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8.01 Physics I: Classical Mechanics, Fall 1999
Transcript – Lecture 22

Today, I will talk to you about elliptical orbits and Kepler's famous laws.

I first want to review with you briefly what we know about circular orbits, so I wrote on the blackboard everything we know about circular orbits.

There's an object mass little m going in a circle around capital M.

This could be the Sun; it could be the Earth.

It has radius R, circular.

We know there in equation one how to derive the time that it takes to go around.

The way we found that was by setting the centripetal force onto little m the same as the gravitational force.

Also, the velocity in orbit--

maybe I should say speed in orbit--

also follows through the same kind of reasoning.

Then we have the conservation of mechanical energy--

the sum of kinetic energy and potential energy.

It's a constant; it's not changing.

You see there first the component of the kinetic energy, which is the one-half mv-squared, and then you see the term which is the potential energy.

We have defined potential energy to be zero at infinity, and that is why all bound orbits have negative total energy.

If the total energy is positive, the orbit is not bound.

And when you add these two up, you have an amazing coincidence that we have discussed before.

We get here a very simple answer.

The escape velocity you find by setting this E total to be zero, so this part of the equation is zero.

Out pops that speed with which you can escape the gravitational pull of capital M, which is the square root of two times larger than this V.

And I want to remind you that for near Earth orbits, the period to go around the Earth is about 90 minutes, and the speed-- this velocity, then, that you see in equation two--

is about eight kilometers per second, and the escape velocity from that orbit would be about 11.2 kilometers per second.

And for the Earth going around the Sun, the period would be about 365 days, and the speed of the Earth in orbit is about 30 kilometers per second, just to refresh your memory.

Now, circular orbits are special.

In general, bound orbits are ellipses, even though I must add to it that most orbits of our planets in our solar system--

very close to circular, but not precisely circular.

But the general solutions call for a elliptical orbit.

And I first want to discuss with you the three famous laws by Kepler from the early 17th century.

These were brilliant statements that he made.

The interesting thing is that before he made these brilliant statements, he published more nonsense than anyone else.

But finally he arrived at two... three golden eggs.

And the first golden egg then is that the orbits are ellipses--

he talked always about planets-- and the Sun is at one focus.

That's Kepler's law number one.

These are from around 1618 or so.

The second...

Kepler's second law is--

quite bizarre how he found that out, an amazing accomplishment.

If you take an ellipse, and you put the Sun here at a focus--

this is highly exaggerated because I told you that most orbits look sort of circular--

and the planet goes from here to here in a certain amount of time, and you compare that with the planet going from here to here in a certain amount of time, then Kepler found out that if this area here is the same as that area here, that the time to go from here to here is the same as to go from there to there.

An amazing accomplishment to come up with that idea.

And this is called "equal areas, equal times."
Somehow, it has the smell of some conservation of angular momentum.