PROPERTIES OF PLANETS AND THEIR MOONS

Knowledge of planet and moon data, both geometrical and thermal, is required to predict the thermal behaviour of spacecraft in planetary orbits and flybys. Table 1 gives a summary of planet and moon mass and size, orbit characteristics, global thermal properties, and surface thermal properties, based on the following assumptions:

1. Spherical geometry. Planets and large moons are quasi-spherical because they deform under their own large gravity forces.
2. Uniform albedo. A single reflectance value is given, the bolometric or energy-balance value, corresponding to the radiative energy reflected by the whole planet or moon in all directions and wavelengths, divided by the global incident radiation from the Sun.
3. Uniform surface temperature. However, diurnal variations may be large on slow-rotating bodies: from 270 K to 300 K on Earth, from 90 K to 400 K on the Moon, from 140 K to 290 K on Mars, 80..700 K on Mercury.
4. Uniform emissivity, corresponding to the energy balance and a black-body emitter at mean surface temperature.
5. Cosmic background radiation (CBR) temperature, T_∞=2.7 K, can be neglected in the energy balance..

Table 1. Geometrical and thermal data for solar planets and their major moons.

Body	Density	Semimajor axis to Sun or Planet	Equator. diameter	Albedo (bolometric / geometric)	$T_{surface}$ min..max	$T_{reference}$ =T_{mean}	T_{bb} or $\alpha=\varepsilon$	Solar irradiat.	Ratio of max/min irradiation	Energy ratio (ent/exit)	Emis. (bolom.)	Atm. pressure
	[kg/m^3]	R [10^9 m] (ua*)	$D\cdot10^{-6}$ [m]	ρ_P	[K]	[K]	[K]	[W·m^{-2}]			ε_P	[Pa]
Sun	1400	-	1390	NA	5800	5800	5800	$62.8\cdot10^6$	1	$\to\infty$	1	
Mercury	5420	58, (0.38)	4.9	0.09 / 0.14	Eq., 100..700	440	450	9147	2.30		0.9	$<10^{-5}$
					85ºN, 80..380							
Venus	5250	108, (0.72)	12.1	0.76 / 0.69	720..740	737	328	2620	1.03		0.013	$9300\cdot10^3$
Earth	5520	150, (1.00)	12.8	0.31 / 0.43	Eq., 270..330	288	278	1361	1.07	1	0.61	$101\cdot10^3$
					Pol, 190..250							
Moon		0.38, (0.0027)	3.5	0.11 / 0.12	Eq., 100..390	250	278	1361	1.07	1	0.95	10^{-8}
					85ºN, 90..230							
Mars	3940	228, (1.50)	6.8	0.25 / 0.17	Eq., 186..268	217	226	590	1.45	1	0.95	$0.8\cdot10^3$
Phobos	1890	0.009 (-)	0.022	/ 0.07	233	233	226	590	1.45	1		
Deimos	1470	0.023 (-)	0.012	/ 0.07	233	233	226	590	1.45	1		

Jupiter	1310	778, (5.20)	14312	0.50 / 0.54	165 at 1 bar	102	123	51	1.21	1.50		$(20..200)\cdot10^3$
(63 moons)					112 at 0.1 bar							at cloud top
Io	3530	0.42, (-)	3.6	/ 0.65	130..1500	130	123	51			0.2	
Europe	3010	0.67, (-)	3.1	/ 0.62	50..100	96	123	51				
Ganymede	1940	1.07, (-)	5.3	/ 0.45		104	123	51				
Callisto	1830	1.88, (-)	4.8	/ 0.20	80..160	116	123	51				
Saturn	690	1427, (9.60)	120	0.34 /0.50	134 at 1 bar	63	90	15.1	1.24	2.50		
					84 at 0.1 bar							
Titan	1880	1.22, (-)	5.1	0.20 / 0.22	95	94	90	15.1			0.6	$150\cdot10^3$
Enceladus	1600	238, (-)	0.5	0.80 / 1.40	33..145	75	90	15.1				
Uranus	1290	2871, (19)	51	0.30 / 0.49	50..100	57	60	3.7	1.22		0.7	
Neptune	1640	4497, (30)	50	0.29 / 0.44	50..100	57	50	1.5	1.02		0.4	
Triton		0.35, (-)	2.7	/ 0.85	40	38	50	1.5				

*1 ua=$150\cdot10^9$ m is the average Sun-to Earth distance (also written as 1 AU). Sun Equatorial diameter corresponds to the photosphere (i.e. the region from which visual light originates).

A few data to keep in mind for spacecraft thermal control

Although we live nowadays with all worldwide data at our fingertips on the Internet, it is convenient to memorise a few numbers (not the whole list that follows), while working on spacecraft thermal control problems, basically:

- Altitudes (over the Earth radius, R_p=6370 km): sounding balloons at 40 km, LEO at 400 km, GEO at 40 000 km, Moon at 400.10^3 km, Mars at 400.10^6 km as most.
- Temperatures: Sun surface temperature (quasi black-body) at 5800 K. Earth surface average is T_s=288 K. Deep space background temperature (quasi black-body) at 2.7 K. Blackbody emission is $M_{bb}=\sigma T^4$, with $\sigma=5.67\cdot10^{-8}$ W/($m^2\cdot K^4$).
- Heat rates (normal radiation flux):
  - The Solar constant: E_0=1360 W/m^2 (at 1 ua=1 AU=$150\cdot10^9$ m). The maximum in the spectrum is at λ_{Emax}=0.5 μm. Daily average is 1360/4=340 W/m^2.
  - The Earth albedo: 30%, so that $1360\cdot0.3$=410 W/m^2 is reflected (with the maximum still at λ_{Emax}=0.5 μm, but free of UV and IR).
  - The Earth emission, 240 W/m^2 when λ_{Emax}=10 μm, corresponding to an emissivity around 60%.($0.60\cdot5.67\cdot10^{-8}\cdot288^4$=240 W/$m^2$), balancing the $340\cdot0.7$=240 W/m^2 absorption.

Back to Spacecraft Thermal Control