Solve the problems listed below, and write up your answers clearly and completely. Do not turn in a rough draft – make a clean copy after checking your calculations. Use brief sentences and phrases to explain your solution and introduce symbols and key equations. Show your work!

Remember: this week, the use of $G$ is forbidden!

1. A rough idea of the relative sizes, masses, and orbital radii of solar-system objects is useful for order-of-magnitude estimates. Look up the physical parameters for the objects mentioned below (Wikipedia is a good source) and compute the quantities requested. Your answers should use the minimum number of significant figures necessary to obtain uncertainties of no more than $\sim 10\%$, and include the uncertainty as a signed percentage.
   (a) Mass of Earth in units of mass of Moon.
   (b) Radius of Earth in units of radius of Moon.
   (c) Radius of Moon’s orbit in units of radius of Earth.
   (d) Radius of Earth’s orbit in units of radius of Moon’s orbit.
   (e) Mass of Jupiter in units of mass of Earth.
   (f) Radius of Jupiter in units of radius of Earth.
   (g) Radius of Jupiter’s orbit in units of radius of Earth’s orbit.
   (h) Mass of Sun in units of mass of Jupiter.
   (i) Radius of Sun in units of radius of Jupiter.

2. Using your results for question #1, and no other data, estimate:
   (a) The surface gravity on the Moon, in units of the surface gravity on the Earth.
   (b) The surface gravity on Jupiter, in units of the surface gravity on the Earth.
   (c) The surface gravity on the Sun, in units of the surface gravity on the Earth.

3. The Moon orbits the Earth with an orbital period $P_M = 27.3$ day and a semi-major axis $a_M = 3.84 \times 10^5$ km. Given this information, use Kepler’s third law to calculate
   (a) the semi-major axis $a_{\text{gso}}$ of a geosynchronous orbit ($P_{\text{gso}} = 1$ day), and
   (b) the orbital period $P_{\text{leo}}$ of a low Earth orbit ($a_{\text{leo}} = 6600$ km; this is $\sim 200$ km above the Earth’s surface).

4. Another way to find the orbital period for a low Earth orbit starts with Galileo’s law for falling bodies. To keep things simple, assume that Earth’s gravitational acceleration $g \approx 9.8 \text{ m s}^{-2}$ is independent of height above the surface; for an orbit 200 km high, the variation is only a few percent.
(a) Consider a body falling vertically from an initial height $y_0 = 200 \text{ km}$ above the surface of the Earth. How long will it take to reach the surface (neglecting atmospheric drag)? Call this time $t_0$.

(b) Consider a satellite in a circular low earth orbit which passes directly overhead at the same height, $y_0 = 200 \text{ km}$ (Fig. 1). How long does it take to cross the $x$ axis? (Note: you may ignore the change in the direction of gravity along the satellite’s path; we’ll call this the “Flat Earth” approximation.)

(c) What horizontal distance $x_0$ has the satellite traveled during the time you calculated in part (b)? (Hint: set up the equation for a circle with radius $a_{\text{leo}} = R_E + 200 \text{ km}$, where $R_E = 6400 \text{ km}$ is the radius of the Earth.)

(d) Using your answers to parts (b) and (c), what is the satellite’s horizontal velocity when it passes overhead?

(e) At the velocity you’ve just calculated, how long does the satellite take to make a complete orbit?

Figure 1: A satellite in a circular orbit maintains a constant height above the surface of the Earth.