Section 6.1: Newtonian Gravitation

Tutorial 1 Practice, page 293

1. Given: $m_1 = 1.0 \times 10^{20}$ kg; $m_2 = 3.0 \times 10^{20}$ kg; $F_g = 2.2 \times 10^9$ N; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: r

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$;

$$r^2 = \frac{Gm_1m_2}{F_g}$$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}}$$

Solution: $r = \sqrt{\dfrac{Gm_1m_2}{F_g}}$

$$= \sqrt{\frac{\left(6.67\times10^{-11}\ \frac{\cancel{\text{N}}\cdot\text{m}^2}{\cancel{\text{kg}^2}}\right)\left(1.0\times10^{20}\ \cancel{\text{kg}}\right)\left(3.0\times10^{20}\ \cancel{\text{kg}}\right)}{\left(2.2\times10^9\ \cancel{\text{N}}\right)}}$$

$$r = 3.0\times10^{10}\ \text{m}$$

Statement: The distance between the two asteroids is 3.0×10^{10} m.

2. Given: $m = 1.9 \times 10^{27}$ kg; $r = 7.0 \times 10^7$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: g_{Jupiter}

Analysis: Start with the universal law of gravitation, $F_g = \dfrac{Gm_1m_2}{r^2}$, then use $F = ma$ to substitute for F_g with the mass of an object on the surface, m_2, and the acceleration of the object, which will be the magnitude of the gravitational field strength on the surface of Jupiter, g_{Jupiter}.

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$\cancel{m_2}a = \frac{Gm_1\cancel{m_2}}{r^2}$$

$$g_{\text{Jupiter}} = \frac{Gm_1}{r^2}$$

Solution: $g_{\text{Jupiter}} = \dfrac{Gm_1}{r^2}$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)\left(1.9\times10^{27}\ \cancel{\text{kg}}\right)}{\left(7.0\times10^7\ \cancel{\text{m}}\right)^2}$$

$$g_{\text{Jupiter}} = 26\ \text{m/s}^2$$

Statement: The magnitude of the gravitational field strength on the surface of Jupiter is 26 m/s².

3. (a) Given: m_A = 40.0 kg; m_B = 60.0 kg; m_C = 80.0 kg; r_{AB} = 0.50 m; r_{BC} = 0.75 m; $G = 6.67 \times 10^{-11}$ N·m²/kg²

Required: $\vec{F}_{net}$

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$

Solution: Determine $\vec{F}_{AB}$.

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$F_{AB} = \frac{Gm_Am_B}{r_{AB}^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(40.0\ \cancel{\text{kg}})(60.0\ \cancel{\text{kg}})}{(0.50\ \cancel{\text{m}})^2}$$

$F_{AB} = 6.403\times10^{-7}$ N (two extra digits carried)

Determine $\vec{F}_{BC}$.

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$F_{BC} = \frac{Gm_Bm_C}{r_{BC}^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(60.0\ \cancel{\text{kg}})(80.0\ \cancel{\text{kg}})}{(0.75\ \cancel{\text{m}})^2}$$

$F_{BC} = 5.692\times10^{-7}$ N (two extra digits carried)

$$\vec{F}_{net} = \vec{F}_{AB} + \vec{F}_{BC}$$
$$= 6.403\times10^{-7}\ \text{N [left]} + 5.692\times10^{-7}\ \text{N [right]}$$
$$= 6.403\times10^{-7}\ \text{N [left]} - 5.692\times10^{-7}\ \text{N [left]}$$
$$\vec{F}_{net} = 7.1\times10^{-8}\ \text{N [left]}$$

Statement: The net force acting on B is 7.1×10^{-8} N [left].

(b) Given: m_A = 40.0 kg; m_B = 60.0 kg; m_C = 80.0 kg; r_{AB} = 0.50 m; r_{BC} = 0.75 m; $G = 6.67 \times 10^{-11}$ N·m²/kg²

Required: $\vec{F}_{net}$

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$; determine the angle using the inverse tan function.

Solution: Determine $\vec{F}_{\text{AB}}$.

$$F_{\text{g}} = \frac{Gm_1m_2}{r^2}$$

$$F_{\text{AB}} = \frac{Gm_{\text{A}}m_{\text{B}}}{r_{\text{AB}}^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(40.0\ \cancel{\text{kg}})(60.0\ \cancel{\text{kg}})}{(0.50\ \cancel{\text{m}})^2}$$

$F_{\text{AB}} = 6.403\times10^{-7}$ N (two extra digits carried)

Determine $\vec{F}_{\text{BC}}$.

$$F_{\text{g}} = \frac{Gm_1m_2}{r^2}$$

$$F_{\text{BC}} = \frac{Gm_{\text{B}}m_{\text{C}}}{r_{\text{BC}}^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(60.0\ \cancel{\text{kg}})(80.0\ \cancel{\text{kg}})}{(0.75\ \cancel{\text{m}})^2}$$

$F_{\text{BC}} = 5.692\times10^{-7}$ N (two extra digits carried)

$$\vec{F}_{\text{net}} = \vec{F}_{\text{AB}} + \vec{F}_{\text{BC}}$$

$$F_{\text{net}} = \sqrt{F_{\text{AB}}^2 + F_{\text{BC}}^2}$$

$$= \sqrt{(6.403\times10^{-7}\ \text{N})^2 + (5.692\times10^{-7}\ \text{N})^2}$$

$$F_{\text{net}} = 8.6\times10^{-8}\ \text{N}$$

$$\theta = \tan^{-1}\left(\frac{F_{\text{BC}}}{F_{\text{AB}}}\right)$$

$$= \tan^{-1}\left(\frac{5.692\times10^{-7}\ \text{N}}{6.403\times10^{-7}\ \text{N}}\right)$$

$$\theta = 42°$$

Statement: The net force acting on B is 8.6×10^{-8} N [W 42° S].

Tutorial 2 Practice, page 295

1. Given: $r = 7.0\times10^6$ m; $m_{\text{white dwarf}} = 1.2\times10^{30}$ kg; $G = 6.67\times10^{-11}$ N·m²/kg²

Required: $g_{\text{white dwarf}}$

Analysis: $g_{\text{white dwarf}} = \dfrac{Gm_{\text{white dwarf}}}{r^2}$

Solution: $g_{\text{white dwarf}} = \dfrac{Gm_{\text{white dwarf}}}{r^2}$

$$= \frac{\left(6.67\times10^{-11}\ \dfrac{\text{N}\cdot\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)\left(1.2\times10^{30}\ \cancel{\text{kg}}\right)}{\left(7.0\times10^{6}\ \cancel{\text{m}}\right)^2}$$

$$g_{\text{white dwarf}} = 1.6\times10^{6}\ \text{N/kg}$$

Statement: The surface gravitational field strength of the white dwarf is 1.6×10^6 N/kg, which is over 100 000 times that of Earth.

2. Given: $r_2 = 2r_{\text{Saturn}}$

Required: g_2

Analysis: $g_2 = \dfrac{Gm}{r_2^2}$

Solution: $g_2 = \dfrac{Gm}{r_2^2}$

$$= \frac{Gm}{\left(2r_{\text{Saturn}}\right)^2}$$

$$= \frac{1}{4}\left(\frac{Gm}{r_{\text{Saturn}}^2}\right)$$

$$g_2 = \frac{1}{4}g_{\text{Saturn}}$$

Statement: The surface gravitational field strength would be one quarter of the old surface gravitational field strength.

Research This: Gravitational Field Maps and Unmanned Underwater Vehicles, page 295

A. Sample answers: A gravitational field map describes the strength of the gravitational field at points across Earth. The map is created by using satellites to detect fine density differences in the crust, which cause increases or decreases in the gravitational force. This information can be used by a UUV to detect where it is on the planet based on the gravitational force.

B. Diagrams may vary depending on the type of UUV chosen. Students should highlight the key feature of the UUV they choose, such as the propulsion system (a propeller is most common), the power source (battery powered), the navigation system, and the sensors, which will vary with purpose of the UUV, but may include depths sensors, sonar, or sensors to measure concentration of compounds in the water.

C. Answers may vary. Students reports should explain the how UUVs use gravitational field maps to compare with measurements collected by the UUV on about the direction, angle, and strength of Earth's magnetic field at its position. Students may also discuss the usefulness of navigation by magnetic fields because UUVs travel to far for remote control and do not have access to satellites for GPS navigation.

Section 6.1 Questions, page 296

1. For your weight to be one half your weight on the surface, the magnitude of the gravitational acceleration must be one half of *g*.

$$g = \frac{Gm}{r_{\mathrm{E}}^2}$$

$$\frac{1}{2}g = \frac{Gm}{2r_{\mathrm{E}}^2}$$

$$\frac{1}{2}g = \frac{Gm}{\left(\sqrt{2}r_{\mathrm{E}}\right)^2}$$

The altitude from Earth's centre is $\sqrt{2}r_{\mathrm{E}}$, or about $1.41r_{\mathrm{E}}$. Therefore, the altitude above Earth's surface is $1.41r_{\mathrm{E}} - 1r_{\mathrm{E}} = 0.41r_{\mathrm{E}}$.

2. Given: $r = 5.3 \times 10^{-11}$ m; $m_1 = 1.67 \times 10^{-27}$ kg; $m_2 = 9.11 \times 10^{-31}$ kg; $G = 6.67 \times 10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$

Required: F_{g}

Analysis: $F_{\mathrm{g}} = \dfrac{Gm_1m_2}{r^2}$

Solution: $F_{\mathrm{g}} = \dfrac{Gm_1m_2}{r^2}$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\mathrm{N}\cdot \cancel{\mathrm{m}^2}}{\cancel{\mathrm{kg}^2}}\right)\left(1.67\times10^{-27}\ \cancel{\mathrm{kg}}\right)\left(9.11\times10^{-31}\ \cancel{\mathrm{kg}}\right)}{\left(5.3\times10^{-11}\ \cancel{\mathrm{m}}\right)^2}$$

$$F_{\mathrm{g}} = 3.6\times10^{-47}\ \mathrm{N}$$

Statement: The magnitude of the gravitational attraction between the proton and the electron is 3.6×10^{-47} N.

3. (a) The value for *r* is squared in the denominator, so as *r* increases, the gravitational force decreases.

(b)

$$F_{\mathrm{g}} = \frac{Gm_1m_2}{r^2}$$

$$= \frac{Gm_1m_2}{\left(4r_1\right)^2}$$

$$= \frac{Gm_1m_2}{16r_1^2}$$

$$F_{\mathrm{g}} = \frac{1}{16}\left(\frac{Gm_1m_2}{r_1^2}\right)$$

The gravitational force changes by a factor of $\dfrac{1}{16}$.

4. (a) Given: $m_1 = 225$ kg; $d = 8.62 \times 10^6$ m; $m_2 = 5.98 \times 10^{24}$ kg; $r_E = 6.38 \times 10^6$ m; $G = 6.67 \times 10^{-11}$ N·m^2/kg^2

Required: F_g

Analysis:

$$F_g = \frac{Gm_1 m_2}{r^2}$$

$$F_g = \frac{Gm_1 m_E}{(d + r_E)^2}$$

Solution: $F_g = \dfrac{Gm_1 m_E}{(d + r_E)^2}$

$$= \frac{\left(6.67 \times 10^{-11} \ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(225 \ \cancel{\text{kg}})(5.98 \times 10^{24} \ \cancel{\text{kg}})}{(8.62 \times 10^6 \ \cancel{\text{m}} + 6.38 \times 10^6 \ \cancel{\text{m}})^2}$$

$$F_g = 399 \text{ N}$$

Statement: The gravitational force is 399 N toward Earth's centre.

(b) Given: $m_1 = 225$ kg; $d = 8.62 \times 10^6$ m; $m_E = 5.98 \times 10^{24}$ kg; $r_E = 6.38 \times 10^6$ m; $G = 6.67 \times 10^{-11}$ N·m^2/kg^2

Required: g

Analysis: $g = \dfrac{Gm}{r^2}$

Solution: $g = \dfrac{Gm}{r^2}$

$$= \frac{Gm_E}{(d + r_E)^2}$$

$$= \frac{\left(6.67 \times 10^{-11} \ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)(5.98 \times 10^{24} \ \cancel{\text{kg}})}{(8.62 \times 10^6 \ \cancel{\text{m}} + 6.38 \times 10^6 \ \cancel{\text{m}})^2}$$

$$g = 1.77 \text{ m/s}^2$$

Statement: The resulting acceleration is 1.77 m/s^2 toward Earth's centre.

5. Given: $g_{\text{Titan}} = 1.3$ N/kg; $m = 1.3 \times 10^{23}$ kg; $G = 6.67 \times 10^{-11}$ N·m^2/kg^2

Required: r

Analysis: $g = \dfrac{Gm}{r^2}$

Solution: $g_{\text{Titan}} = \dfrac{Gm}{r^2}$

$$r = \sqrt{\frac{Gm}{g_{\text{Titan}}}}$$

$$= \sqrt{\frac{\left(6.67\times10^{-11}\ \dfrac{\cancel{\text{N}}\cdot\text{m}^2}{\cancel{\text{kg}^2}}\right)\left(1.3\times10^{23}\ \cancel{\text{kg}}\right)}{\left(1.3\ \cancel{\text{N}}/\cancel{\text{kg}}\right)}}$$

$$r = 2.6\times10^6\ \text{m}$$

Statement: The radius of Titan is 2.6×10^6 m.

6. Given: g_E = 9.8 N/kg; g_2 = 3.20 N/kg

Required: r

Analysis: Use the equation $g = \dfrac{Gm}{r^2}$ to determine the change in r given the change in the value of g.

Solution: $\dfrac{g_2}{g_E} = \dfrac{3.20\ \cancel{\text{N/kg}}}{9.8\ \cancel{\text{N/kg}}}$

$$\frac{g_2}{g_E} = \frac{16}{49}$$

$$g_2 = \frac{16}{49}g_E$$

$$= \frac{16}{49}\left(\frac{Gm}{r_E^2}\right)$$

$$= \frac{Gm}{\frac{49}{16}r_E^2}$$

$$g_2 = \frac{Gm}{\left(\frac{7}{4}r_E\right)^2}$$

Statement: The acceleration due to gravity is 3.20 N/kg at $\dfrac{7}{4}r_E$ from Earth's centre, or $0.75r_E$ above Earth's surface,

7. Given: $m_{\text{Sun}} = 2.0 \times 10^{30}$ kg; $r = 1.5 \times 10^{11}$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²

Required: g

Analysis: $g = \dfrac{Gm}{r^2}$

Solution: $g = \dfrac{Gm}{r^2}$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)\left(2.0\times10^{30}\ \cancel{\text{kg}}\right)}{\left(1.5\times10^{11}\ \cancel{\text{m}}\right)^2}$$

$$g = 5.9\times10^{-3}\ \text{N/kg}$$

Statement: The gravitational field strength of the Sun at a distance of 1.5×10^{11} m from its centre is 5.9×10^{-3} N/kg.

8. Let m_1 be the larger mass, and let x be the distance from m_1 to the location of zero net force. Set the two gravitational field strengths equal to each other, and develop a quadratic equation. Solve for x.

$$\frac{Gm_1}{x^2} = \frac{Gm_2}{(r-x)^2}$$

$$\cancel{G}(r-x)^2 = \frac{\cancel{G}m_2}{m_1}x^2$$

$$(r-x)^2 = \frac{m_2}{m_1}x^2$$

$$r^2 - 2rx + x^2 = \frac{m_2}{m_1}x^2$$

$$\left(1-\frac{m_2}{m_1}\right)x^2 - 2rx + r^2 = 0$$

Use the quadratic formula:

$$x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

$$= \frac{-(-2r)\pm\sqrt{(-2r)^2 - 4\left(1-\frac{m_2}{m_1}\right)(r^2)}}{2\left(1-\frac{m_2}{m_1}\right)}$$

$$= \frac{2r\pm\sqrt{4r^2-4r^2+4\frac{m_2}{m_1}r^2}}{2\left(1-\frac{m_2}{m_1}\right)}$$

$$= \frac{2r \pm \sqrt{4\frac{m_2}{m_1}r^2}}{2\left(1-\frac{m_2}{m_1}\right)}$$

$$= \frac{2r \pm 2r\sqrt{\frac{m_2}{m_1}}}{2\left(1-\frac{m_2}{m_1}\right)}$$

$$x = r\frac{1 \pm \sqrt{\frac{m_2}{m_1}}}{\left(1-\frac{m_2}{m_1}\right)}$$

Since the greater value will not be between the two masses but will be the other side of m_2 from m_1:

$$x = r\frac{1 - \sqrt{\frac{m_2}{m_1}}}{\left(1-\frac{m_2}{m_1}\right)}$$

$$x = \left(r\frac{1 - \sqrt{\frac{m_2}{m_1}}}{\left(1-\frac{m_2}{m_1}\right)}\right)\left(\frac{1 + \sqrt{\frac{m_2}{m_1}}}{1 + \sqrt{\frac{m_2}{m_1}}}\right)$$

$$x = r\frac{1-\frac{m_2}{m_1}}{\left(1-\frac{m_2}{m_1}\right)\left(1+\sqrt{\frac{m_2}{m_1}}\right)}$$

$$x = \frac{r}{1+\sqrt{\frac{m_2}{m_1}}}$$

The location of zero force is $\dfrac{r}{1+\sqrt{\frac{m_2}{m_1}}}$ from the larger object, m_1.

9. (a) Given: m_1 = 537 kg; $m_E = 5.98 \times 10^{24}$ kg; $r = 2.5 \times 10^7$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: g

Analysis: $g = \dfrac{Gm}{r^2}$

Solution: $g = \dfrac{Gm}{r^2}$

$$= \frac{Gm_E}{r^2}$$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)\left(5.98 \times 10^{24}\ \cancel{\text{kg}}\right)}{\left(2.5 \times 10^7\ \cancel{\text{m}}\right)^2}$$

$$g = 0.64\ \text{m/s}^2$$

Statement: The resulting acceleration is 0.64 m/s² toward Earth's centre.

(b) Given: m_1 = 537 kg; $m_E = 5.98 \times 10^{24}$ kg; $r = 2.5 \times 10^7$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: F_g

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$

Solution: $F_g = \dfrac{Gm_1m_2}{r^2}$

$$= \frac{Gm_1m_E}{r^2}$$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)\left(537\ \cancel{\text{kg}}\right)\left(5.98 \times 10^{24}\ \cancel{\text{kg}}\right)}{\left(2.5 \times 10^7\ \cancel{\text{m}}\right)^2}$$

$$F_g = 340\ \text{N}$$

Statement: The gravitational force is 340 N toward Earth's centre.

10. Given: $r = 2.44 \times 10^6$ m; $m_{\text{Mercury}} = 3.28 \times 10^{23}$ kg; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: g_{Mercury}

Analysis: $g_{\text{Mercury}} = \dfrac{Gm_{\text{Mercury}}}{r^2}$

Solution: $g_{\text{Mercury}} = \dfrac{Gm_{\text{Mercury}}}{r^2}$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)\left(3.28 \times 10^{23}\ \cancel{\text{kg}}\right)}{\left(2.44 \times 10^6\ \cancel{\text{m}}\right)^2}$$

$$g_{\text{Mercury}} = 3.67\ \text{N/kg}$$

Statement: The surface gravitational field strength on Mercury is 3.67 N/kg. The value provided in Table 2 is 3.7 N/kg, which is the same the value that I calculated to two significant digits.
11. (a) Given: $g = 5.3$ N/kg; $m_E = 5.98 \times 10^{24}$ kg; $r_E = 6.38 \times 10^6$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: r

Analysis: $g = \dfrac{Gm}{r^2}$

Solution: $g = \dfrac{Gm}{r^2}$

$$r = \sqrt{\frac{Gm}{g}}$$

$$= \sqrt{\frac{\left(6.67 \times 10^{-11}\ \frac{\cancel{\text{N}} \cdot \text{m}^2}{\cancel{\text{kg}^2}}\right)\left(5.98 \times 10^{24}\ \cancel{\text{kg}}\right)}{\left(5.3\ \cancel{\text{N}}/\cancel{\text{kg}}\right)}}$$

$r = 8.675 \times 10^6$ m (two extra digits carried)

Calculate the altitude above Earth's surface:
$8.675 \times 10^6\text{ m} - 6.38 \times 10^6\text{ m} = 2.3 \times 10^6\text{ m}$
Statement: The altitude of the satellite is 2.3×10^6 m.
(b) Given: $m_1 = 620$ kg; $m_E = 5.98 \times 10^{24}$ kg; $r_{satellite} = 8.675 \times 10^6$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: F_g

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$

Solution: $F_g = \dfrac{Gm_1m_2}{r^2}$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)\left(620\ \cancel{\text{kg}}\right)\left(5.98 \times 10^{24}\ \cancel{\text{kg}}\right)}{\left(8.675 \times 10^6\ \cancel{\text{m}}\right)^2}$$

$F_g = 3.3 \times 10^3$ N

Statement: The gravitational force on the satellite is 3.3×10^3 N toward Earth's centre.
12. The motion of the Moon depends on Earth's mass and G through the universal law of gravitation. Using data on the mass and orbital radius of the Moon and G, we can determine Earth's mass using the universal law of gravitation, $F_g = \dfrac{Gm_1m_2}{r^2}$, and the equation for centripetal acceleration, $F_c = \dfrac{mv^2}{r}$, since the two forces are equal.

$$F_g = F_c$$
$$\frac{Gm_1m_2}{r^2} = \frac{mv^2}{r}$$
$$\frac{Gm_{\text{Earth}}\cancel{m_{\text{Moon}}}}{r^{\cancel{2}}} = \frac{\cancel{m_{\text{Moon}}}v^2}{\cancel{r}}$$
$$\frac{Gm_{\text{Earth}}}{r} = v^2$$
$$m_{\text{Earth}} = \frac{rv^2}{G}$$

13. From question 8, the location of zero force is $\dfrac{r}{1+\sqrt{\dfrac{m_2}{m_1}}}$ from the larger object, m_1. r is the centre to centre distance between the Moon and Earth.
Since $m_E = 5.98 \times 10^{24}$ kg and $m_{\text{Moon}} = 7.36 \times 10^{22}$ kg:

$$\begin{aligned}
r_0 &= \frac{r}{1+\sqrt{\dfrac{m_2}{m_1}}} \\
&= \frac{r}{1+\sqrt{\dfrac{7.36\times10^{22}}{5.98\times10^{24}}}} \\
&= \frac{r}{1.111} \\
r_0 &= 0.9r
\end{aligned}$$

The mass should be $0.9r$ from the centre of the Earth, or $\dfrac{r}{10}$ from the centre of the Moon.