Discuss and Answer:

Of the topics we’ve been learning in class this semester so far which has been your favorite? Least favorite? (Regardless of difficulty)

Notes

- Homework on Gravity due Friday
- Exam II will be Nov 20 (Momentum, Rotational Motion - Dynamics, and Gravity)
- Next Monday, Nov 18 will be a review day

Recap: Gravitational Work and Energy

- We can find the work done by the gravitational force
- We can assign an associated potential energy (set E=0 at infinity)
- We can find the total energy in different situations: negative, zero, positive, setting stationary on the surface of an object, etc.

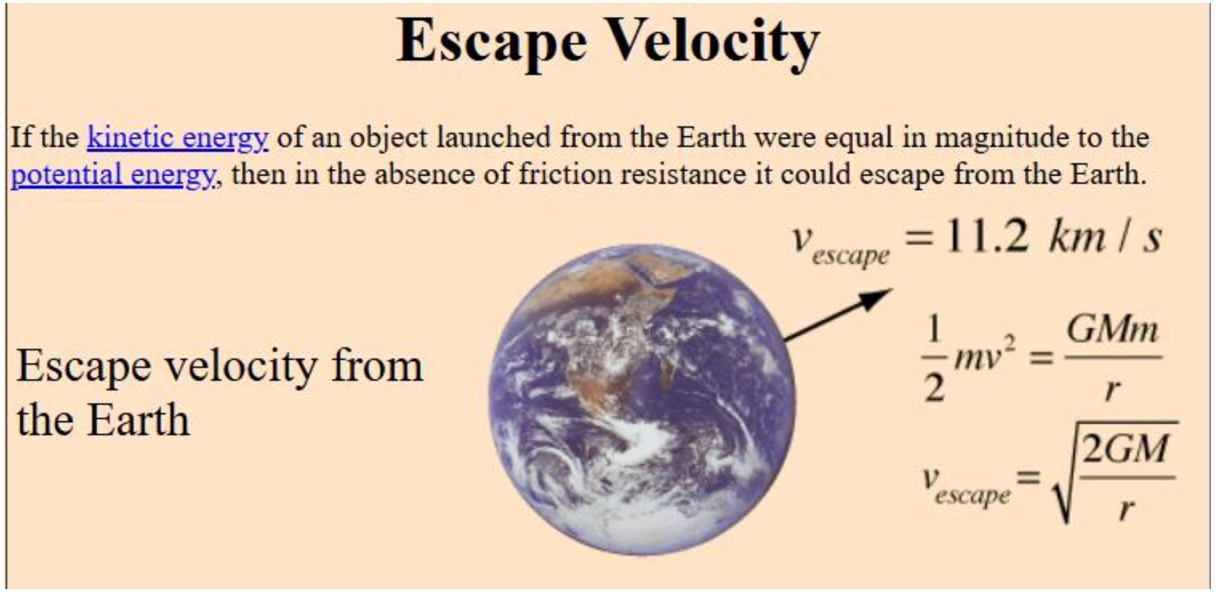
Gravitation

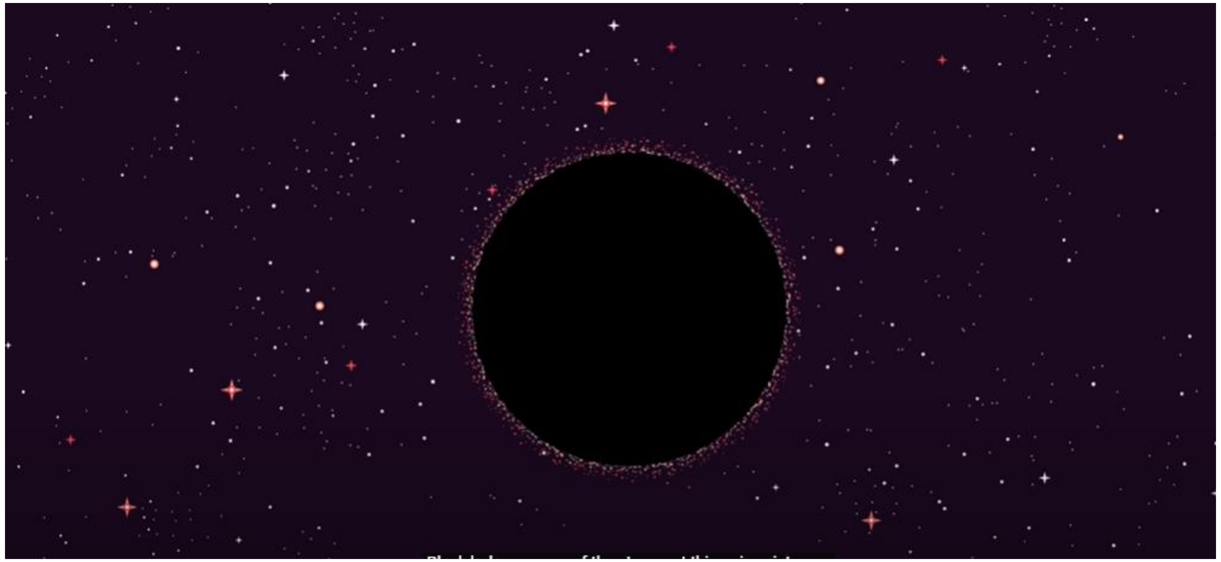
$$\vec{F}_g = \vec{g}m = -\frac{GMm}{r^2}\hat{r} \qquad U = -\frac{GMm}{r}$$

$$E_{escape} = 0 \qquad E_{orbit} = -\frac{1}{2}\frac{GMm}{r} \qquad E_{surf} = -\frac{GMm}{R}$$

$$\eta_{Kepler} = 4\frac{\pi^2}{GM}$$

Prelecture Review: Escape Velocity and Black Holes





Escape Speed

$$0 = \frac{1}{2}mv_e^2 - \frac{GMm}{r}$$

What are our comments and questions?

Comments and Questions

- Does the "escape velocity" only apply to escaping the gravitational pull of earth, or is it for any two objects being pulled together?
- Is the space of a black hole actual physical matter, or is it emptiness that just has immense gravitational pull?
- How does the concept of escape speed relate back to what we learned during unit 1 about kinematics?

My Comments and Questions

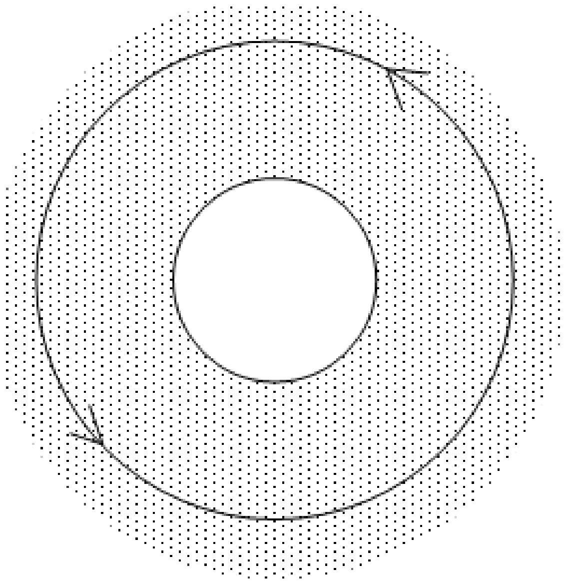
- Comment: The equation for escape speed allows us to determine the event horizon radius of a black hole correctly, even without taking into account General Relativity!

- Question: If something (like a book) is thrown into a black hole, is the information it contains lost forever?

Discuss and Answer:

A satellite is in circular orbit around a planet that has a very tenuous atmosphere extending up to the altitude of the satellite. Due to atmospheric drag, the speed of the satellite…

A) increases
B) decreases
C) remains constant



SQUARECAP

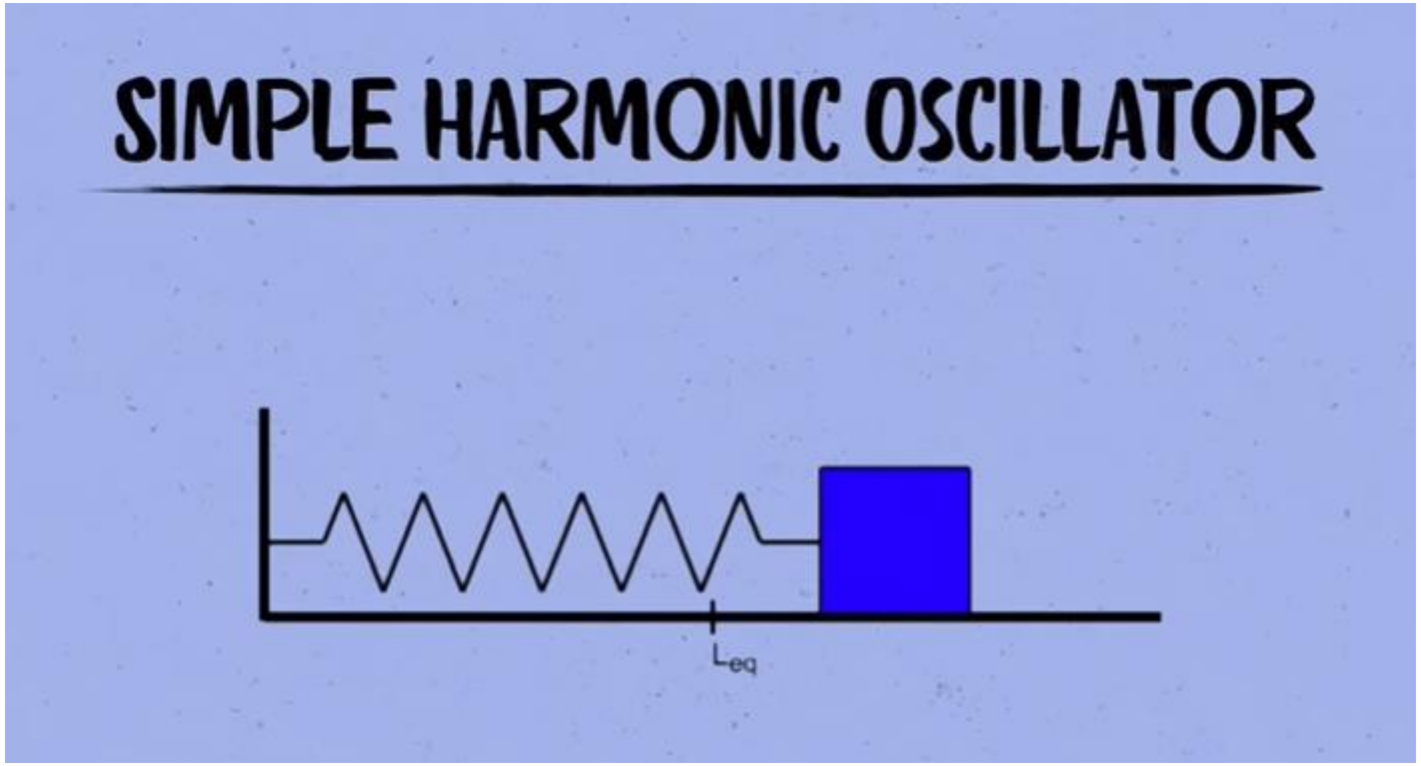
Discuss and Answer:

Suppose a projectile is fired straight upward from the surface of an airless planet of radius R with the escape velocity vesc (meaning the projectile will just barely escape the planet's gravity -- it will assymtotically approach infinite distance and zero speed.) What is the projectile's speed when it is a distance 4R from the planet's center (3R from the surface).

A) 1/2 vesc
B) 1/4 vesc
C) 1/9 vesc
D) 1/3 vesc
E) None of these is correct.

(Ignore the gravity of the Sun and other astronomical bodies.)

Prelecture Review: Small Oscillations



Energy near an equilibrium:

$$U \approx U_0 + \frac{1}{2}kx^2 + \cdots$$

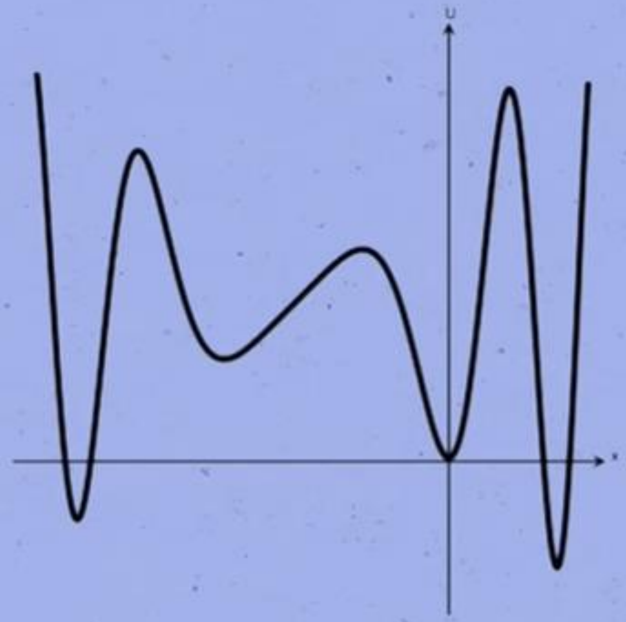
Oscillations:

$$\ddot{x} = -\omega^2 x$$

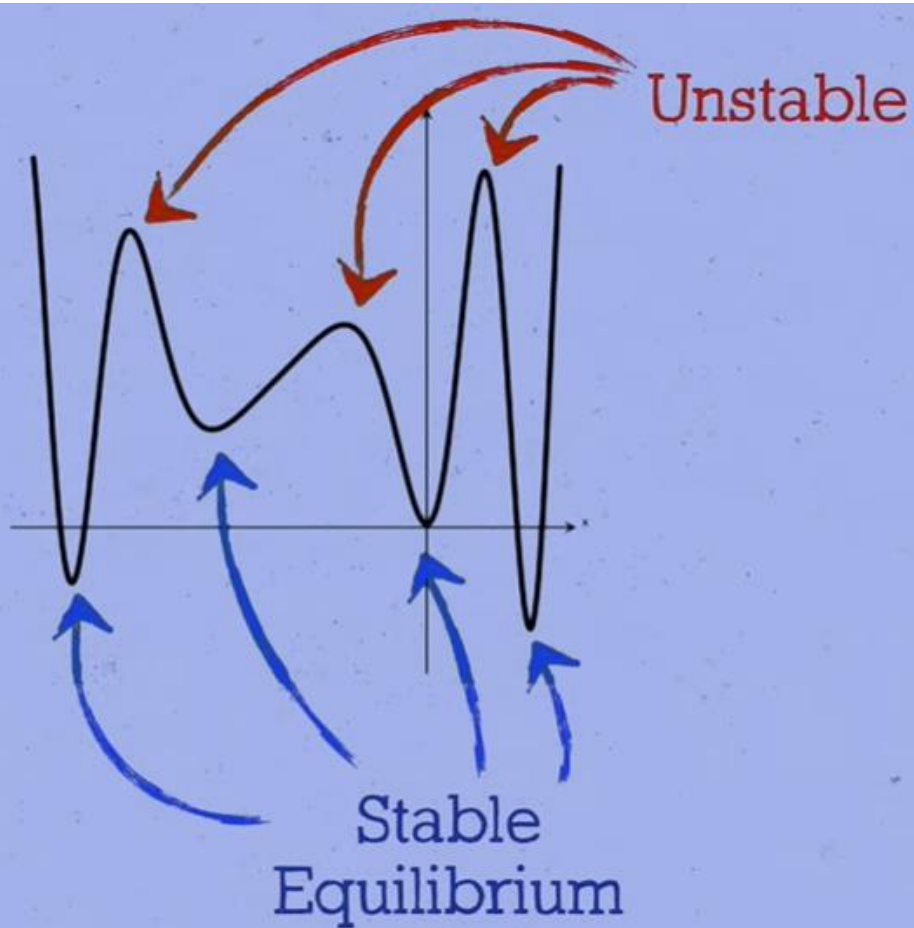
Natural Frequency

$$x(t) = A\cos\omega t + B\sin\omega t$$

What are our comments and questions?



$$m\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = -\frac{\mathrm{d}U}{\mathrm{d}x} \rightsquigarrow x(t) = \cdots$$



Comments and Questions

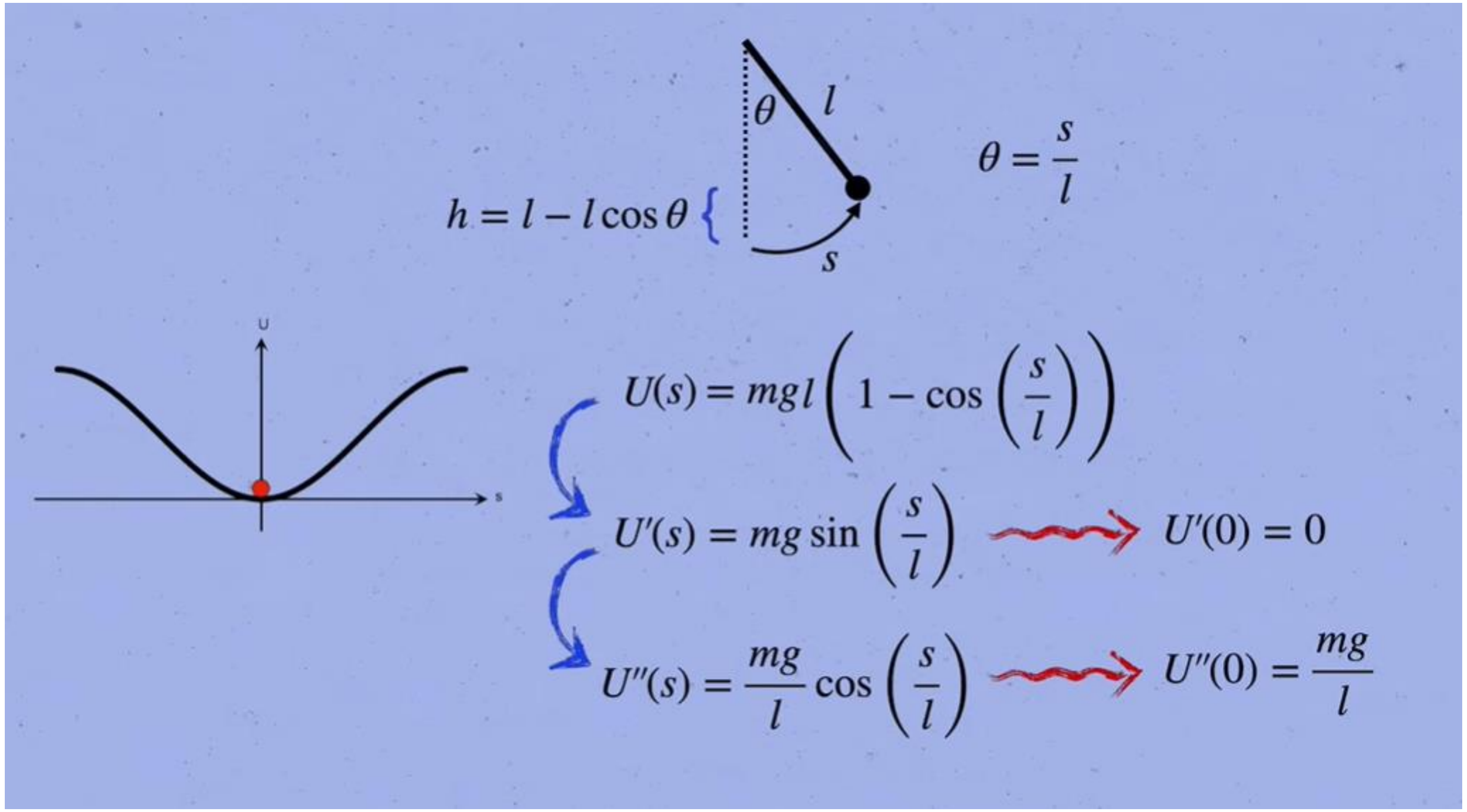
- What I wonder is if that harmonic oscillating pattern applies for all angles, or up to a certain angle.
- Does hookes law explain why the earth spins in an elipse instead of a perfect circle?
- How would the behavior of the system change if we were to include damping forces, such as friction, and how would this affect our understanding of small oscillations in both classical and quantum contexts?
- I'm confused by the introduction of sin and cos from omega squared; does this come from the pythagorean theorem or a different trig identity?

My comments and Questions

- Comment: “Empty” space in our universe is near equilibrium. Particles are, in some sense, oscillations of fields about this equilibrium in the same way.

- Question: How can we describe systems that a far from equilibrium? We have to go beyond “perturbation theory” like Taylor series, which is challenging.

Example: Pendulum



$$U(s) \approx \frac{1}{2}U''(0)s^2$$

$$k = \frac{mg}{l}$$

$$\Omega = \sqrt{\frac{g}{l}}$$

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

$$g\left(\frac{T}{2\pi}\right)^2 = l?$$