ON THE HEAT CAPACITY OF ASTEROIDS, SATELLITES AND TERRESTRIAL PLANETS.

M. Szurgot, Technical University of Lodz, Center of Mathematics and Physics, Al. Politechniki 11, 90 924 Lodz, Poland, (mszurgot@p.lodz.pl).

Introduction: Thermal properties of meteorites are important physical properties that have been investigated since 1958 [1-11]. Recently, relationships between thermophysical properties and bulk density of meteorites have beeen established [12-14]. It was postulated that they can be applied for evaluation of heat capacity, thermal conductivity and thermal diffusivity of extraterrestrial objects [12-14]. The aim of the paper was to evaluate heat capacity of selected asteroids, satellites and terrestrial planets at room temperature using values of specific heat capacity of meteorites.

Results and discussion: Heat capacity C of asteroids, satellites and planets was calculated using the equation

$$C = M \cdot Cp, \quad (1)$$

where M is the mass of the object, and Cp is its specific heat capacity. Cp was determined using the relationship between Cp (J/kg·K) and bulk density d (kg/m^3) of meteorites [12]

$$Cp = a + b/d, \quad (2)$$

where a, and b are constants ($a = 303$ J/kg·K, $b = 1.31 \cdot 10^6$ J/K· m^3). In the range of densities between $3 \cdot 10^3 kg/m^3$ and $8 \cdot 10^3 kg/m^3$ equation (2) satisfactorily describes Cp(d) dependence at room temperature ($R^2=0.79$) [12]. In this paper we assumed that the same relationship (eq. (2)) is valid for the matter of asteroids, satellites and terrestrial planets. Mass M and mean density d of the objects are in most cases well-known quantities, but for certain asteroids and small satellites they can be only approximate values. Substitution of eq. (2) into eq. (1) gives

$$C = M \cdot (a + b/d). \quad (3)$$

Table 1 presents results of calculations of Cp and C values for selected asteroids.

Table 1 Heat capacity C of selected asteroids at room temperature.

Asteroid	M(kg)	d(g/cm^3)	Cp(J/kg·K)	C (J/K)
Ceres	$8.7 \cdot 10^{20}$	2.077	937	$8.15 \cdot 10^{23}$
Vesta	$3.0 \cdot 10^{20}$	3.42	689	$2.07 \cdot 10^{23}$
Eros	$6.7 \cdot 10^{15}$	2.67	797	$5.34 \cdot 10^{18}$
Nysa	$3.7 \cdot 10^{17}$	2.0	961	$3.56 \cdot 10^{20}$
Psyche	$5.2 \cdot 10^{11}$	3.3	703	$3.65 \cdot 10^{14}$
Mathilde	$2.0 \cdot 10^{17}$	1.3	1314	$2.63 \cdot 10^{20}$
Ida	$1.0 \cdot 10^{17}$	2.60	810	$8.10 \cdot 10^{19}$
Hebe	$1.3 \cdot 10^{19}$	3.81	650	$8.45 \cdot 10^{19}$

It is seen that the range of C values for asteroids is between $4 \cdot 10^{14}$ J/K and $8 \cdot 10^{23}$ J/K, and of Cp values between 689 J/kg·K and 1314 J/kg·K.

Table 2 presents results of calculations of Cp and C values for natural satellites. It is seen that the range of C values for satellites is between $1.7 \cdot 10^{18}$ J/K and $1.4 \cdot 10^{26}$ J/K, and of Cp values between 677 J/kg·K and 1197 J/kg·K.

Table 2 Heat capacity C of natural satellites at room temperature.

Satellite	M(kg)	d(g/cm^3)	Cp(J/kg·K)	C(J/K)
Moon	$7.35 \cdot 10^{22}$	3.34	698	$5.13 \cdot 10^{25}$
Io	$8.93 \cdot 10^{22}$	3.53	677	$6.05 \cdot 10^{25}$
Europa	$4.80 \cdot 10^{22}$	3.01	741	$3.56 \cdot 10^{25}$
Ganimede	$1.48 \cdot 10^{23}$	1.94	981	$1.45 \cdot 10^{26}$
Callisto	$1.07 \cdot 10^{23}$	1.83	1022	$1.09 \cdot 10^{26}$
Phobos	$1.07 \cdot 10^{16}$	1.88	1003	$1.07 \cdot 10^{19}$
Deimos	$1.45 \cdot 10^{15}$	1.47	1197	$1.74 \cdot 10^{18}$

Table 3 presents results of calculations of Cp and C values for terrestrial planets. It is seen that the range of C values for terrestrial planets is between $1.8 \cdot 10^{26}$ J/K and $3.2 \cdot 10^{27}$ J/K, and of Cp values between 547 J/kg·K and 638 J/kg·K.

Table 3 Heat capacity C of terrestrial planets at room temperature.

Planet	M($\cdot 10^{24}$kg)	d(g/cm^3)	Cp(J/kg·K)	C(J/K)
Mercury	0.33	5.427	547	$1.81 \cdot 10^{26}$
Venus	4.87	5.243	556	$2.71 \cdot 10^{27}$
Earth	5.97	5.52	543	$3.24 \cdot 10^{27}$
Mars	0.642	3.94	638	$4.10 \cdot 10^{26}$

It is well-known that the specific heat capacity Cp depends on temperature. At low temperatures Cp is lower and at high temperatures is higher than at room temperature. Literature data show that at 100 K specific heat capacity of stony meteorites and of lunar regolith is about three times lower, and of iron meteorites about five times lower than at room temperature. At high temperatures specific heat capacity increases, and at 400 K for stony meteorites is about 1.2 times higher, and for iron meteorites is about 1.4 times higher than at room temperature [4].

Conclusions: Relationship between specific heat capacity and bulk density of meteorites enables one to evaluate mean specific heat capacities of asteroids, satellites and terrestrial planets, and to determine their heat capacities at room temperature. Heat capacity C of terrestrial planets is between 10^{26} J/K and 10^{27} J/K, asteroids is between 10^{14} J/K and 10^{23} J/K, and of satellites is between 10^{18} J/K and 10^{26} J/K at room temperature.

References: [1] Alexeyeva K.N. (1958) *Meteoritka, 16,* 67-77. [2] Alexeyeva K.N. (1960) *Meteoritka, 18,* 68-76. [3] Butler C.P. and Jenkins R.J. *Science (1963), 139*, 486-487. [4] Matsui T. and Osako M. (1979) *Nat. Inst.Polar. Spec. Issue, 15,* 243-252. [5] Osako M. (1981) *Bull. Natn. Sci. Mus. Tokyo, Ser. E, 4, Dec. 22,* 1-8. [6] Yomogida K. and Matsui T. (1981) *Mem.Natl. Inst.Polar.Res. Spec. Issue, 20,* 384-394. [7] Opeil C.P. et al. (2010) *Icarus 208*, 449-454. [8] Beech M. et al. (2009) *Planet. Space Sci. 57*, 764-770. [9] Ghosh A. and McSween H.J. (1999) *Meteor. Planet. Sci. 34*, 121-127. [10] Szurgot M. (2003) in: *II Seminarium Meteorytowe Olsztyn 2003,* Olsztynskie Planetarium i Obserwatorium Astronomiczne, Polskie Towarzystwo Meteorytowe, Olsztyn-Sosnowiec, 136-145. [11] Szurgot M. et al. (2008) *Cryst. Res. Technol., 43,* 921-930. [12] Szurgot M. (2011) *LPSC* XXXXII, Abstract #1150. [13] Szurgot M. and Wojtatowicz T.W. (2011) *Meteoritics & Planet. Sci., 46,* Suppl. A230. [14] Szurgot M. (2011) *Meteoritics & Planet. Sci., 46,* Suppl. A230.