Exercise Session 1

Note Problems marked with a ($\star$) are complimentary exercises and will not be solved in class.

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's atmosphere, which is 100 km above the Earth's surface?

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

B) A spacecraft moves towards the Sun from the Earth along the line joining the two centers. At which distance from the Earth's center does the spacecraft feel 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) ($\star$) Estimate the equilibrium temperature of the Earth (considered without atmosphere) by using the formula of the radiation power from the Sun and that of the self-radiation power from the Earth into space, and solving for the temperature. Use the black body 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 to explore Saturn. It was roughly of cylindrical shape with two straight arms whose purpose was to deploy antennas far from the main body some time after the launch, at an angle of 90 degrees with the cylindrical axis. If before antenna deployment the spacecraft was rotating around its main axis at a rate of 1 rpm, what was the rotation rate after antenna deployment? Consider the antennas to be point masses and the mass of the deployment arms, negligible.
Mass of Cassini without the antennas: $M_c = 5600$ kg, 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.

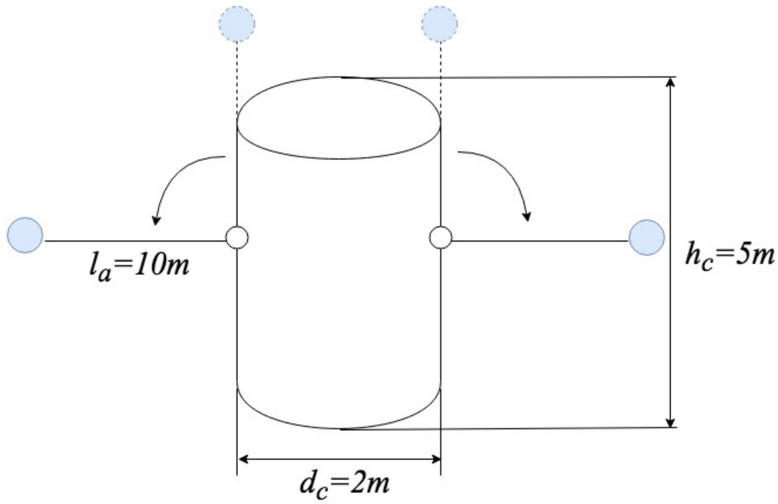

Figure 1: *The two spherical masses should be considered point masses.*

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

E) ($\star$) An artificial satellite orbiting the Earth is in an elliptical orbit with a perigee altitude of $h_p = 250$ km and an apogee altitude of $h_a = 800$ km. What is its orbital period?

(1) 18.0 min
(2) 89.5 min
(3) 95.1 min
(4) 100.9 min

F) A spacecraft is on a free trajectory in the vicinity of the Earth. From which statement can it be deduced that this spacecraft has sufficient energy to leave the gravitational well of the Earth (i.e., to not be on orbit around the Earth)?

(1) $E_{tot} \geq 0$
(2) $E_{tot} < 0$
(3) $E_{tot} \to \infty$
(4) $E_{tot} \to -\infty$

G) You are currently aboard the ISS (orbiting at an altitude of 400 km) and ground control tells you that there is another satellite on the same orbital plane but 50 km higher. Assuming you have just spotted it exactly above you at a certain time (conjunction), how long do you have to wait until the next conjunction?

(1) 13.2 days
(2) 2.1 hours
(3) 15.2 hours
(4) 5.9 days

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. On 12 November 2014 the *Philae* lander was released and touched down 7 hours later at a speed of 1 m/s.
The harpoon mechanism that was supposed to secure the lander failed and bounced off the comet. Assuming a purely elastic impact, will the lander leave the comet or return at some point?
Mass of the lander: $m_l = 100$ kg, mass of the comet: $M_c = 3.14 \cdot 10^{12}$ kg, radius of the comet (assume a spherical shape): $R_c = 2$ km.

Problem 3 ($\star$) Potential energy close to the surface of the Earth

The general expression for the potential energy of a mass m in Earth's 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 radii r and $2r$, respectively. Determine the radiation balance of each object 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, and hence rotating about its longitudinal axis. Assume that it is on an orbit where eclipses are negligible, and that its longitudinal axis of rotation remains 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 infrared self-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?

Problem 5 ($\star$) Gravitational wells of Mars and Deimos

Determine the gravitational accelerations on the surface of Mars and one of its two satellites, Deimos, and make a scale drawing of the gravitational wells of both of them, normalized by the Earth's gravitational acceleration.

	Mars	Deimos
Mass M (kg)	$6.39 \cdot 10^{23}$	$1.48 \cdot 10^{15}$
Mean radius R (km)	3397.0	6.2
Mean distance Mars center – Deimos d (km)	23'460	