Exercise Session 1

Problem 1 Multiple Choice Questions

A) A geostationary satellite is orbiting the Earth at an altitude of 36'000 km. Assuming the satellite is stopped instantaneously and starts to fall, at what speed will it reach the top of the Earth atmosphere, 100 km above the Earth surface?

(1) 89.2 km/s
(2) 10.2 km/s
(3) 14.8 km/s
(4) 7.4 km/s

B) Assuming that a spacecraft moves towards the Sun along the line joining their centers, at which distance from the Earth center does the spacecraft feels no net gravitational force ?

(1) $2.58 \cdot 10^5$ km
(2) $1.48 \cdot 10^6$ km
(3) $2.59 \cdot 10^8$ km
(4) $1.49 \cdot 10^8$ km

C) Estimate the equilibrium temperature of the Earth given the radiation power from the Sun, and the self-radiation power from the Earth into space, and solving for temperature. Use the blackbody assumption $\alpha/\epsilon = 1$.

(1) $21°C$
(2) $6°C$
(3) $-21°C$
(4) $0°C$

D) The Cassini-Huygens spacecraft was launched in 1997 towards Saturn. It was roughly of cylindrical shape with two straight arms along the cylinder whose purpose was to deploy antennas far from the main body some time after launch. After deployment from the launcher, the spacecraft was turning along its main axis at a rate of 1 rpm or 6 degrees per second. After deployment of the antennas 90 degrees off the axis of the spacecraft, what was the rotation rate of the spacecraft? (consider the antennas as point masses and the arms are supposed massless)
Data : Cassini total mass $M_c = 5600\ kg$ without the antennas, height $h_c = 5\ m$, diameter $d_c = 2\ m$. Mass of each antenna $m_a = 50\ kg$, length of each arm $l_a = 10\ m$.

(1) 7.61 deg /s
(2) 0.57 deg /s
(3) 1.16 deg /s
(4) 3.84 deg /s

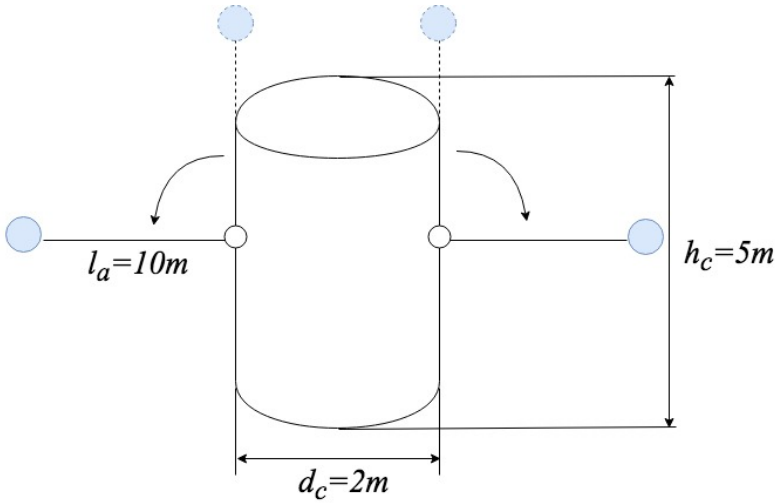

Figure 1: *The two spherical masses have to be considered as point masses.*

Problem 2 Escape velocity

The Rosetta spacecraft launched by the European Space Agency successfully entered the orbit of the comet 67P/Churyumov Gerasimenko in August 2014. November 12 2014, the *Philae* lander was released and touched down 7 hours later at a speed of $1m/s$.
The harpoon mechanism which was supposed to secure the lander failed and it bounced off the comet. Assuming purely elastic impact, will the lander leave the comet or return at some point?
data: Mass of the lander : $m_l = 100\ kg$, Mass of the comet : $M_c = 3.14 \cdot 10^{12} kg$, Radius : $R_c = 2\ km$ (assume a spherical shape).

Problem 3 Potential energy close to the surface of the Earth

The general expression for the potential energy of a mass m in the Earths gravitational field is $E_{\text{pot}} = -\frac{m\mu}{r}$, r being the distance to the center of the Earth. In the vicinity of the surface of the Earth, the difference in potential energy for a mass m when the height above the ground is changed by Δh is equal to $mg\Delta h$, where g is the gravitational acceleration at the surface of the Earth. Derive this approximate expression from the general expression.

Problem 4 Radiation balance

A) Consider two spherical satellites with a radius r, respectively $2r$. Determine the radiation balance of these objects if they are exposed to solar radiation only and compare their temperatures.

B) Consider a cylindrical satellite (radius = 1 m, height = 2 m) that is spin-stabilised, hence turning on its longitudinal axis. It is supposed to be on an orbit where eclipses are negligible, and the satellite's longitudinal axis of rotation stays perpendicular to the sun rays. The external structure of the satellite is made of steel (AM 350) with a (α/ε) ratio of 1.79. We only consider the Sun's radiation on the satellite and neglect the Earth's albedo and self IR radiation.

During a space shuttle mission, the science instrument of this satellite has to be replaced, and a spacewalk of two crew-members is planned. Will it be safe for the astronauts performing this task to touch the surface of the satellite with their gloves if the "touch" – "no touch" limit is at 80 °C?