Some Equations and Constants

1 Physical Constants

Table B.1: Physical constants

Name	Symbol	Value
Speed of light	c	$3.00 \cdot 10^8 m/s$
Elementary charge	e	$1.60 \cdot 10^{-19} C$
Electron mass	m_e	$9.11 \cdot 10^{-31} kg = 0.511 MeV/c^2$
Proton mass	m_p	$1.67 \cdot 10^{-27} kg = 938 MeV/c^2$
Gravitational constant	G	$6.67 \cdot 10^{-11} N \cdot m^2/kg^2$
Gravitational acceleration	g	$9.81 m/s^2$
Boltzmann's Constant	k_B	$1.38 \cdot 10^{-23} J/K$
Planck's Constant	h $\hbar = h/2\pi$	$6.63 \cdot 10^{-34} J \cdot s$ $1.05 \cdot 10^{-34} J \cdot s$

2 Moments of Inertia

Table B.2: Moments of inertia, all about axes of symmetry through the center of mass.

Object	Moment of Inertia
Thin stick (length L)	$\frac{1}{12} ML^2$
Ring of hollow cylinder (radius R)	MR^2
Disk or solid cylinder (radius R)	$\frac{1}{2} MR^2$
Hollow sphere (radius R)	$\frac{2}{3} MR^2$
Solid sphere (radius R)	$\frac{2}{5} MR^2$
Rectangle (size $a \times b$), perpendicular axis	$\frac{1}{12} M(a^2 + b^2)$
Rectangle (size $a \times b$), axis parallel to side b	$\frac{1}{12} Ma^2$

3 Solar System Objects

Table B.3: Characteristics of the Sun, Earth and Moon.

	Sun	Earth	Moon
Mass (kg)	$1.99 \cdot 10^{30}$	$5.97 \cdot 10^{24}$	$7.35 \cdot 10^{22}$
Mean radius (m)	$6.96 \cdot 10^8$	$6.37 \cdot 10^6$	$1.74 \cdot 10^6$
Orbital period (s)	$6 \cdot 10^{15}$ (200 My)	$3.16 \cdot 10^7$ (365.25 days)	$2.36 \cdot 10^6$ (27.3 days)
Mean orbital radius (m)	$2.6 \cdot 10^{20}$	$1.50 \cdot 10^{11}$	$3.85 \cdot 10^8$
Mean density (kg/m^3)	$1.4 \cdot 10^3$	$5.5 \cdot 10^3$	$3.3 \cdot 10^3$

Table B.4: Properties of a number of solar system objects. Equatorial radii and masses are compared to those of Earth (see Table B.3). Orbital properties are around primary (the sun for (dwarf) planets, the planet for moons). Orbital radii and periods for planets again compared to Earth, for moons in kilograms and days. Rotation period for all objects in days. Inclination and axial tilt in degrees. Data from NASA planetary fact sheets [31].

Name	Symbol	Equatorial radius	Mass	Mean orbit radius	Orbital period	Inclination	Orbital eccentricity	Rotation period	Confirmed moons	Axial tilt
Mercury	☿	0.382	0.06	0.39	0.24	3.38	0.206	58.64	0	0.04
Venus	♀	0.949	0.82	0.72	0.62	3.86	0.007	-243.02	0	177.36
Earth	♁	1	1	1	1	7.25	0.017	1	1	23.44
Moon	☾	0.272	0.0123	384399	27.32158	18.29-28.58	0.0549	27.32158	0	6.68
Mars	♂	0.532	0.107	1.52	1.88	5.65	0.093	1.03	2	25.19
Ceres		0.0742	0.00016	2.766	4.599	10.59	0.08	0.3781	0	4
Jupiter	♃	11.209	317.8	5.2	11.86	6.09	0.048	0.41	69	3.13
Io		0.285	0.015	421600	1.769	0.04	0.0041	1.769	0	0
Europa		0.246	0.008	670900	3.551	0.47	0.009	3.551	0	0
Ganymede		0.423	0.025	1070400	7.155	1.85	0.0013	7.155	0	0
Callisto		0.378	0.018	1882700	16.689	0.2	0.0074	16.689	0	0
Saturn	♄	9.449	95.2	9.54	29.46	5.51	0.054	0.43	62	26.73
Titan		0.404	0.023	1221870	15.945	0.33	0.0288	15.945	0	0
Uranus	⛢	4.007	14.6	19.22	84.01	6.48	0.047	-0.72	27	97.77
Oberon		0.119	0.00051	583519	13.46	0.1	0.0014	13.46	0	0
Neptune	♅	3.883	17.2	30.06	164.8	6.43	0.009	0.67	14	28.32
Triton		0.212	0.00358	354759	5.877	157	0.00002	5.877	0	0
Pluto	♇	0.186	0.0022	39.482	247.9	17.14	0.25	6.39	5	119.59
Charon		0.095	0.00025	17536	6.387	0.001	0.0022	6.387	0	unknown
Haumea		0.13	0.0007	43.335	285.4	28.19	0.19	0.167	2	unknown
Makemake		0.11	unknown	45.792	309.9	28.96	0.16	unknown	1	unknown
Eris		0.18	0.0028	67.668	557	44.19	0.44	unknown	1	unknown

4 Equations

4.1 B.4.1 Vector Derivatives

Gradient:

$$\nabla f(\boldsymbol{r}) = \nabla f(x, y, z) = \begin{pmatrix} \partial_x f \\ \partial_y f \\ \partial_z f \end{pmatrix} = \left(\frac{\partial f}{\partial x} \hat{x} + \frac{\partial f}{\partial y} \hat{y} + \frac{\partial f}{\partial z} \hat{z} \right) \tag{1}$$

Divergence:

$$\nabla \cdot \boldsymbol{v} = (\partial_x, \partial_y, \partial_z) \cdot \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \tag{2}$$

Curl:

$$\nabla \times \boldsymbol{A} = (\partial_x, \partial_y, \partial_z) \times \begin{pmatrix} A_x \\ A_y \\ A_z \end{pmatrix} = \begin{pmatrix} \partial_y A_z - \partial_z A_y \\ \partial_z A_x - \partial_x A_z \\ \partial_x A_y - \partial_y A_x \end{pmatrix} \tag{3}$$

4.2 B.4.2 Special Relativity

Lorentz transformations for the coordinates of a frame S' that moves with a speed u in the positive x-direction of frame S:

$$x' = \gamma(u)\left(x - \frac{u}{c} ct\right) \tag{4}$$

$$ct' = \gamma(u)\left(ct - \frac{u}{c} x\right) \tag{5}$$

$$\gamma(u) = \frac{1}{\sqrt{1-(u/c)^2}} \tag{6}$$

Velocity addition in a relativistic system:

$$v_x = \frac{u + v_x'}{1 + u v_x'/c^2} \quad \text{(longitudinal)}\,, v_y = \frac{1}{\gamma(u)} \frac{v_y'}{1 + u v_x'/c^2} \quad \text{(transversal)} \tag{7}$$