Answers to selected problems from Essential Physics, Chapter 8

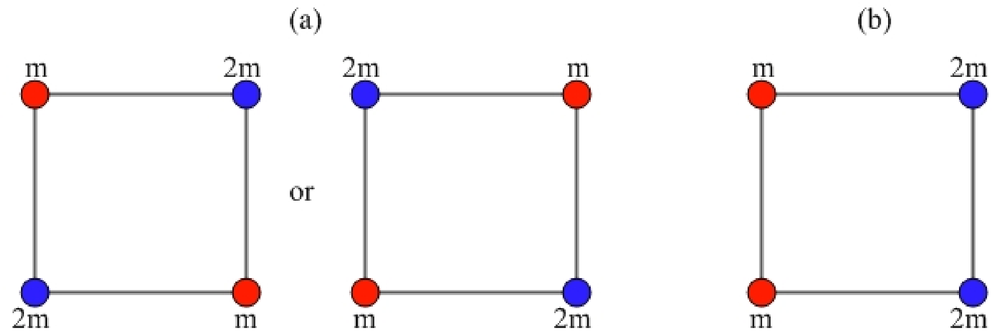
1. The unknown mass is larger than M. Both large objects are attracting the small object, but the net force is pointing more toward the ball with the unknown mass, so the unknown mass is exerting a large force on the small object than is the ball of mass M. The distances involved are the same, so the larger force requires a larger mass.

3. (a) More than M (b) $2M$

5. This is not possible. The two large masses would have to be repelling the smaller mass, but gravitational forces can only be attractive.

7. $\dfrac{Gm^2}{r^2}$, straight down

9.



11. (a) Kinetic energy is conserved – the speed is constant. (b) Gravitational potential energy is conserved – the distance between the centers-of-mass of the objects remains the same. (c) Total mechanical energy is conserved – this is based on the fact that kinetic energy and potential energy are each conserved, and also because no non-conservative forces act. (d) Linear momentum of the smaller object is not conserved. The magnitude of the linear momentum stays the same, but its direction steadily changes because of the gravitational force exerted on it by the massive object.

13. (a) No, we can not arrange the balls so that all three simultaneously experience no force. With the balls placed in a line, the left-most ball will experience two forces directed right, and the right-most ball will experience two forces directed left. Thus, those two balls each have a net force acting on them. (b) If we place the third ball carefully, then the ball that is between the other two balls can experience no net force, with the forces it experiences from the other two balls cancelling out.

15. $F_{2m} > F_m > F_{3m}$

17. $F_{Venus} > F_{Earth} > F_{Mercury} > F_{Mars}$

19. (a) zero (b) $\dfrac{GM}{R^2}$, directed straight down

21. The two solutions are $\dfrac{m}{2}$ or 2.5m.

23. The two solutions are $x = -\dfrac{a}{2}$ or $x = +\dfrac{a}{2\sqrt{2}}$

25. (a) 2 > 1 > 3 (b) $-\dfrac{8Gm^2}{r}$

27. (a) $\dfrac{2Gm^2}{r^2}$, directly toward the ball of mass 4m

(b) $\dfrac{\sqrt{2}Gm^2}{r^2}$, in the positive x direction

(c) $\dfrac{(1.40)Gm^2}{r^2}$, at an angle of 30.4° above the positive x-axis

29. (a) $\dfrac{2\sqrt{2}Gm^2}{r}$ (b) $\dfrac{2\sqrt{2}Gm^2}{r}$ (c) $\dfrac{\left(1+\sqrt{2}\right)Gm^2}{r}$

31. (a) At only one location. (b) $x = 5a$

33. Most years have 365 days. However, it take the Earth about 365.25 days to travel once around the Sun, so every 4th year we add an extra day to the calendar so that we are, every 4th year, at the same point in the orbit on a particular time and day. The Earth's orbital period is actually slightly less than 365.25 days (currently 365.242374 days), so adding one day every 4th year is slightly more than we need to correct the problem. Thus, almost every 100 years, we don't add a 366th day to the calendar. Leap years are every year that is a multiple of 4, except for those that are multiples of 100 that are not multiples of 400. The years 1700, 1800, and 1900 were not leap years, for example, but the year 2000 was a regular leap year.

35. (a) 3×10^4 m/s (b) 0.006 m/s^2 (c) The acceleration of the Sun because of the force the Earth exerts on it is about 1.8×10^{-8} m/s^2

37. (a) $F_{3m} > F_{2m} > F_m$ (b) $\sqrt{52}\,Gm^2$ in units of m^{-2}

39. (a) The ball of mass m at the top of the picture experiences a larger gravitational force than does the ball of mass m at the center. The forces on the ball at the center mostly cancel – the net force acting on the ball at the center is the same as the force the

ball at the center applies to the ball at the top. However, the ball at the top experiences three additional forces, all of which have a downward component, so the ball at the top experiences a larger net force. (b) The ball of mass 2*m* on the negative *y*-axis experiences a net force of magnitude $5.33\frac{Gm^2}{r^2}$. The other two balls of mass 2*m* experience forces of magnitude $5.17\frac{Gm^2}{r^2}$.

41. (a) $v = \sqrt{\frac{2GM_{moon}}{R_{moon}}} = \sqrt{\frac{2\left(6.67\times10^{-11}\text{ Nm}^2/\text{kg}^2\right)\left(7.35\times10^{22}\text{ kg}\right)}{1.737\times10^{6}\text{ m}}} = 2380\text{ m/s}$

(b) There is some logic to this idea. For one thing, it would take a tremendous amount of fuel, and impressive engines, to launch a manned mission to Mars from the surface of the Earth, with the mass of the fuel adding significantly to the mass of the spacecraft. Ferrying everything to the Moon in a few trips, constructing the spacecraft there, and then blasting off from the Moon would take more total energy, but there are definite advantages in terms of the lower mass of the spacecraft and the smaller energy needed for any one trip. There are also obvious technological challenges associated with setting everything up on the Moon, however!

43. $v = \sqrt{\frac{2Gm}{L}}$

45. (a) They will not come back together. Because *G* is such a small number, the initial kinetic energy is a much larger number than the initial gravitational potential energy, which is negative, so the total mechanical energy is positive. That means that there is enough energy in the system for the objects to escape from one another.
(b) Only very slightly less than 0.10 m/s.

47. (a) $v = \frac{2\pi r}{T}$ (b) $\sum \vec{F} = ma \quad \Rightarrow \quad \frac{GmM}{r^2} = \frac{mv^2}{r}$

(c) First, in our equation in (b) we can cancel *m*, the mass of the orbiting object, as well as one factor of *r*, which gives us: $\frac{GM}{r} = v^2 = \frac{4\pi^2 r^2}{T^2}$.

Re-arranging this equation gives us the required result: $T^2 = \frac{4\pi^2 r^3}{GM}$

49. (a) 3.88×10^8 m
(b) 6.2×10^{24} kg (this is only slightly higher than the accepted value)

51. (a) 4.22×10^7 m

53. There are two possible solutions. The mass of the second ball is 3*m*, and its location is either at $x = -4a$ or at $x = +2a$.

55. The mass of the second ball is 4*m*, and its location is at $x = +2a$.

57. (a) $\left(4+6\sqrt{2}\right)\frac{Gm^2}{L^2}$, toward the center of the square.

(b) $17.7\frac{Gm^2}{L^2}$, at an angle of 31.2° above the negative *x*-direction, defining the negative *x*-direction as pointing to the left.

59. (a) 3.0×10^4 m/s (b) The speed is independent of the mass of the orbiting object, so the speed would not change at all.