ASTR 2320 General Astronomy II – Spring 2020, Brotherton
Homework 4, due Tuesday March 3, 2020

Instructions: This homework covers topics featured in chapters 1-3 of Dobson's text, as well as associated labs, lectures, homeworks, and discussions. Calculators are allowed (and likely needed!). Some constants and equations you may need are provided on the last pages, as well as an explicit list of some things you're expected to have memorized. Please write all answers clearly and use good English. Box final answers when calculations are required. Use units when appropriate. Show your work. Draw pictures when helpful.

Write your name on every page in case pages become separated!

Part 1. Multiple choice. Please give the best answer. (6 Problems, 5 points each = 30)

1. The moon is overhead at 6AM. What phase is it in?
A) New
B) First quarter
C) Full
D) Third quarter
E) None of the above

2. The moon is first quarter and rising. What time is it?
A) Noon
B) 6PM
C) 9PM
D) Midnight
E) 6AM

3. The moon is a waxing crescent phase and it's dusk. Where is the moon?
A) The moon is not visible in the sky.
B) The moon is on the eastern horizon.
C) The moon is on the western horizon.
D) The moon is at an intermediate angle in the eastern sky.
E) The moon is at an intermediate angle in the western sky.

4. Laramie is at 41 degrees north latitude. What are the coordinates of an object overhead at midnight around March 21?
A) RA 0 hours, declination 41 degrees
B) RA 12 hours, declination 41 degrees
C) RA 0 hours, declination 49 degrees
D) RA 12 hours, declination 49 degrees
E) None of the above are close

5. For a comet with an elliptical orbit with a period of 100 years, what is the semi-major axis?
A) 4.6 AU
B) 10 AU
C) 21.5 AU
D) 100 AU
E) 1000 AU

6. What are Lagrangian points?
A) Rewards you earn on your physics department credit card.
B) Talking points favoring a heliocentric solar system over a Earth-centered solar system.
C) Center of mass in multi-body gravitational systems.
D) Locations of balanced gravity in 2-body systems.
E) Locations to measure angles to solar system objects in order to measure relative distances.

Part 2. Short answers (please explain as appropriate, and draw figures if that will help illustrate your answer). (5 questions, 5 points each = 25)

7. Why are there more lunar eclipses than solar eclipses? Note that the angular sizes of the sun and moon are nearly the same.

8. Is the Moon's orbital radius changing, and if so, why?

9. What is the astrophysical process that eliminates the smallest dust grains from the solar system and how does it work? Don't just give a name, but describe the physics.

10. What is the difference between sidereal and synodic periods?

11. What is the virial theorem? Express in words and give the formula.

Part 3. Quantitative problems. (3 problems, 15 points each = 45). Give answers to three significant figures in each case.

12. A) Assuming a circular orbit (not quite true!), what is the velocity of Mercury around the sun in km/s? B) What is the maximum angle of the aberration of starlight at Mercury? Please give your answer in arcseconds.

13. A comet is observed to return to the inner solar system every 64 years. A) What is the semi-major axis of its orbit in astronomical units? B) If the eccentricity e=0.9, what is the perhelion distance from the sun in AUs?

14. Antiope is a binary asteroid that has two components of very nearly the same size in nearly circular orbits around their common center of mass. The orbital period is 16.5 hours. The separation between the centers of the asteroids is 171 kilometers. A) What is the mass of each of the asteroids in kg? B) If the resolution of your eyes is 1 arcminute, how close would you have to be in kilometers to separate the two objects into one? (Assume the most favorable geometry.)

Equations or other information that may be useful:

$$P^2 = \frac{4\pi^2}{G(m_1 + m_2)} a^3.$$

$$v^2 = GM\,(2/r - 1/a)$$

You should know Newton's Law of Gravitation, Newton's second law of motion, and the virial theorem. You should also know or be able to quickly derive escape velocity and circular velocity.

$G=6.67\times10^{-11}$ N x m ^{2} x kg $^{-2}$.
Mass of the sun is 2×10^{30} kg.
1 AU is 150 million km.
$c = 3.00\times10^8$ m/s.

You should know equations for circumference and area for circles, and surface area and volume for spheres. Also know your right triangle trigonometry.
You should know the small angle formula and conversions between units of angles.

Tidal forces:

$$\vec{a}_{t,\text{axial}} \approx \pm\hat{r}\; 2\Delta r\; G\; \frac{M}{R^3}$$

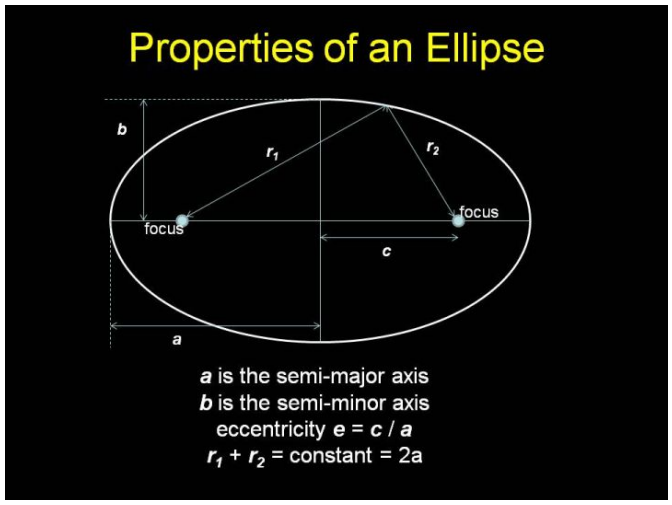

Table 4.1: Summary of orbital and physical properties of selected solar system objects

Object	semi-major axis (AU or km)	revolution period (days or years)	orbit eccentricity	& inclination to ecliptic or planet equator (°)	rotation period (hours or days)	obliquity (°)
Sun	–	–	–	–	25 – 34 d	7.25
Mercury	0.387	87.97 d	0.206	7.0	58.65 d	0.003
Venus	0.723	0.615	0.007	3.39	–243 d	177.4
Earth	1.0	1.0	0.017	7.2 to Sun eq.	23.93	23.44
Moon	384,400 km	27.32 d	0.055	5.15 to ecl.	27.32 d	6.69
Mars	1.52	1.88	0.094	1.85	1.026 d	25.19
Phobos	9,376 km	0.32 d	0.015	1.09	0.32 d	0
Deimos	23,463 km	1.26 d	~0	0.93	1.26 d	
4 Vesta	2.36	3.63	0.09	7.14	5.34	
Ceres	2.77	4.60	0.08	10.59	9.07	~3
2 Pallas	2.77	4.61	0.23	34.84	7.81	~78?
10 Hygiea	3.14	5.56	0.12	3.84	27.62	
Jupiter	5.20	11.86	0.05	1.31	9.93	3.13
Io	421,700 km	1.77 d	0.004	0.05	1.77 d	
Europa	670,900	3.55 d	0.009	0.47	3.55 d	0.1
Ganymede	$1.070 \cdot 10^6$ km	7.15 d	0.0013	0.20	7.15 d	
Callisto	$1.883 \cdot 10^6$ km	16.69 d	0.0074	~1	16.69 d	0
Saturn	9.58	29.46	0.056	2.49	10.55	26.73
Mimas	185,539 km	0.94 d	0.02	1.57	0.94 d	0
Enceladus	237,948 km	1.37 d	0.005	0.019	1.37 d	0
Tethys	294,619 km	1.89 d	~0	1.12	1.89 d	0
Dione	377,396 km	2.74 d	0.002	0.019	2.74 d	0
Rhea	527,108 km	4.52 d	0.001	0.345	4.52 d	0
Titan	$1.222 \cdot 10^6$ km	15.95 d	0.029	0.35	15.95 d	0
Iapetus	$3.561 \cdot 10^6$ km	79.32 d	0.029	15.47	79.32 d	0
2060 Chiron	13.71	50.76	0.38	6.93	5.92	
Uranus	19.19	84.02	0.05	0.77	–17.24	97.8
Miranda	129,390 km	1.41 d	0.0013	4.23	1.41 d	0
Ariel	191,020 km	2.52 d	0.0012	0.26	2.52 d	?
Umbriel	266,300 km	4.14 d	0.0039	0.21	4.14 d	0?
Titania	435,910 km	8.71 d	0.0011	0.34	8.71 d	?
Oberon	583,520 km	13.46 d	0.0014	0.06	13.46 d	?
5145 Pholus	20.36	91.85	0.57	24.65	9.98	?
Neptune	30.07	164.8	0.0087	1.77	16.11	28.32
Proteus	117,647 km	1.122 d	~0	0.52	1.122 d	~0
Triton	354,759 km	– 5.88 d	~0	157	5.88	0
Pluto	39.26	247.7	0.25	17.16	6.387 d	122.5
Charon	19,591 km	6.387 d	0	0	6.387 d	
Haumea	43.22	284	0.19	28.19	3.92	?
Makemake	45.72	309	0.16	29.00	7.8	?
Eris	67.78	558	0.44	44.04	25.9	?
90377 Sedna	524.4	~11,400	0.85	11.93	10.3	?

Table 4.1: Summary of orbital and physical properties of selected solar system objects

Object	mass (kg)	diameter (km)	ave. density (g/cm^3)	albedo (Bond or geom.)	surface temp. (K)
Sun	$1.99 \cdot 10^{30}$	$1.39 \cdot 10^{6}$ (eq.)	1.41	_	5780
Mercury	$3.30 \cdot 10^{23}$	4,879	5.43	0.068 Bond	80 – 700
Venus	$4.87 \cdot 10^{24}$	12,104	5.24	0.90 Bond	737
Earth	$5.97 \cdot 10^{24}$	12,742	5.51	0.31 Bond	184 – 330
Moon	$7.35 \cdot 10^{22}$	3,474	3.35	0.12 geom	70 – 390
Mars	$6.42 \cdot 10^{23}$	6,779	3.93	0.25 Bond	130 – 308
Phobos	$1.07 \cdot 10^{16}$	27 x 22 x 18	1.88	0.071 geom	~233
Deimos	$\cdot 10^{20}$	15 x 12 x 11	1.47	0.068 geom	~233
4 Vesta	$2.59 \cdot 10^{20}$	~525	3.46	0.42 geom	85 – 270
Ceres	$9.39 \cdot 10^{20}$	938	2.17	0.09 geom	168 – 235
2 Pallas	$2.11 \cdot 10^{20}$	544	~2.8	0.16 geom	~164
10 Hygiea	$8.67 \cdot 10^{19}$	~431	2.08	0.07 geom	~164
Jupiter	$1.90 \cdot 10^{27}$	139,822	1.33	0.34 Bond	165 @ 1 bar
Io	$8.93 \cdot 10^{22}$	3,643	3.53	0.63 geom	110
Europa	$4.80 \cdot 10^{22}$	3,122	3.01	0.67 geom	102
Ganymede	$1.48 \cdot 10^{23}$	5,268	1.94	0.43 geom	110
Callisto	$1.08 \cdot 10^{23}$	4.821	1.83	0.2 geom	134
Saturn	$5.68 \cdot 10^{26}$	116,464	0.69	0.34 Bond	134 @ 1 bar
Mimas	$3.75 \cdot 10^{19}$	396	1.15	0.86 geom	~64
Enceladus	$1.08 \cdot 10^{20}$	504	1.61	0.99 Bond	75 (ave)
Tethys	$6.17 \cdot 10^{20}$	1,062	0.98	0.80 Bond	86
Dione	$1.10 \cdot 10^{21}$	1,123	1.48	0.99 geom	87
Rhea	$2.31 \cdot 10^{21}$	1,527	1.24	0.95 geom	53 – 99
Titan	$1.345 \cdot 10^{23}$	5,150	1.88	0.2 geom	93.7
Iapetus	$6.5xx \cdot 10^{19}$	1,470	1.09	~0.6 geom	90 – 130
2060 Chiron	?	~166 km	?	~0.15 geom	~75
Uranus	$8.68 \cdot 10^{25}$	50,724	1.27	0.30 Bond	76 K @ 1 bar
Miranda	$6.59 \cdot 10^{19}$	471	1.20	0.32 geom	~60
Ariel	$1.35 \cdot 10^{21}$	1,158	1.59	0.23 Bond	~60
Umbriel	$1.17 \cdot 10^{21}$	1,169	1.39	0.10 Bond	~75
Titania	$3.53 \cdot 10^{21}$	1,577	1.71	0.17 Bond	70
Oberon	$3.01 \cdot 10^{21}$	1,523	1.63	0.14 Bond	70-80
5145 Pholus	?	185	?	0.046	~62
Neptune	$1.02 \cdot 10^{26}$	49,244	1.64	0.29 Bond	72 K @ 1 bar
Proteus	$4.4 \cdot 10^{19}$	~420	~1.3	0.096 geom	~51
Triton	$2.14 \cdot 10^{22}$	2,706	2.06	0.719 geom	38
Pluto	$1.303 \cdot 10^{22}$	2,377	1.86	0.49 – 0.66 geo	33 – 55
Charon	$1.586 \cdot 10^{21}$	1,212	1.66	0.37 geom	53