

# Chapter 13

$$F_g = G \frac{M_E m}{R_E^2}$$

$$g = G \frac{M_E}{R_E^2}$$

$$g = \frac{GM_E}{r^2} = \frac{GM_E}{(R_E + h)^2}$$

3. A 200-kg object and a 500-kg object are separated by 0.400 m. (a) Find the net gravitational force exerted by these objects on a 50.0-kg object placed midway between them. (b) At what position (other than an infinitely remote one) can the 50.0-kg object be placed so as to experience a net force of zero?

- (a) At the midpoint between the two objects, the forces exerted by the 200-kg and 500-kg objects are oppositely directed,

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

we have 
$$\sum F = \frac{G(50.0 \text{ kg})(500 \text{ kg} - 200 \text{ kg})}{(0.200 \text{ m})^2} = \boxed{2.50 \times 10^{-5} \text{ N}}$$
 toward the 500-kg object.

- (b) At a point between the two objects at a distance  $d$  from the 500-kg objects, the net force on the 50.0-kg object will be zero when

$$\frac{G(50.0 \text{ kg})(200 \text{ kg})}{(0.400 \text{ m} - d)^2} = \frac{G(50.0 \text{ kg})(500 \text{ kg})}{d^2}$$

or 
$$d = \boxed{0.245 \text{ m}}$$

4. Two objects attract each other with a gravitational force of magnitude  $1.00 \times 10^{-8}$  N when separated by 20.0 cm. If the total mass of the two objects is 5.00 kg, what is the mass of each?

$$m_1 + m_2 = 5.00 \text{ kg} \quad m_2 = 5.00 \text{ kg} - m_1$$

$$F = G \frac{m_1 m_2}{r^2} \Rightarrow 1.00 \times 10^{-8} \text{ N} = (6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2) \frac{m_1 (5.00 \text{ kg} - m_1)}{(0.200 \text{ m})^2}$$


$$(5.00 \text{ kg})m_1 - m_1^2 = \frac{(1.00 \times 10^{-8} \text{ N})(0.0400 \text{ m}^2)}{6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2} = 6.00 \text{ kg}^2$$

$$\text{Thus, } m_1^2 - (5.00 \text{ kg})m_1 + 6.00 \text{ kg} = 0$$

$$\text{or } (m_1 - 3.00 \text{ kg})(m_1 - 2.00 \text{ kg}) = 0$$

giving  $\boxed{m_1 = 3.00 \text{ kg, so } m_2 = 2.00 \text{ kg}}$ .

The answer  $m_1 = 2.00 \text{ kg}$  and  $m_2 = 3.00 \text{ kg}$  is physically equivalent.

9.  When a falling meteoroid is at a distance above the Earth's surface of 3.00 times the Earth's radius, what is its acceleration due to the Earth's gravitation?

$$a = \frac{MG}{(4R_E)^2} = \frac{9.80 \text{ m/s}^2}{16.0} = \boxed{0.613 \text{ m/s}^2} \text{ toward the Earth.}$$

- 10.** The free-fall acceleration on the surface of the Moon is about one sixth of that on the surface of the Earth. If the radius of the Moon is about  $0.250R_E$ , find the ratio of their average densities,  $\rho_{\text{Moon}}/\rho_{\text{Earth}}$ .

$$g = \frac{GM}{R^2} = \frac{G\rho\left(\frac{4\pi R^3}{3}\right)}{R^2} = \frac{4}{3}\pi G\rho R$$

$$\text{If } \frac{g_M}{g_E} = \frac{1}{6} = \frac{\frac{4\pi G\rho_M R_M}{3}}{\frac{4\pi G\rho_E R_E}{3}}$$

$$\text{then } \frac{\rho_M}{\rho_E} = \left(\frac{g_M}{g_E}\right)\left(\frac{R_E}{R_M}\right) = \left(\frac{1}{6}\right)(4) = \boxed{\frac{2}{3}}.$$