PHY131 F Fall 2020
Class 15

Today:

- We finish up Chapter 5 on Circular Motion
- We will take 10 minutes in the middle of class to do a **Group Discussion Quiz** by you opening

Microsoft Teams

Technology & Science CBC

Russian-U.S. crew launches on fast track to the space station

Crew spent weeks in quarantine ahead of launch

The Associated Press · Posted: Oct 14, 2020 2:41 AM ET | Last Updated: October 14

In this image made from video footage released by the Roscosmos Space Agency, a Soyuz-2.1a rocket booster with a Soyuz MS-17 space ship carrying a new crew to the International Space Station blasts off from the Baikonur cosmodrome in Kazakhstan today. (Roscosmos Space Agency via The Associated Press)

A trio of space travelers has launched successfully to the International Space Station, for the first time using a fast-track manoeuvre to reach the orbiting outpost in just three hours.

NASA's Kate Rubins along with Sergey Ryzhikov and Sergey

1

Poll

Crazy Friday: Let's Choose a Zoom-Filter my face today

What Studio Filter would you prefer on my face today?

A. "We Can Do It!"

B. "Movember"

C. Beret

D. Goatie

E. Red lipstick

2

PHY131 Help Centre moving to Zoom

The PHY131 Help Centre has moved to Zoom:

https://zoom.us/j/93809642256

Passcode: 723874

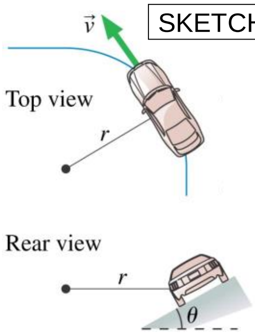
- Sundays: 1:30-2:30pm
- Mondays: 12:00-1:30pm
- Tuesdays: 9:30-10:30am, 3:00-4:00pm
- Wednesdays: 12:00-1:30pm
- Thursdays: 9-10am (updated)
- Fridays: 12:00-1:30pm

3

Banked Curve Example

A highway curve of radius 70.0 m is banked at a 15° angle. At what speed v_0 can a car take this curve without assistance from friction?

SKETCH & TRANSLATE.



SIMPLIFY & DIAGRAM

4

Banked Curve Example

A highway curve of radius 70.0 m is banked at a 15° angle. At what speed v_0 can a car take this curve without assistance from friction?

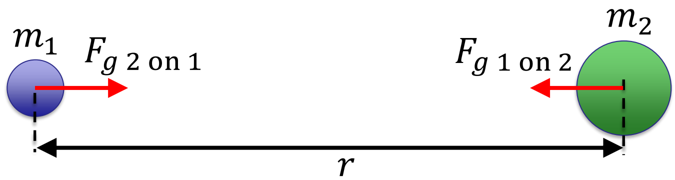
REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

5

Gravity

It was Newton who first recognized that **gravity is an attractive, long-range force between *any* two objects.**



When two objects have masses m_1 and m_2 and centers are separated by distance r, each object attracts the other with a force given by Newton's law of gravity, as follows:

$$F_{g\ 1\ \mathrm{on}\ 2} = F_{g\ 2\ \mathrm{on}\ 1} = \frac{G m_1 m_2}{r^2}$$

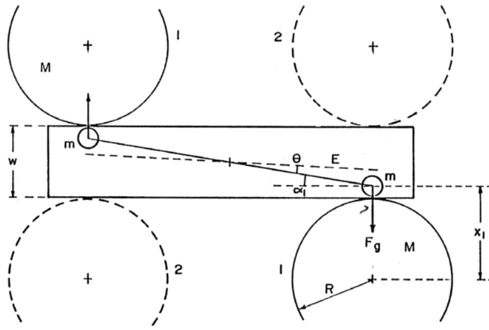
where $G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$ is the Gravitational constant (the same everywhere in the universe).

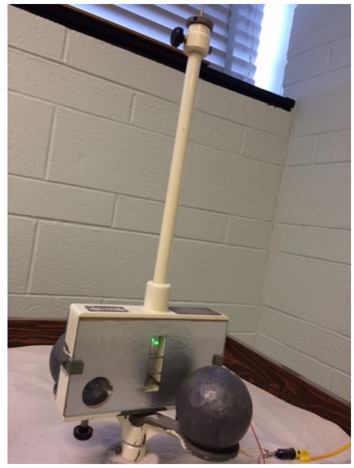
6

Cavendish Experiment

Done in second year labs (PHY224).

A required **in-person** course.





You end up measuring a force of about 10^{-8} N (10 nano-Newtons!) which is equivalent to the weight of 0.1 μg.

But it is doable in less than 2 weeks.

7

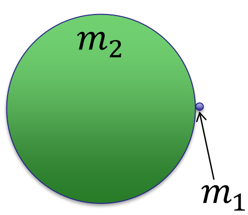
Gravity Example

"Object 1", with mass m_1, sits at the surface a giant spherical rock which is floating in space.

The giant rock called "object 2" has a mass of $m_2 = 6 \times 10^{24}$ kg and a radius of 6400 km.

(a) What is the force of gravity of 2 on 1?

(b) Can you think of a good name for object 2?



8

Gravity for Earthlings

If you happen to live on the surface of a large planet with radius R and mass M, you can write the gravitational force more simply as:

$$\vec{F}_G = (mg, \text{straight down}) \qquad \text{(gravitational force)}$$

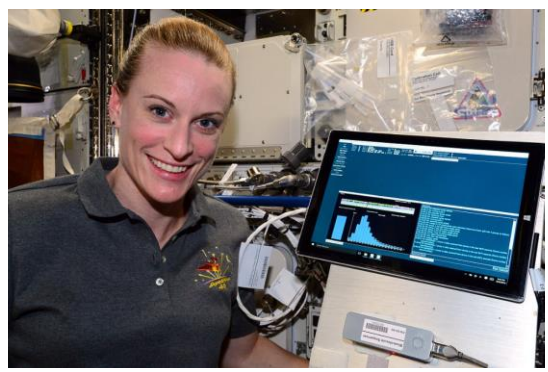
where the quantity g is defined to be:

$$g = \frac{GM}{R^2}$$

At sea level, $g = 9.83$ m/s^2.
At 39 km altitude, $g = 9.71$ m/s^2.

9

- Kate Rubins launched on her second mission to the International Space Station on Wednesday (also her 42nd birthday!)
- She is currently in orbit, working with Russian cosmonauts Sergey Ryzhikov and Sergey Kud-Sverchkov.
- Her return to Earth is scheduled for April 2021.

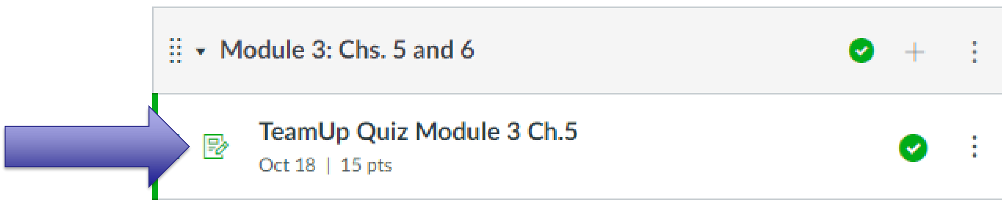


- She has a Bachelor of Science in molecular biology, and a Ph.D. in cancer biology from Stanford.
- In 2016 she was the first person to perform DNA sequencing in space.

10

TeamUp Time!!

- Today you will be doing three multiple choice questions, all from Chapter 5, as a team of 2-4 students in your Practicals Pod.
- Your pod-team shares the mark!
- I’m going to mute here for 10 minutes; right now you should open Microsoft Teams and someone (most recent Facilitator) should place a **video call** to all 3 or 4 members of your Pod-Chat.



11

Now: TeamUp! You have 10 minutes

- The first step is to decide who will be the TeamUp **Driver**
- All students must log-in to Quercus [You will now have three windows open: my zoom lecture, Microsoft Teams, and Quercus]
- **Non-drivers**: Wait!
- **Driver**: Go to the TeamUp Quiz in this module, click Go to Tool, then Create a Group. Let everyone in the Breakout Room know the session ID. Then WAIT – don’t drive off alone!
- **Non-drivers**: Once you get the session ID, go to the TeamUp Quiz in this module, click Go to Tool, then Join Session and type the ID you were given.
- Once everyone in your room arrives in TeamUp, start going through the questions. Please **achieve consensus** before the driver submits.
- Note: if your pod-mates are available on Microsoft Teams right now, go to the PHY131 Help Centre and I’ll set up breakout rooms there.

12

Question 1 Discussion

- Astronaut Kate Rubins is currently living on the International Space Station, which orbits at 370 km above the surface of the Earth (low earth orbit).
- Assuming Kate has not changed her mass since moving to space, what is the force of gravity of the Earth on Kate?

A. Zero
B. The same as the force of gravity on her while she was on earth.
C. A little bit less than the force of gravity on her while she was on earth.
D. Not exactly zero, but much, much less than the force of gravity on her while she was on earth.

13

Question 2 Discussion

- You are right now a certain distance from the centre of the Earth.
- Astronaut Kate Rubins is currently living on the International Space Station, which orbits at 370 km above the surface of the Earth (low earth orbit).
- How much farther from the center of the Earth is Kate than you?

A. 1.06 times as far
B. 1.5 times as far
C. Twice as far
D. 10.6 times as far

14

Question 3 Discussion

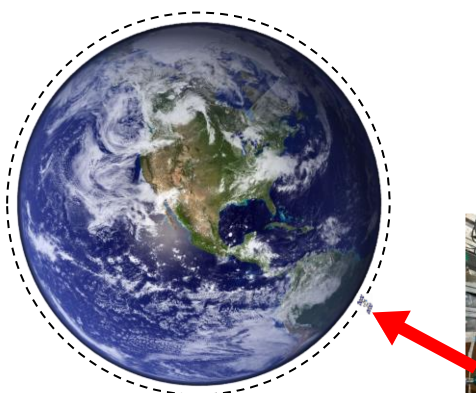
- The International Space Station is accelerating toward the Earth at 8.9 m/s^2. Why doesn't it crash into the Earth?

  A. Bad question: it is not actually accelerating at 8.9 m/s^2 toward the Earth.
  B. Because, as it accelerates toward the Earth, it also moves in a sideways direction, so it misses the Earth.
  C. This acceleration is compensated for by rocket blasters which continuously point away from the Earth.
  D. 8.9 m/s^2 is not a noticeable acceleration – it would take millions of years to travel 370 km in a straight line at that acceleration.

15

International Space Station

Orbit is drawn **to scale**



Kate ***feels*** weightless because she is in freefall!

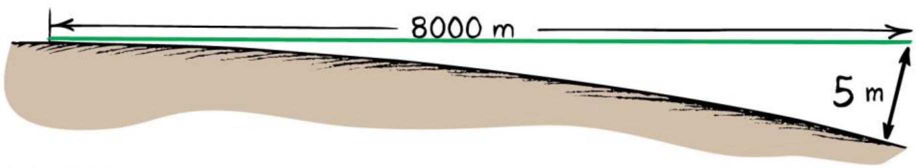
Radius of the Earth: 6400 km, g = 9.8 m/s^2

Altitude of Space Station: 370 km, g = 8.9 m/s^2 (about 10% less)

16

The Curvature of the Earth

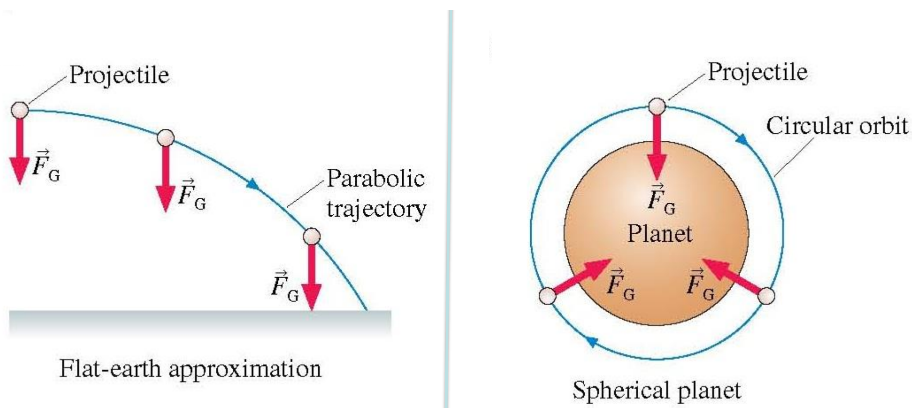
- Earth surface drops a vertical distance of 5 meters for every 8000 meters tangent to the surface.



Ball Launched Horizontally

- Consider a ball launched horizontally, so the initial *y*-component of the velocity is zero.
- How far down does it fall in 1 second?

17



18

Example

How fast would you have to drive in order to be “weightless” – ie, no normal force needed to support your car?

19

Circular Orbits

An object moving in a circular orbit of radius r at speed v_{orbit} will have centripetal acceleration of

$$a_r = \frac{(v_{\text{orbit}})^2}{r} = g$$

That is, if an object moves parallel to the surface with the speed

$$v_{\text{orbit}} = \sqrt{rg}$$

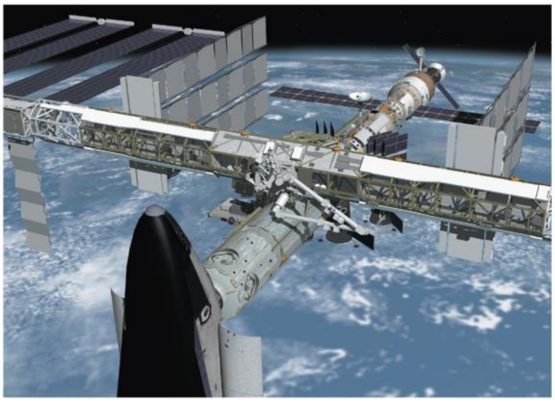
then the free-fall acceleration provides exactly the centripetal acceleration needed for a circular orbit of radius r.

Near the surface of the Earth, this speed is about 8 km/s.

An object with any other speed will not follow a circular orbit.

20

Circular Satellite Orbits



- Positioning: beyond Earth's atmosphere, where air resistance is almost totally absent
- Example: Low-earth orbit communications satellites are launched to altitudes of 150 kilometers or more, in order to be above air drag
- But even the ISS, as shown, experiences *some* air drag, which is compensated for with periodic upward boosts.

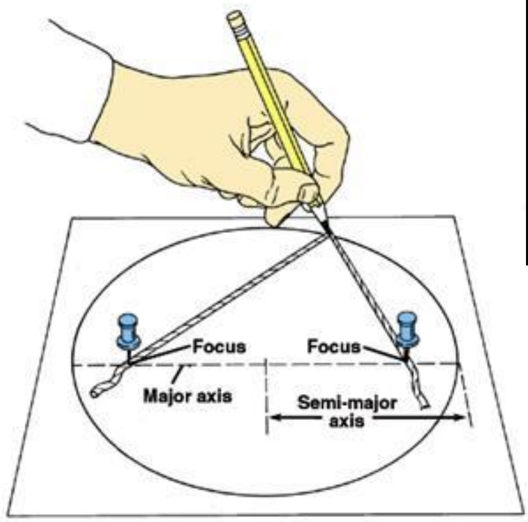
21

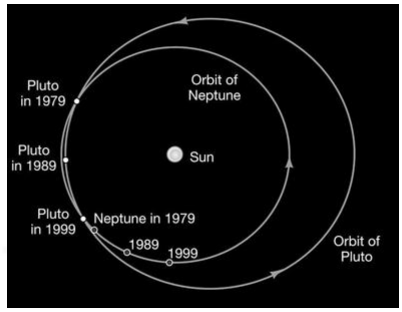
The state of physics around 1650…

- In 1609 Galileo started observing the sky with a telescope.
- Around that same time, Kepler was investigating careful observations of the apparent positions of planets in the sky.
- It was determined that planets orbit the Sun, and that Earth was the third planet out from the Sun.
- Kepler noted that the shapes of the orbits of all the planets were not quite circles, but actually ellipses.

22

An ellipse is a mathematical shape.





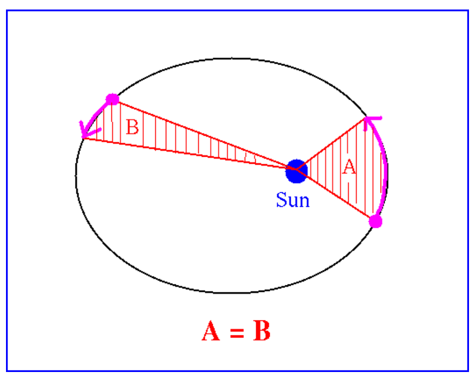
- The furthest distance from the centre of an ellipse to its edge is called the “semi-major axis”
- The eccentricity, e, tells you how squished the orbit is.
- A circle is a special case of an ellipse, when $e = 0$.

23

Kepler’s Laws of Planetary Motion

1. Planets, asteroids and comets move in orbits whose shapes are ellipses, with the sun at one focus of the ellipse. (Planetary orbits normally have low eccentricity: almost circular.)

2. A line drawn between the sun and a planet sweeps out equal areas during equal intervals of time. (They go faster when they are closer to the sun.)



3. The square of a planet’s orbital period is proportional to the cube of the semimajor-axis length. ($T^2 = C r^3$, where C is some constant.)

24

Newton's Laws

• Kepler's Laws are empirical, like Hooke's Law, or the equation for kinetic friction or drag. They were written down in order to describe the observations. Kepler did not know "why" the planets moved in this way.

• Many scientists at the time, including Edmund Halley, believed that there was some kind of force from the Sun pulling the planets, asteroids and comets toward it.

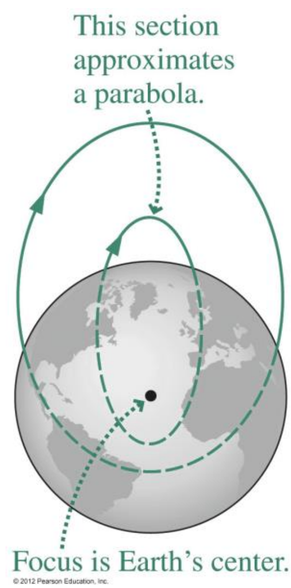
• In 1687 Isaac Newton published one simple theory which explained all of Kepler's laws, as well as motion observed here on Earth:

  • The 3 Newton's Laws you already learned, plus:
  • "Newton's Law of Gravity"

25

Projectile Motion and Orbits

- The "parabolic" trajectories of projectiles near Earth's surface are actually sections of elliptical orbits that intersect Earth.
- The trajectories are parabolic only in the approximation that we can neglect Earth's curvature and the variation in gravity with distance from Earth's center.



26

Before Class 16 on Monday

- Next week we start on Chapter 6 on Impulse and Linear Momentum!!
- Please read:
- 6.1 Conservation of Mass
- 6.2 Conservation of Momentum
- Something to think about: When a ball is thrown up in the air and then falls back down, is its momentum conserved during freefall?

27