Chapter 2

Exercise Solutions

1. From Eq.2.1, $F_\text{g} = G\frac{m_1 m_2}{R^2}$
   $G = 6.67 \times 10^{-11}$ Nm^2/kg^2
   $m_1 = m_2 = 80$ kg
   $R = 2$ m

$$F_\text{g} = \frac{6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}(80 \text{ kg})(80 \text{ kg})}{(2 \text{ m})^2} = 1.07 \times 10^{-7} \text{ N}$$

2. From Eq.2.1, $F_\text{g} = G\frac{m_1 m_2}{R^2}$
   $G = 6.67 \times 10^{-11}$ Nm^2/kg^2
   $m_1 = 50$ kg

   a) $m_2 = 6 \times 10^{24}$ kg; $R = 6378$ km $= 6.378 \times 10^6$ m

$$F_\text{g} = \frac{6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}(50 \text{ kg})(6 \times 10^{24} \text{ kg})}{(6.378 \times 10^6 \text{ m})^2} = 491.9 \text{ N}$$

   b) $m_2 = m_\text{Mars} = 0.11\, m_\text{Earth} \times \left(\frac{6\times10^{24} \text{ kg}}{1\, m_\text{Earth}}\right) = 6.60 \times 10^{23}$ kg
   $R = R_\text{Mars} = 0.53\, R_\text{Earth} \times \left(\frac{6.378\times10^6 \text{ m}}{1\, R_\text{Earth}}\right) = 3.38 \times 10^6$ m

$$F_\text{g} = \frac{6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}(50 \text{ kg})(6.6 \times 10^{23} \text{ kg})}{(3.38 \times 10^6 \text{ m})^2} = 192.6 \text{ N}$$

Or using ratios:

$$\frac{F_{\text{g,Mars}}}{F_{\text{g,Earth}}} = \left(\frac{m_{\text{Mars}}}{m_{\text{Earth}}}\right)\left(\frac{R_{\text{Earth}}}{R_{\text{Mars}}}\right)^2 = (0.11)\left(\frac{1}{0.53}\right)^2 = 0.39$$
$$F_{\text{g,Mars}} = 0.39 F_{\text{g,Earth}} = (0.39)(491.9\text{ N}) = 192.6\text{ N}$$

c) $m_2 = m_{\text{Saturn}} = 95.2\, m_{\text{Earth}} \times \left(\frac{6\times10^{24}\text{ kg}}{1\, m_{\text{Earth}}}\right) = 5.712\times10^{26}\text{ kg}$

$R = R_{\text{Saturn}} = 9.5\, R_{\text{Earth}} \times \left(\frac{6.378\times10^{6}\text{ m}}{1\, R_{\text{Earth}}}\right) = 6.059\times10^{7}\text{ m}$

$$F_{\text{g}} = \frac{6.67\times10^{-11}\frac{\text{Nm}^2}{\text{kg}^2}(50\text{ kg})(5.712\times10^{26}\text{ kg})}{(6.059\times10^{7}\text{ m})^2} = 518.9\text{ N}$$

Or using ratios:

$$\frac{F_{\text{g,Saturn}}}{F_{\text{g,Earth}}} = \left(\frac{m_{\text{Saturn}}}{m_{\text{Earth}}}\right)\left(\frac{R_{\text{Earth}}}{R_{\text{Saturn}}}\right)^2 = (95.2)\left(\frac{1}{9.5}\right)^2 = 1.055$$
$$F_{\text{g,Saturn}} = (1.055)F_{\text{g,Earth}} = (1.055)(491.9\text{ N}) = 518.9\text{ N}$$

d) $491.9\text{ N} \times \left(\frac{1\text{ lb}}{4.45\text{ N}}\right) = 110.5\text{ lbs}$
$192.6\text{ N} \times \left(\frac{1\text{ lb}}{4.45\text{ N}}\right) = 43.3\text{ lbs}$
$518.9\text{ N} \times \left(\frac{1\text{ lb}}{4.45\text{ N}}\right) = 116.6\text{ lbs}$

3. From Eq.2.3, $a = \frac{F}{m}$, so $F = m\,a$

$m = 1,200$ kg and $a = 0.25\text{ m/s}^2$

$$F = m\,a = (1200\text{ kg})(0.25\text{ m/s}^2) = 300\,\frac{\text{kg m}}{\text{s}^2} = 300\text{ N}$$

4. From Eq.2.3, $a = \frac{F}{m}$, so $F = m\,a$

$m = 100$ kg and $a = g = 9.8\text{ m/s}^2$

$$F = m\,a = (100\text{ kg})(9.8\text{ m/s}^2) = 980\,\frac{\text{kg m}}{\text{s}^2} = 980\text{ N}$$

By Newton's 3rd Law, force of floor on piano is the same as piano's force on floor.

5. From Eq.2.4, $a = \frac{F_g}{m_1} = G\frac{m_2}{R^2}$

   $G = 6.67 \times 10^{-11}$ Nm^2/kg^2; $m_2 = 6.4 \times 10^23$ kg; $R = 3,390$ km $=$ 3.39×10^6 m

   $$a = G\frac{m_2}{R^2} = (6.67 \times 10^{-11}\frac{\text{Nm}^2}{\text{kg}^2})\frac{(6.4 \times 10^{23}\ \text{kg})}{(3.39 \times 10^6\ \text{m})^2} = 3.71\frac{\text{N}}{\text{kg}} = 3.71\frac{(\text{kg m/s}^2)}{\text{kg}}$$
   $$= 3.71\frac{\text{m}}{\text{s}^2}$$

6. From Eq.2.7, $a = \frac{\text{dist}_{\text{peri}} + \text{dist}_{\text{ap}}}{2}$

   $\text{dist}_{\text{ap}} = 1.67$ AU and $\text{dist}_{\text{peri}} = 1.38$ AU

   $$a = \frac{1.38\ \text{AU} + 1.67\ \text{AU}}{2} = 1.53\ \text{AU}$$

7. From Eq.2.11, $e = \frac{\text{dist}_{\text{ap}} - \text{dist}_{\text{peri}}}{\text{dist}_{\text{ap}} + \text{dist}_{\text{peri}}}$

   $\text{dist}_{\text{ap}} = 1.67$ AU and $\text{dist}_{\text{peri}} = 1.38$ AU

   $$e = \frac{1.67\ \text{AU} - 1.38\ \text{AU}}{1.67\ \text{AU} + 1.38\ \text{AU}} = \frac{0.29\ \text{AU}}{3.05\ \text{AU}} = 0.095$$

8. Fig. 2.6 shows that distance from Sun to center of orbit if “f,” and Table 2.1 gives $f = ae$.

   $a = 1.5 \times 10^8$ km and $e = 0.017$

   $$f = ae = (1.5 \times 10^8\ \text{km})(0.017) = 2.55 \times 10^6\ \text{km}$$

9. From Eq. 2.12, $P^2 = a^3$ (as long as "P" is in years, "a" is in AU, and the object being orbited is the Sun)

$P = 248$ years and $a^3 = P^2$

$$a = \sqrt[3]{P^2} = \sqrt[3]{(248)^2} = 39.5 \text{ AU}$$

10. From Eq. 2.15, $P^2 = a^3/M$ (as long as "P" is in years, "a" is in AU, and "M" is in solar masses)

$P = 3.55 \text{ days} = 3.55 \text{ days} \times \left(\frac{1 \text{ yr}}{365 \text{ days}}\right) = 9.726 \times 10^{-3}$ years

$a = 671,000 \text{ km} = 6.71 \times 10^5 \text{ km} \times \left(\frac{1 \text{ AU}}{150 \times 10^6 \text{ km}}\right) = 4.47 \times 10^{-3}$ AU

$$M = \frac{a^3}{P^2} = \frac{(4.47 \times 10^{-3})^3}{(9.726 \times 10^{-3})^2} = 9.4 \times 10^{-4} \text{ solar masses}$$

11. Eq. 2.13 says $[P(\text{yrs})]^2 = [a(\text{AU})]^3$

$a = 3.2$ AU, so $P = \sqrt{a^3} = \sqrt{(3.2)^3} = 5.72$ years

Eq. 2.16 says $[P(\text{yrs})]^2 = [a(\text{AU})]^3/M(\text{solar masses})$

$M = 1$ solar mass, so $P = \sqrt{a^3/M} = \sqrt{(3.2)^3/1} = 5.72$ years

Eq. 2.17 says $P^2 = \frac{4\pi^2 a^3}{G\,M}$ (SI units)

$a = 3.2 \text{ AU} = 4.787 \times 10^{11}$ m
$M = 1 \text{ solar mass} = 2 \times 10^{30}$ kg
$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 = 6.67 \times 10^{-11} \text{ m}^3/\text{kg s}^2$

$$P = \sqrt{\frac{4\pi^2 a^3}{G\,M}} = \sqrt{\frac{4\pi^2 (4.787 \times 10^{11} \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{kg s}^2)(2 \times 10^{30} \text{ kg})}} = 1.80 \times 10^8 \text{ sec} = 5.72 \text{ yrs}$$