Warm-up exercises

- Pick one of the questions below (A, B or C)
- You can hand-write your answers on a clean sheet of paper and submit a clear picture of your work.
- You can also type your answers in Word. If you do, please remember to copy-paste questions above your answers. If you type any Math formulae, please make sure you use the “equation mode” (insert-> equation)
- If you complete your homework in Word, please submit it as a PDF file (File -> Save As... -> PDF file

Warm-up exercises

Question A

Orbits and satellites

For many centuries, astronomers described the Solar system as a bunch of planets and the Sun all traveling along complicated routes around the Earth. In 16th c., a Polish astronomer Nicholas Copernicus built a new model in which it is not the Earth, but the Sun in the center of the Solar System, and the planets rotate around the Sun.

1. Who was "right" and why?
2. What does it mean that a satellite is in Earth's "orbit"? How do satellites move (describe their trajectory, velocity, etc.), and why? Is the Sun "stationary" or is it rotating around something?
3. When sending satellites to Earth's orbit, we use a rocket. What if instead we wanted to build a large "satellite launcher" or "satellite cannon" to achieve the same goal?

- Draw a simple design of such launcher: what direction (expressed as angle with Earth's surface at the point where you are standing) should you aim the cannon's barrel?
- Can you figure out the force you would need to give the satellite at launch to make sure it stays on Earth's orbit? **(Hint: You might have to Google things such as "escape velocity" if you have not hear about it before!)**
- List all the assumptions you make, values of constants you use (such as Earth's gravitational acceleration) and other ideas you have.
- Why don't we use "space cannons" like this to send satellites to space?

4. Is it possible to build an elevator to take people to space? If possible, what would be key challenges when building such elevator? If impossible, why?

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Question B

Exploring Earth's Core

You might have already learned in your physics classes that gravitational force between 2 bodies with masses m and M separated by a distance R is given by $F = G\frac{mM}{R^2}$, where G is the gravitational constant.

1. What is the meaning of the "mass" of the objects? The distance R in question in measured from what point to what point? *(you can draw a diagram to illustrated this)*

2. When two bodies such as the Sun and Earth are sitting in space, how do they "know" that there is another body close by? How does the planet Earth "know" that you are walking on its top so it should attract you gravitationally? *(You can be creative here - don't worry, you are not expected to know the correct answer!)*

3. Can you plot the graph of gravitational force as a function of R? *(On y-axis you should have the force, and on the x-axis you should have the distance R)*. What happens when $R = 0$?

4. Imagine we drill a tunnel all through Earth's core to see what's inside. What does your diagram in 3. look like for $R <$ radius of planet Earth? What do you think is the gravitational attraction at the very middle of Earth's core?

5. Is there a paradox between your answers to 3. and 4.? Is it possible for any body to behave like your plot in 3.?

6. What could be some benefits (if you think there are any?) of using a tunnel through Earth's core?

   - What could we use it for?

   - What would be some key challenges when constructing such tunnel?

Warm-up exercises

Question C

Fly me to the Moon

Rockets such as those produced by NASA to take humans to the Moon in the 1960s, or by the modern day commercial companies SpaceX and BlueOrigin use propulsion (which basically means 'pushing') to accelerate. They are also in the shape of a long cylinder with a pointy end.

1. Can you explain this shape of a space rocket? Why is it different from a commercial passenger jet that we use to fly around the world? Could adding wings to a rocket be beneficial to the machine?

2. Imagine we are building a space rocket to take humans to the Moon, or even another planet or stellar system. If we want to completely escape Earth's gravitational field and find ourselves at a distance R from the Earth, what initial velocity does our rocket have to reach? **(HINT: you can consider kinetic / potential energy of your rocket to answer this question.)**

3. Imagine we are launching a space ship from another, larger "mother" spaceship. The mother spaceship is huge for humans, but it is much, much smaller than a planet, it's size is that of a large city. In this case, what would be the optimal shape for the spaceships launched from this ship directly into space?

4. Imagine you are traveling from the Solar system to the Alpha Centauri stellar system. Assume distance between the two systems is D.

   - Plot a diagram showing how our acceleration will change as a function of D

   - If our rocket can accelerate with up to 3G (G is Earth's gravitational pull), what is the fastest we can get to Alpha Centauri *(derive a **formula** for the time expressed using G and D)*?