Examination
Space Missions and Applications I (AE2103)
Faculty of Aerospace Engineering
Delft University of Technology

SAMPLE EXAM

Please read these instructions first:

This are a series of multiple-choice questions that are similar to what you might expect for the actual exams. Note that the number of questions here is not necessarily representative of the number of questions on the actual exam (there will likely be more questions given on the actual exam). You will record your answers on an answer that will be provided to you along with the exam questions. **The exam is closed-book**, meaning you are not allowed to have any books, hand-outs, or notes on your table during the exam. You should bring a pocket calculator with you to the exam; however, for programmable calculators, you must clear the memory beforehand (and show this to the exam proctor if asked).

Question 1: True/False, 2 pts.

A geostationary orbit can be geosynchronous, but not all geosynchronous orbits are geostationary.

a) True   b) False

Question 2: True/False, 2 pts.

A repeat orbit is often defined in terms of the number of orbits within the repeat time frame. Is it possible to have a low Earth orbit (LEO) repeat track of 200/8, i.e. 200 orbits every 8 days? Assume a circular orbit with an angular velocity defined by $w_0 = (\frac{\mu}{a^3})^{1/2} = 1.107\text{e-}3$ rad/s.

a) True   b) False

Question 3: True/False, 2 pts.

An orbit can be both in a sun-synchronous orbit and in a repeat orbit at the same time.

a) True   b) False

Question 4: True/False, 2 pts.

Until the early 1920's, a clock did not exist that was more accurate than that of the Earth's daily rotation about its axis.

a) True   b) False

Question 5: True/False, 2 pts.

The geoid is a mathematically perfect ellipsoid that is sized to coincide with the mean sea level.

a) True   b) False

Question 6: The Global Positioning System (GPS), 10 pts.

We are able to determine our absolute position using the Global Positioning System (GPS) through signals transmitted by the various orbiting GPS satellites. These signals must propagate through the ionosphere (and the rest of the atmosphere), whose high electron content can often cause distortions. This, in turn, can lead to errors in the estimated position at the ground level. The designers of the GPS satellite network were aware of this problem in advance, but used the fact that, when not in a vacuum, different frequencies travel at different velocities to their advantage to help eliminate these errors. The measured travel time delay (Δt_{iono}) due to the ionosphere for a GPS signal of a given frequency, f, is described as:

$$\Delta t_{iono} \approx \frac{\Delta s}{c_{vac}} + \frac{A}{f^2}$$

Using this equation, which of the expressions below for Δs represents the range correction that can be computed when using the L1 and L2 frequencies of the GPS system.

a) $\Delta s = c_{vac}\left[\Delta t^{L1}_{iono} - \frac{f^2_{L1} \cdot f^2_{L2} \cdot \left(\Delta t^{L1}_{iono} - \Delta t^{L2}_{iono}\right)}{\left(f^2_{L1} - f^2_{L2}\right)}\right]$

b) $\Delta s = c_{vac}\left[\Delta t^{L1}_{iono} - \frac{f^2_{L2} \cdot \left(\Delta t^{L1}_{iono} - \Delta t^{L2}_{iono}\right)}{\left(f^2_{L2} - f^2_{L1}\right)}\right]$

c) $\Delta s = c_{vac}\left[\Delta t^{L1}_{iono} + \frac{\left(\Delta t^{L1}_{iono} - \Delta t^{L2}_{iono}\right)}{\left(f^2_{L1} - f^2_{L2}\right)}\right]$

d) $\Delta s = \frac{f^2_{L1} \cdot f^2_{L2} \cdot \left(\Delta t^{L1}_{iono} - \Delta t^{L2}_{iono}\right)}{\left(f^2_{L1} - f^2_{L2}\right)}$

e) $\Delta s = \frac{\left(f^2_{L1} - f^2_{L2}\right)}{f^2_{L1} \cdot f^2_{L2} \cdot \left(\Delta t^{L1}_{iono} - \Delta t^{L2}_{iono}\right)}$

Question 7: Gravity, 10 pts.

A new satellite was launched last year by ESA called the Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission. The goal of the GOCE mission is to measure the Earth's static (i.e., non-variable) gravity field using the technique of satellite gravity gradiometry (SGG), which involves 3 pairs of very precise accelerometers taking direct measurements of the gravity gradient at satellite altitude. For GOCE, the accelerometer pairs are separated by roughly 0.5 meter, and each accelerometer has an accuracy (i.e. σ), of 1.5e-12 m/s^2. Assuming the GOCE satellite is flying in an orbit with an altitude of 250km, what is the expected overall accuracy of the the on-board gradiometer, expressed in units of Eötvös (1 Eötvös = 1E = 1e-9 Gal/cm = 1e-9 $1/s^2$, and 1 Gal = .01 m/s^2)?

a) 2.5e-4 mE b) 3e-3 mE c) 60 mE d) 6 mE e) 250 mE

Question 8: Gravity (cont'd), 10 pts.

The accelerometers on GOCE are extremely sensitive because they must detect small variations in the gravity field, caused by mass elements located at or below the Earth's surface, from a distance of 250km away. The required sensitivity of the accelerometers would decrease if the gradiometer of GOCE could take measurements directly at the Earth's surface. Assuming this could be done, what level of sensitivity would the accelerometers need to have in order for the gradiometer to maintain the same level of accuracy as that described in the previous question?

a) 3.0e-6 m/s^2 b) 1.62e-12 m/s^2 c) 3.0e-12 m/s^2 d) 1.39e-12 m/s^2 e) 3.75e-7 m/s^2

Question 9: EO Mission Design, 5 pts.

Satellite altimetry missions often use a sun-synchronous, repeat track orbit design so that the solar panels can receive the highest degree of exposure. Assuming a spherical Earth, what would the rate of the longitude of the ascending node, $\dot{\Omega}$, need to be in order to maintain this orbit?

a) 1.16 rad/s b) 7.27e-5 rad/s c) 3.64e-5 rad/s d) .0172 rad/s e) 1.991e-7 rad/s

Question 10: EO Mission Design (cont'd), 5 pts.

The Topex/Poseidon altimetry satellite was a joint NASA/CNES mission launched in 1993. It flew for 13 years collecting valuable information about the surface of the Earth's oceans. It was placed into a sun-synchronous orbit at roughly 1300 km in altitude, with a repeat period of 10 days, meaning that the satellite would fly over the same location on the Earth once every ten days. What would the sampling density at the equator be for such a mission design? In other words, if you were to plot the ground track of the Topex/Poseidon mission, how far apart would the ascending tracks be along the equator?

a) 313 km b) 127 km c) 6695 km d) 669.5 km e) 400 km

Question 11: RADAR, 5 pts.

A radar antenna with a length of 10 m, operating at a center frequency of 1.25 GHz, will have a beam width of

a) 140 degrees b) 14 degrees c) 1.4 degrees d) 0.14 degrees e) 0.014 degrees

Question 12: Optical remote sensing, 5 pts.

Categorizing visible wavelengths from high to low frequencies, we find

a) red, yellow, blue
b) red, blue, yellow
c) blue, yellow, red
d) blue, red, yellow
e) yellow, red, blue

Question 13: Optical remote sensing (cont'd), 5 pts.

The spatial resolution of a VIR satellite sensor...

a) is limited by optics (lenses etc.)
b) is limited by the minimum integration time of the sensor
c) depends on the "width" of the spectral bands
d) all of the above may apply
e) none of the above applies

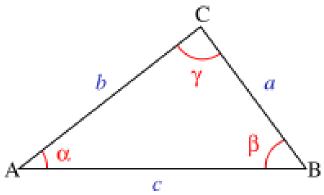
Equation sheet AE2103, Space Missions and Applications I

Physical constants		
c	Speed of light *in vacuo*	2.9979×10^8 m s^{-1} (defined as 299 792 458 m s^{-1})
h	Planck constant	6.6261×10^{-34} J s
e	Charge on the proton	1.6022×10^{-19} C
m_e	Mass of the electron	9.1094×10^{-31} kg
u	Atomic mass unit	1.6605×10^{-27} kg
m_0	Permeability of free space	1.2566×10^{-6} H m^{-1} (defined as $4\pi \times 10^{-7}$ H m^{-1})
ε_0	Permittivity of free space	8.8542×10^{-12} F m^{-1}
Z_0	Impedance of free space	$3.7673 \times 10^2\,\Omega$
G	Gravitational constant	6.6726×10^{-11} N m^2 kg^{-2}
R	Gass constant	8.3145 J K^{-1} mol^{-1}
N_A	Avogadro number	6.0221×10^{23} mol^{-1}
k	Boltzmann constant	1.3807×10^{-23} J K^{-1}
σ	Stefan-Boltzmann constant	5.6705×10^{-8} W m^{-2} K^{-4}
A	Wien's displacement constant	2.8978×10^{-3} K m

Units		
AU	Astronomical unit	1.496×10^{11} m

Properties of the Sun and Earth	
Sun's radius	6.96×10^8 m
Sun's mass	1.99×10^{30} kg
Total radiated solar power	3.85×10^{26} W
Sun's black-body temperature	5770 K
Earth's equatorial radius	6378135 m
Semi-major axis of Earth's orbit around the Sun	1.496×10^{11} m
Earth's mass $M_\oplus$	5.976×10^{24} kg
Standard gravitational parameter $\mu = GM_\oplus$	3.986×10^{14} m^3 s^{-2}
Mean global albedo	0.35
Moon's radius	1.738×10^6 m
Average Earth-Moon distance	3.844×10^8 m

Law of cosines: $c^2 = a^2 + b^2 - 2ab\cos\gamma$



Surface area of a sphere: $4\pi r^2$

Volume of a sphere: $\frac{4}{3}\pi r^3$

Circumference of a circle: $2\pi r$

Planck: $L_\lambda = \frac{2hc^2}{\lambda^5\left(e^{hc/\lambda kT}-1\right)}$

Rayleigh-Jeans: $L_f \approx \frac{2kTf^2}{c^2} = \frac{2kT}{\lambda^2}$

Stefan: $M = \sigma T^4$

Wien: $\lambda_{\mathsf{max}} = C_3/T$
$C_3 = 2898\ \mu\text{m K}$

Kirchhoff: $L_\lambda = \varepsilon(\lambda) L_{\lambda,\mathsf{bb}}$

Wave equation:

$$\begin{aligned} E &= Ae^{j(kr-\omega t+\phi)} \\ k &= 2\pi\sqrt{\varepsilon_r}/\lambda \\ \lambda &= 2\pi c/\omega \\ \omega &= 2\pi f \end{aligned}$$

Miscellaneous:

GSI = inter-detector spacing $\times \frac{H}{f} = \frac{\text{inter-detector spacing}}{m}$

GIFOV $= 2H\tan(\frac{IFOV}{2}) = w \times \frac{H}{f} = \frac{w}{m}$

$P_r = \frac{A_e G P_t}{(4\pi)^2 R^4}\sigma^0 A$

$P_n = k \cdot T_{sys} \cdot B$

$\Omega = 2\pi(1-\cos(\alpha/2))$

$\Theta = \lambda/D$

$dB - 10\log^{10}(P)$

$G = \frac{4\pi A_e}{\lambda^2}$

SNR $= P_r/P_n$

Keplerian orbits:

$$\begin{aligned} r &= \frac{a(1-e^2)}{1+e\cos(\theta)} \\ e &= \frac{r_a-r_p}{r_a+r_p} \\ T &= \frac{2\pi}{n} \\ n &= \sqrt{\frac{\mu}{a^3}} \end{aligned}$$

Repeat orbits:

$$\begin{aligned} j(\Delta L_1 + \Delta L_2) &= k2\pi \\ \Delta L_1 &= -2\pi\frac{T}{T_E} \\ \Delta L_2 &= -\frac{3\pi J_2 R_e^2\cos(i)}{a^2(1-e^2)^2} \end{aligned}$$

Node rate: $\frac{d\Omega}{dt} = -3\pi J_2(\frac{R_e}{a(1-e^2)})^2\cos(i)\frac{1}{2\pi}\sqrt{\frac{\mu}{a^3}}$

Newton's 2nd Law: $\bar{F} = m\bar{a} = \frac{\mu m}{r^2}\frac{\bar{r}}{r}$

Solutions:

1) a
2) b
3) a
4) a
5) b
6) b
7) d
8) b
9) e
10) a
11) c
12) c
13) d