1. a. No, it is not possible to go around a curve without acceleration – if there is no acceleration there is no change in velocity and the object will move in a straight line.
   b. Yes, a certain type of curve can be accomplished with constant acceleration – one example is the parabolic curve followed by a projectile, during which the acceleration is constantly 9.8 m/s^2 down.
   c. Circular motion with constant speed is not constant acceleration because the acceleration vector changes direction so that it always points to the center.
2. a. 22.0 m/s
   b. 9.65 m/s^2 toward center
   c. 5940 N
3. a. 66.6 ms
   b. 19.1 m/s, 270.0°
   c. 1800 m/s^2, 180.0°
   d. 36.0 N, 180.0°
   e. 1.15 km
4. a. 4.5 m/s
   b. 1.1 s
5. a. toward the center
   b. 1.1, 2.2, 3.3 m/s^2
   c. friction
   d. 0.34 – With this value of μ_s there is enough friction acting on the coin (of any mass) to cause an acceleration of 3.3 m/s^2. With less friction than this the inertia of the coin will cause it to slide off the record in a tangent direction.
6. $r = \frac{\mu_s g}{4\pi^2 f^2}$
7. a. 2.64×10^7 m/s^2
   b. 26.4 kN toward the center
   c. 126,000 rpm
8. a. 14 m/s
   b. 95 m/s^2
   c. The centripetal force is the normal force of the wall pushing inward on the person.
   d. 0.10
9. a. 3.27 N
   b. 951 N
   c. 948 N, 90°
10. a. $a = \frac{2\pi v}{T}$
    b. $a = \frac{4\pi^2 r}{T^2}$
11. a. 0.22 kN $\leq F_N \leq$ 3.0 kN
    b. 8.9 m/s
12. a. 15 m/s
    b. 110 m
    c. 8.6 kN
    d. 0.80

13. $t = p\sqrt{\frac{r}{mg}}$
14. A force that acts perpendicular to an object's velocity (continuously) will cause that object to move in a circular path with uniform speed. The force must be toward the center to cause acceleration toward the center. Without force the object would continue on its tangent path due to its inertia. The force cannot at all point in the direction of the velocity or opposite to the direction of the velocity without changing the speed, therefore it points perpendicular to the velocity.
15. As you round a curve in a car your body has a natural tendency to move in a tangent direction due to its inertia. This is what makes you feel like there is an outward pushing force when there is not. The inward pulling force comes from the seatbelt, your hands on the wheel, and friction with the seat.
16. 1300 *g*
17. All masses in the universe attract all other masses. BUT, the result of that attraction depends on many factors. The motion and inertia of objects can prevent collapse. There are also other forces such as friction, normal, etc. And very distant objects have little impact because of the inverse square nature of gravity.
18. Descending into a hole in the Earth the pull of gravity will decrease. This is due to the fact that when you are at or above the surface *all* of the Earth pulls you downward, but when you are below the surface there is then some part of the Earth (above you) that pulls you *upward* and now a lesser part of the Earth pulling you downward. At the center of the Earth you would be weightless because the Earth pulls you equally in all directions!
19. 0.584 nN
20. a. 64 nN toward the other ball
    b. 460 s *if* initial acceleration of each ball remained *constant*
    (Acceleration actually would increase, which would shorten the time required)
21. 3.90×10^{24} kg
22. 0.37 kg, 0.75 kg
23. Sun pulls 2.3 times the Earth
24. 346 Mm from Earth and 38.3 Mm from Moon
25. a. 0.280 m/s^2
    b. 24 N
26. a. ¼ *g*
    b. 35 *g*
    c. 500 billion *g*
    d. 2 *g*
27. a. 35.5 s
    b. Because the person's frame of reference is always accelerating toward the center the direction of the perceived *g* would change. Dropping an object it will be noted that it does not accelerate in a constant "downward" direction and will follow a curved path, unlike an object dropped on earth.

28. a. earth: 32 μm/s^2 toward moon
moon: 2.6 mm/s^2 toward earth
b. As Earth and Moon got closer to one another the rates of acceleration would increase because the pull of gravity is greater when the objects are closer together
c. The distance from Earth to Moon does not decrease because the two objects both move in circular paths and the acceleration represents the rate of turning – not an increase in speed or a literal movement toward the center of the circle.
29. a. 735 N
b. 651 N
c. The space station and the astronaut are both under the sole influence of gravity and each orbits the Earth at the same speed. In this situation the acceleration of the astronaut toward the Earth equals the acceleration of the station toward the Earth (both equal *g*). Therefore the velocity and acceleration of the astronaut *relative* to the station are both equal to <u>zero</u> and he can "float" indefinitely at any particular location inside the station.
30. A satellite does not fall because of its inertia. It has this natural tendency to keep moving forward, and unless there is force to prevent this it will do so indefinitely. Gravity pulls the satellite "to the side" and causes it to change direction but does not cause it to slow down.
31. a. 120 minutes
b. 1600 m/s
32. 1.99×10^{30} kg
33. a. $M = \dfrac{v^3 T}{2\rho G}$
b. A moon of any mass could have the same orbit because it would accelerate in freefall amount *g*. Because the mass of the moon does not affect the orbit of the moon, the orbital properties do not reveal its mass.
34. altitude = 35 780 km; speed = 3075 m/s
35. $v = \sqrt{\dfrac{GM}{r}}$
36. 15/16 or 94%
37. a. –5.7 m/s
b. 210 N
38. a. 1.28 s
b. 4.80 m/s^2
39. a. 81.7 N/m
b. 0.852 s
c. 1.09 m/s^2, 270.0°
40. a. 7.5 N/m
b. 1.5 N
c. $x = 0.30 \cos(3.5t)$
41. a. 0.635 s
b. 1.56 s
42. 99.3 cm
43. a. $k = mg/L$
b. 4.90 N/m
c. 0.735 m/s^2, 0.0°