Homework #9 due Tonight
Hour exam Friday, Nov 30 -- Material in Ch 9, 10, and 11 through 11.2. Understanding 11.3 might not hurt. (also Tutorial and Lab as usual)

Office hrs today 4-5:30 and tomorrow 4-5:30.

CLUE exam review tonight at 7pm in Mary Gates Hall 254

Final homework assignment due Friday Dec 7

MASS – why is gravity mass and inertia mass the same? Or is it? Experimental

$$F_g = GMm / r^2 = ma$$ **same *m*.**

Consequence – different materials fall the same, or equivalently, don't need a different *G* for each kind of stuff.

Best experiments with torsion pendulums, compare attraction of source masses to different material test masses. $\Delta a / a < 2 \times 10^{-13}$ **done here at UW by Adelberger, Heckel, Gundlach.**

"The equivalence principle" – basis for general relativity.

Gravitational potential energy: We will treat the special case of a big object attracting a small one. So C.M. of system is approx at center of large object.

Small one located at r from the center of the big one. (r for gravity and r to cm are same.)

$$U(r) = -\int_{r_0}^{r} \vec{F} \bullet d\vec{r} = -\int_{r_0}^{r} \left(\frac{-GMm}{r^2}\hat{r}\right) \bullet d\vec{r}$$

$$= GMm \int_{r_0}^{r} \frac{dr}{r^2} = GMm(-1/r + 1/r_0)$$

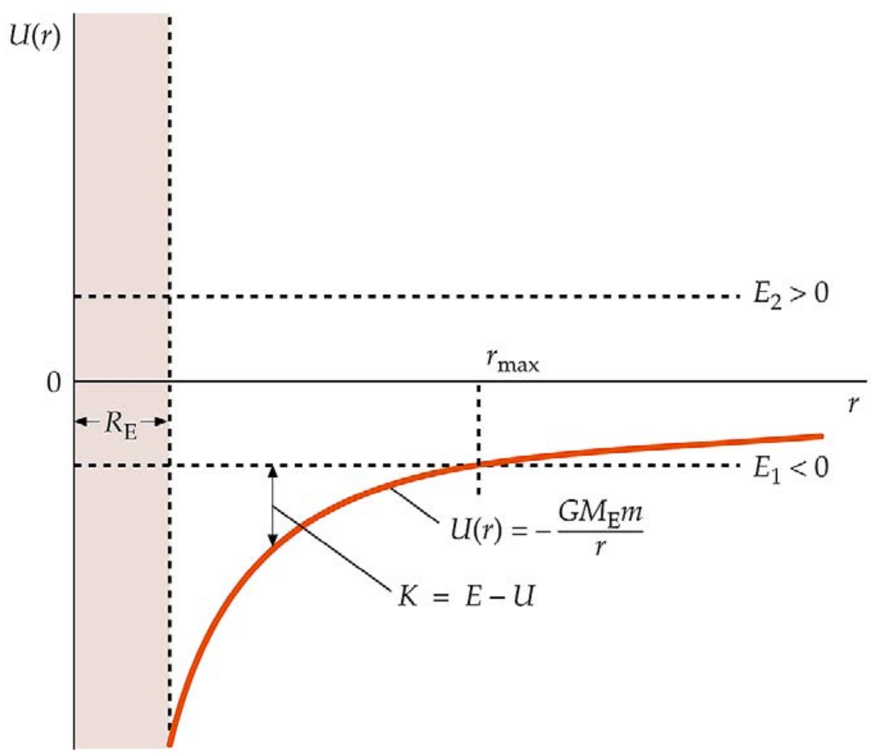
Pick constant r_0 so $U \rightarrow 0$ as $r \rightarrow \infty$

That is $r_0 = \infty$ **Then** $U(r) = -GMm/r$
Show $U(R_E + h) = U(R_E) + mgh$

Binding energy: **Object at rest at, say, R_E has negative energy. If you add an equal magnitude of positive energy, the object could be free, with net energy 0. Bound things have E<0.**

Escape velocity: **v_{esc} (in the $\hat{r}$ direction) so ½ $mv_{esc}^2 = GM_Em/R_E$ for object on surface of Earth. (or appropriate M and R for other thing.)**
$GM_E/R_E^2 = g$ so $v_{esc}^2 = 2g\, R_E$ →

$$v_{esc} = \sqrt{2(9.8)(6.4\text{x}10^6)} \approx 11 \text{ km/s}$$



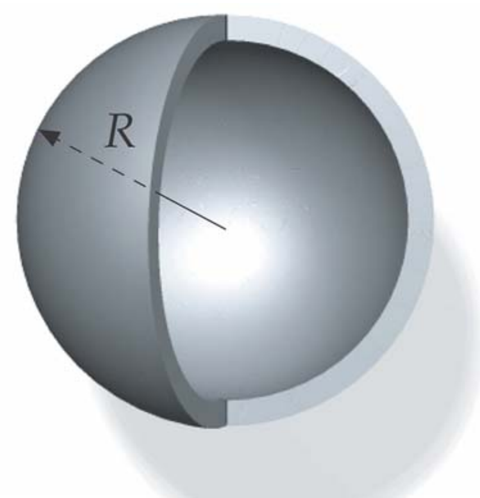
For gravity from complicated objects, we can define the Gravitational Field (works for simple objects too.)

What is force on a unit mass? $\vec{g} = \vec{F}_g / m$

This is just the acceleration.

If the field comes from several masses, the fields from each sum: $\vec{g} = \sum_i \vec{g}_i$ **or** $\vec{g} = \int d\vec{g}$

In 11.5 the derivation is done showing, for a shell of mass M, radius R, centered at the origin, the field is



1. **g(r)=0 if you are inside the shell**

2. $\vec{g}(r) = -\frac{GM}{r^2}\hat{r}$ **outside.**

So outside it looks like a point mass at the origin.

Thus a sphere also looks like a point mass at the origin from outside, as long as the density only depends on r. (think of an onion)
Inside you get field from the sphere contained within the radius you are at.

SUMMARY of material covered since last exam

Ch 9 – Rotational motion.
Angular coordinates, velocity, acceleration.
Moment of inertia and Torque
See table 9-2 for analogs.
Rolling without (then with) slipping.

Ch 10 – Polar vectors and angular momentum
Vector products (cross products) for torque and angular momentum.

Conservation of angular momentum – collisions where angular momentum is conserved.

Newton's law for torques and angular momentum in vector form. – The gyroscope

(Skipped 10-4, quantization of angular momentum)

Ch 11 – Gravity: Kepler's laws, Newton's law of gravity. Orbits of various sorts. (also 11.3-5, which will not be on the coming exam.)