Answers, Even-Numbered Problems, Chapter 12

12.2

(a) $F_{\text{net}} = 0$.

(b) $3.81 \times 10^{-8}\ \text{N} \cdot \text{m}$.

(c) The torque is very small and the apparatus must be very sensitive. The torque could be increased by increasing the mass of the spheres or by decreasing their separation.

12.4

$GM^2/(2R)^2 = GM^2/4R^2$.

12.6

(a) $-2.32 \times 10^{-11}\text{N}$, with the minus sign indicating a net force to the left.

(b) No, the force found in part (a) is the *net* force due to the other two spheres.

12.8

The acceleration is $2.2 \times 10^{-9}\ \text{m/s}^2$, toward the 8.00 kg mass.

12.10

$F_{\text{onA}} = 8.2 \times 10^{-3}\ \text{N}$ toward the center of the square.

12.12

(a) $x = \dfrac{L}{1+\sqrt{2}} = 0.414L$.

(b) The graph of F_x versus x is sketched in Figure 12.12b.

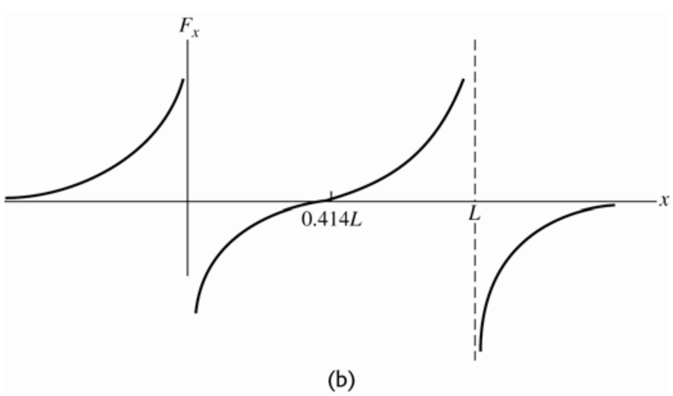

Figure 12.12

12.14

A $0.757\ \text{m}^2/\text{s}^2$.

12.16

(a) $g_{\rm V} = 0.905 g_{\rm E}$.

(b) $67.9\ \rm N$.

12.18

$M = 2.44 \times 10^{21}\ \rm kg$ and $\rho = 1.30 \times 10^{3}\ \rm kg/m^3$.

EVALUATE: The average density of Rhea is about one-fourth that of the earth.

12.20

$g_{\rm n} = G\dfrac{m_{\rm n}}{R_{\rm n}^2}$, where the subscript n refers to the neutron star. $w = mg$.

12.22

. $\omega = (0.553\ \rm rad/s) = 5.28\ \rm rpm$.

12.24

(a) $M = 3.37 \times 10^{13}\ \rm kg$.

(b) (i) $r = 45\ \rm km$.

(ii) The debris never loses all of its initial kinetic energy, but $K_2 \to 0$ as $r \to \infty$.

12.26

(a) $3.49 \times 10^{9}\ \rm J$

(b) $-8.73 \times 10^{7}\ \rm J$.

The total energy $K + U$ is positive.

12.28

(a) $T = 5.94 \times 10^{3}\ \rm s = 99.0\ min$

(b) $v = 7.49 \times 10^{3}\ \rm m/s = 7.49\ km/s$

12.30

$r = 6.75 \times 10^{6}\ \rm m$ and $h = r - R_{\rm E} = 3.7 \times 10^{5}\ \rm m = 370\ km$.

12.32

$T = 4.13 \times 10^{6}\ \rm s = 47.8\ days$

12.34

$24.5\ \rm days$ and $37.7\ \rm days$.

12.36

(a) $T = 2.67 \times 10^5\ \text{s}$. $r = (5.79 \times 10^{10}\ \text{m})/9 = 6.43 \times 10^9\ \text{m}$. $T = \dfrac{2\pi r^{3/2}}{\sqrt{Gm_{\text{star}}}}$ gives

$$m_{\text{star}} = \frac{4\pi^2 r^3}{T^2 G} = \frac{4\pi^2 (6.43 \times 10^9\ \text{m})^3}{(2.67 \times 10^5\ \text{s})^2 (6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2)} = 2.21 \times 10^{30}\ \text{kg}.$$

$\dfrac{m_{\text{star}}}{m_{\text{sun}}} = 1.11$, so $m_{\text{star}} = 1.11 m_{\text{sun}}$.

(b) $v = \dfrac{2\pi r}{T} = \dfrac{2\pi(6.43 \times 10^9\ \text{m})}{2.67 \times 10^5\ \text{s}} = 1.51 \times 10^5\ \text{m/s}$

EVALUATE: The orbital period of Mercury is 88.0 d. The period for this planet is much less primarily because the orbit radius is much less and also because the mass of the star is greater than the mass of our sun.

12.38

(a) (i) $5.31 \times 10^{-9}\ \text{N}$.
(ii)0.
(iii) 0.
(b) For $r < 5.00\ \text{m}$ the force is zero and for $r > 5.00\ \text{m}$ the force is proportional to $1/r^2$. The graph of F_g versus *r* is sketched in Figure 12.38.

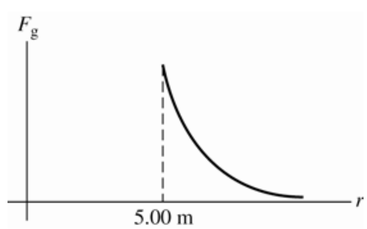

Figure 12.38

12.40

(a)

$U = -\dfrac{GmM}{L} \ln\left(1 + \dfrac{L}{x}\right)$ For $x >> L$, $U \rightarrow -GmM/x$.

(b) $F_x = -\dfrac{GmM}{(x^2 + Lx)}$, with the minus sign indicating an attractive force. As $x >> L$, $F_x \rightarrow -GmM/x^2$, as expected.

12.42

. $872\ \text{N}$

12.44

3.4×10^{11} kg

12.46

(b) 350 N.

(c) 9.44×10^{24} kg.

12.48

(a) 4.64×10^{11} m .

(b) 6.26×10^{36} kg .

(c) 9.28×10^{9} m

12.50 $F = 2.20\times10^{-10}$ N ; $\theta = 163°$

(b) The sphere would have to be placed at the point $x = 0,\ y = 1.39$ m

12.52

(a) the force on the spacecraft is 3.4 N, an angle of $0.61°$ from the earth-spacecraft line.

(b) $W = -1.31\times10^{9}$ J.

12.54 $r = 3.83\times10^{8}$ m.

12.56

677 N .

12.58

$R = 3.7$ km..

$3.03\times10^{3}\ \text{kg/m}^3$.

12.60

(a) $T = 2.65\times10^{4}\text{s} = 7.36$ h .

(b) $T = 8.90\times10^{3}$ s $= 2.47$ hours .

12.62

(a) $m_{\text{M}} = 4.55\times10^{25}$ kg

(b) $T = 5.54\times10^{4}$ s $= 15.4$ h

12.64

(a) The total gravitational potential energy in this model is $U = -Gm\left[\frac{m_{\text{E}}}{r} + \frac{m_{\text{M}}}{R_{\text{EM}} - r}\right]$.

(b) See Exercise 12.5. The point where the net gravitational force vanishes is $r = 3.46\times10^{8}$ m. ; $11.1\ \text{km/s}$.

(c) $3.823\times10^{8}\ \text{m}$.

12.66.

$5.07\times10^{3}\ \text{s}$, or 84.5 min, or about an hour and a half.

12.68

(a) The work needed to put it in orbit is $W=\dfrac{GmM_{\text{E}}}{2R_{\text{E}}}$.

(b) the additional work needed is $\dfrac{GmM_{\text{E}}}{2R_{\text{E}}}$.

(c) The work needed to put the satellite into orbit was the same as the work needed to put the satellite from orbit to the edge of the universe.

12.70

(a) $98.0\ \text{N}$.
(b) $=110\ \text{N}$.
(c) $44\ \text{N}$.
(d) At $r=0$, $F_{\text{g}}=0$.

12.72

(a) In moving to a lower orbit by whatever means, gravity does positive work, and so the speed does increase.

(b) $W=\Delta U+\Delta K=-\left(Gm_{\text{E}}m/2r^{2}\right)\ \Delta r$

(c) $v=\sqrt{Gm_{\text{E}}/r}=7.72\times10^{3}\ \text{m/s},\backslash\ \Delta v=\left(\Delta r/2\right)\sqrt{Gm_{\text{E}}/r^{3}}=28.9\ \text{m/s},$

$E=-Gm_{\text{E}}m/2r=-8.95\times10^{10}\ \text{J}$ (from Eq.(12.15)),

$\Delta K=\ \left(Gm_{\text{E}}m/2r^{2}\right)\left(\Delta r\right)=6.70\times10^{8}\ \text{J},\ \ \Delta U=-2\Delta K=-1.34\times10^{9}\ \text{J}$, and

$W=-\Delta K=-6.70\times10^{8}\ \text{J}.$

(d) As the term “burns up” suggests, the energy is converted to heat or is dissipated in the collisions of the debris with the ground.

12.74

(c) $M_{\alpha}=7.80\times10^{29}\ \text{kg}$ and $M_{\beta}=2.34\times10^{30}\ \text{kg}$.

(d) For Monocerotis, $R_{\alpha}=1.9\times10^{9}\ \text{m},\ v_{\alpha}=4.4\times10^{2}\ \text{km/s}$ and for the black hole

$R_{\beta}=34\times10^{8}\ \text{m},\ v_{\beta}=77\ \text{km/s}.$

EVALUATE: Since *T* is the same, *v* is smaller when *R* is smaller.

12.76

$2.650\times10^{4}\ \ \text{m/s}.$

12.78

(a) 1.09×10^{26} kg.

(b) 0.432 m/s^2.

(c) 0.080 m/s^2.

(d) No. Both the object and Miranda are in orbit together around Uranus, due to the gravitational force of Uranus. The object has additional force toward Miranda.

12.80.

1.4×10^{14} m.

12.82.

$F = \dfrac{2\pi GmM}{L^2}$ in the $+x$ direction

12.84

$$F = \frac{GMm}{x(L+x)}$$

For $x >> L$ this result become $F = GMm/x^2$, the same as for a pair of point masses.

.

12.86

(b) It will take 22 minutes for the cable to break.

(c) $2.5 \times 10^8 \text{ s} = 2900 \text{ d} = 7.9 \text{ y}$.

12.88

A 2.1 kN.

This tension is much larger than that which could be sustained by human tissue, and the astronaut is in trouble.

(b) The center of gravity is not the center of mass. The gravity force on the two ears is not the same.

12.90

From symmetry, the component of the gravitational force parallel to the rod is zero.

the perpendicular component is $F = \dfrac{GmM}{a\sqrt{a^2 + L^2}}$.