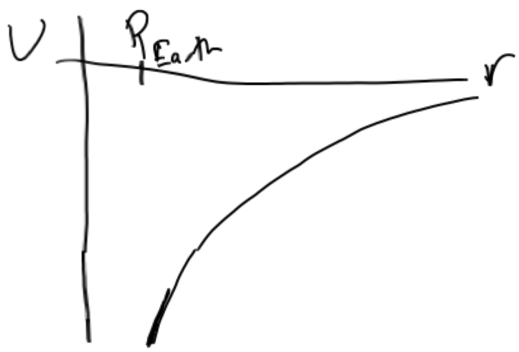
$$F_r = -\frac{dU}{dr}$$

Force = - slope



Potential energy near surface of Earth

$$U_{grav} = -\frac{GMm}{r} \longleftrightarrow U = mgh$$



$$g = \frac{GM_{Earth}}{R_{Earth}^2}$$

$$(1+\epsilon)^n = 1 + \frac{n}{1}\epsilon + \frac{n(n-1)}{2\times 1}\epsilon^2 + \dots$$

binomial expansion

$$r = R_{Earth} + h$$

$$U = -\frac{GmM}{r} = -\frac{GMm}{(R_{Earth}+h)}$$

$$= -\frac{GMm}{R_{Earth}}\left(1+\frac{h}{R_{Earth}}\right)^{-1} = -\frac{GmM}{R_{Earth}}\left(1-\frac{h}{R_{Earth}}+\dots\right)$$

$$= -\frac{GMm}{R_{Earth}} + \frac{GMmh}{R_{Earth}^2} + \dots$$

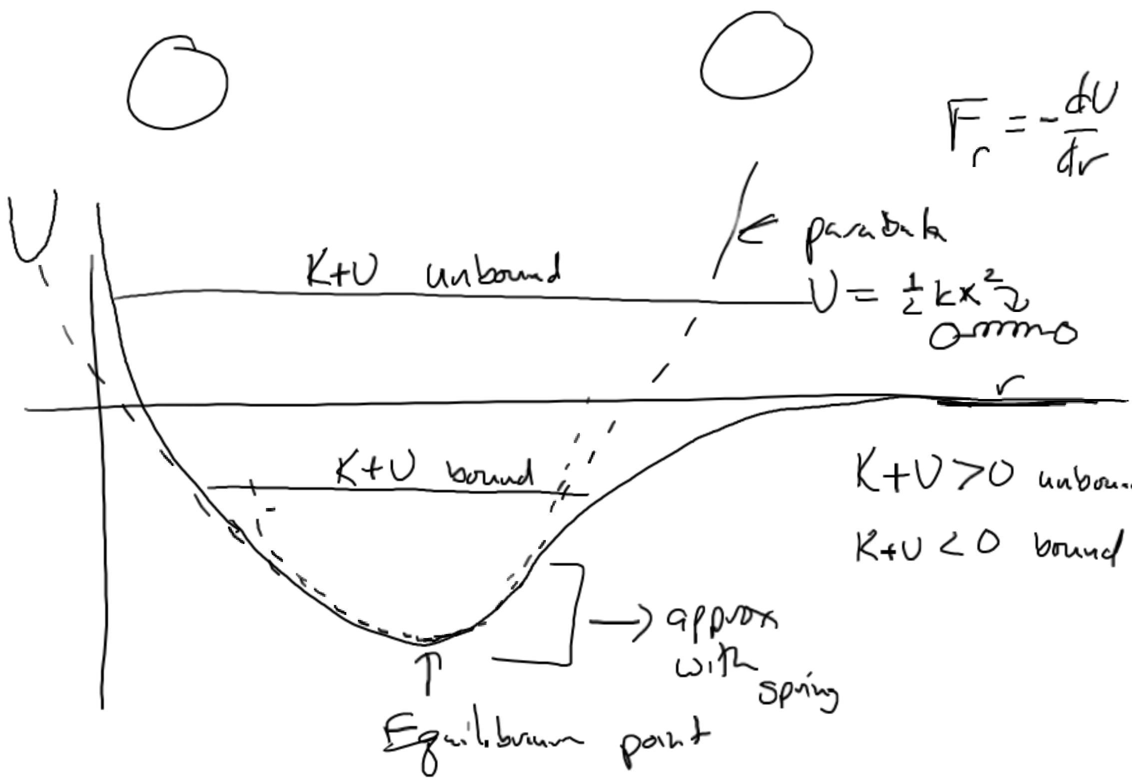
$$= C + mgh$$

Molecular binding

Draw potential energy curve:

1. Where is equilibrium position?
2. What happens to the potential energy/force if you push them together? (Just a little, and as much as possible)
3. What happens if you pull them apart? (Just a little, and an infinite amount)

$F_r = -\frac{dU}{dr}$



K+U > 0 unbound

K+U < 0 bound

E = K+U

Review for Midterm 2 Chapter Ch 4 + 5

Ch 4

Young's Modulus $Y = \frac{\text{stress}}{\text{strain}} = \frac{(F_{\perp}/A)}{(\Delta L/L)}$

Micro/macro $Y = \frac{k_{s,i}}{d}$ ← interatomic spring const; d ← diameter

↳ know how to get diameter, etc from density, etc.

Speed of Sound

$$v = \sqrt{\frac{k_{s,i}}{m_a}}\, d$$

More on momentum principle

$$\frac{d\vec{p}}{dt} = \vec{F}_{net}, \quad \left(\frac{d|\vec{p}|}{dt}\right)\hat{p} = \vec{F}_{\parallel} \text{ and } |\vec{p}|\frac{d\hat{p}}{dt} = \vec{F}_{\perp}$$

Analytic solution to harmonic oscillator

$$x = A\cos(\omega t) \qquad \omega = \sqrt{\frac{k_s}{m}}$$

↑ amplitude

Assuming no friction, spring mass negligible

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$

Chapter 5

Energy of particle : $E_{particle} = \gamma mc^2 = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$

$= mc^2 + K$

↑ rest ↑ kinetic

Kinetic energy

$K = \gamma mc^2 - mc^2$

$K \approx \frac{1}{2} mv^2 = \frac{p^2}{2m}$ if $v \ll c$

Connection between energy + momentum

$E^2 - (pc)^2 = (mc^2)^2$

so for massless particles $\Rightarrow E = pc$

Energy principle $\Delta E_{system} = W_{surrounding}$

Work $W = \vec{F} \cdot \Delta\vec{r} = F_x \Delta r_x + F_y \Delta r_y + F_z \Delta r_z$

$= |\vec{F}||\Delta\vec{r}| \cos\theta$

$W = \sum \vec{F} \cdot \Delta\vec{r}$ or $W = \int \vec{F} \cdot d\vec{r}$

Conservation of energy $\Delta E_{system} + \Delta E_{surrounding} = 0$

Potential energy (energy of interacting pair of particles) $\Delta U = -W_{internal}$

Force & potential energy $F_x = -\frac{dU}{dx}$

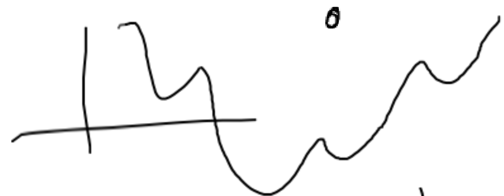
Know how to plot potential & Kinetic energy

$$U_{gravity} = -G \frac{m_1 m_2}{r} \quad , \quad G = 6.7 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$$

near the surface of Earth $\Delta U \approx \Delta(mgy)$ ← height

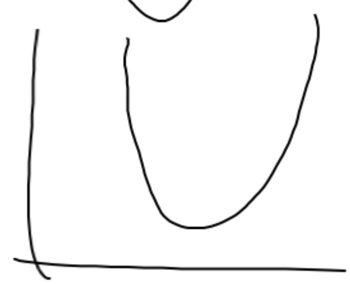
$$U_{electric} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r} \quad , \quad \frac{1}{4\pi\epsilon_0} = 9 \times 10^{9} \frac{N \cdot m^2}{C^2}$$

$$\rho_{macro} = \frac{M}{V} = \frac{N_{atom}\, m_{atom}}{N_{atom}\, d_{atom}^3} = \rho_{micro}$$



$$d_{atom}^3 = \frac{m_{atom}}{\rho}$$

$$d = \sqrt[3]{\frac{m_{atom}}{\rho}}$$



$$m_{atom} = \frac{\text{Mass per mole}}{N_{Avogadro}}$$