Answer all question on a separate sheet. Please be as neat as you can. Show all work, including units. Circle your final answer clearly.

PART I - GETTING TO SPACE

There is no obvious boundary between where the Earth's atmosphere ends and space begins. But since this is a class about sending people into space, let us use the the definition that the United States designates people who travel above an altitude of 80 km (80,000 meters) as astronauts.

In order to throw and object, straight up, to a height **h**, you have to throw it with a velocity **v**:

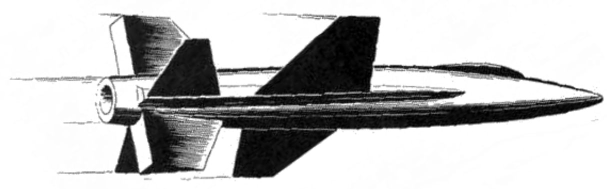
$$v = \sqrt{2gh}$$

where **g** is the acceleration due to gravity of the Earth (g = 9.8 m/s^2). The velocity **v** is measured in meters per second (m/s) and the height **h** is in meters (m). Air resistance is ignored.

1 (5 pts) Calculate how fast you have to throw someone, straight up, to make them an astronaut.

2 (3 pts) Express your calculated speed in miles-per-hour. 1 m/s = 2.24 mph.

3 (2 pts) The fastest airplane (really rocket-plane) was the X-15 with a top speed of about 4,000 mph. Could the X-15 go to space?



The rocket equation can be rewritten to find how much payload we can lift if we are given a value for ΔV and u. **Payload Fraction** is the fraction of the total rocket mass that is payload. A value of 0.05 that means that 5% of the rocket's mass can be payload.

$$\text{Payload Fraction} = e^{-\Delta V/u} = \exp(-\Delta V/u)$$

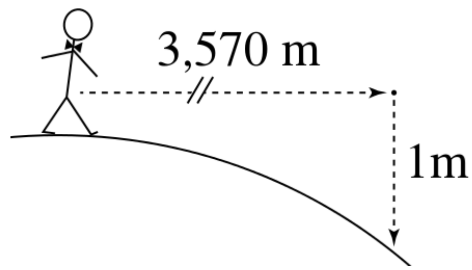
4 (5 pts) Calculate the Payload Fraction of a rocket that is just able to make a person an astronaut. Assume that u = 2,300 m/s.

Part II - Staying in Space.

Getting to space is easy(ish). Staying in space is hard.

The Earth is a sphere (almost). This means that as you travel horizontally across the surface, the surface continuously curves downwards. The Earth is really big so the curve is very slight.

For every 3,570 meters you walk, the Earth curves downward by 1 meter.

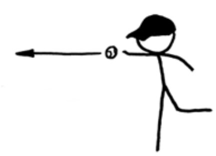


The time is takes an object to fall from a height **h** is:

$$t = \sqrt{\frac{2h}{g}}$$

where **t** is measured in seconds (s), **h** is in meters (m), and **g** is 9.8 m/s^2. Again, air resistance is ignored.

5 (5 pts) Calculate how long is takes an object to fall from a height of 1 meter.



If you can throw an object horizontally, fast enough, so that is goes 3,570 meters before it falls 1 meter, that object will never hit the surface of the Earth. This is the definition of an object in orbit.

6 (10 pts) Calculate how fast you have to throw a person horizontally, so that they are in orbit around the Earth.

7 (3 pts) Express your answer in miles per hour

8 (2 pts) Can the X-15 go into orbit?

9 (5 pts) How does the speed needed to orbit compare to the speed needed to get a person to space?

10 (5 pts) Calculate the Payload Fraction of a rocket that is just able to make a person **orbit** the Earth. Assume that u = 2,300 m/s.