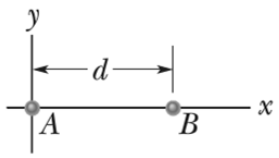
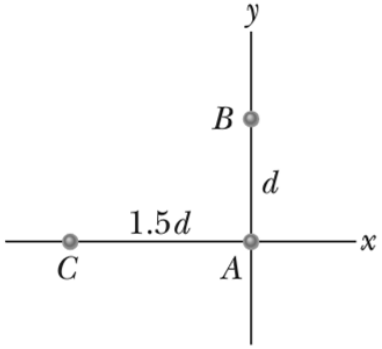
- For material covering Ch. 13 (skipping Sects. 13-6 thru 13-8)
- Due Friday, Nov. 21 at 5 pm

1. *Miniature black holes.* Left over from the big-bang beginning of the universe, tiny black holes might still wander through the universe. If one with a mass of 2×10^{11} kg (and a radius of only 2×10^{-16} m) reached Earth, at what distance from your head would its gravitational pull on you match that of Earth's? Assume free-fall acceleration $a_g = 9.83$ m/s^2. [Answer: 1.16 m].

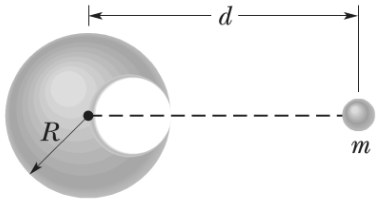
2. *One dimension.* Two point particles are fixed on an x axis separated by distance d. Particle A has mass m_A and particle B has mass 5.00 m_A. A third particle C, of mass 94.0 m_A, is to be placed on the x axis and near particles A and B. In terms of distance d, at what x coordinate should C be placed so that the net gravitational force on particle A from particles B and C is zero? [Answer: -4.34 d].



3. *Two dimensions.* Three point particles are fixed in place in an xy plane. Particle A has mass $m_A = 5$ g, particle B has mass 2.00 m_A, and particle C has mass 3.00 m_A. A fourth particle D, with mass 4.00 m_A, is to be placed near the other three particles. What **(a)** x coordinate and **(b)** y coordinate should particle D be placed so that the net gravitational force on particle A from particles B, C, and D is zero (d = 18 cm)? [Answer: **(a)** 0.129 m; **(b)** -0.193 m].

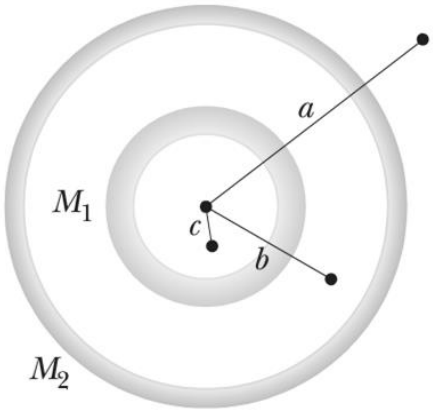


4. A spherical hollow inside a lead sphere of radius R = 4.4 m; the surface of the hollow passes through the center of the sphere and "touches" the right side of the sphere. The mass of the sphere before hollowing was M = 392 kg. With what gravitational force does the hollowed-out lead sphere attract a small sphere of mass m = 31 kg that lies at a distance d = 15 m from the center of the lead sphere, on the straight line connecting the centers of the spheres and of the hollow? [Answer: 3.0 nN].



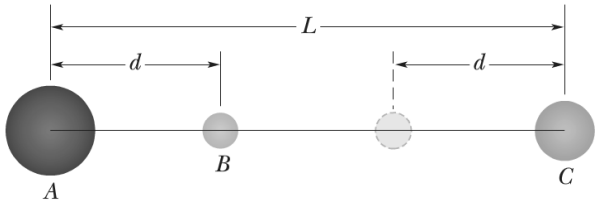
5. At what altitude above Earth's surface would the gravitational acceleration be 1.10 m/s^2? (Take the Earth's radius as 6370 km.) [Answer: 12700 km].

6. Two concentric spherical shells have uniformly distributed masses M_1 and M_2. Find the magnitude of the net gravitational force on a particle of mass m, due to the shells, when the particle is located at each of the radial distances shown: **(a)** a, outside both shells, **(b)** b, between the two shells and **(c)** c, inside both shells. State your answers in terms of the given variables, using G when applicable. [Answer: **(a)** $Gm(M_1 + M_2)/a^2$; **(b)** GmM_1/b^2; **(c)** 0].



7. Assume a planet is a uniform sphere of radius R that (somehow) has a narrow radial tunnel through its center. Also assume we can position an apple anywhere along the tunnel or outside the sphere. Let F_R be the magnitude of the gravitational force on the apple when it is located at the planet's surface. How far from the surface is there a point where the magnitude of the gravitational force on the apple is $F_R/2$ if we move the apple **(a)** away from the planet and **(b)** into the tunnel? Express you answer in terms of the variables given. [Answer: **(a)** $R(\sqrt{2}-1)$; **(b)** $R/2$].

8. The three spheres, with masses m_A = 84 g, m_B = 13 g, and m_C = 19 g, have their centers on a common line, with L = 24 cm and d = 6 cm. You move sphere B along the line until its center-to-center separation from C is d = 6 cm. How much work is done on sphere B **(a)** by you and **(b)** by the net gravitational force on B due to spheres A and C? [Answer: **(a)** 0.63 pJ; **(b)** -0.63 pJ].



9. (a) What is the escape speed on a spherical asteroid whose radius is 823 km and whose gravitational acceleration at the surface is 1.38 m/s^2? **(b)** How far from the surface will a particle go if it leaves the asteroid's surface with a radial speed of 1200 m/s? **(c)** With what speed will an object hit the asteroid if it is dropped from 1387 km above the surface? [Answer: **(a)** 1.51 km/s; **(b)** 1430 km; **(c)** 1.19 km/s].

10. A projectile is shot directly away from Earth's surface. Neglect the rotation of the Earth. What multiple of Earth's radius R_E gives the radial distance (from the Earth's center) the projectile reaches if **(a)** its initial speed is 0.779 of the escape speed from Earth and **(b)** its initial kinetic energy is 0.779 of the kinetic energy required to escape Earth? (Give your answers as unitless numbers.) **(c)** What is the least initial mechanical energy required at launch if the projectile is to escape Earth? [Answer: (a) 2.54; (b) 4.52; (c) 0 J].