19. You have two golf balls that differ only in their surfaces. One has dimples on it while the other is smooth. If you drop these two balls simultaneously from a tall tower, which one will hit the ground first?
   E.19 The dimpled ball will hit first.

20. If you ride your bicycle directly behind a large truck, you will find that you don’t have to pedal very hard to keep moving forward. Why?
   E.20 You will be pedaling inside the truck's turbulent wake and will find that the air there is moving along at roughly the truck's speed.

21. How does running directly behind another runner reduce the wind resistance you experience?
   E.21 The front runner drags the air forward so that you experience less drag while running through forward-moving air.

22. When a car is stopped, its flexible radio antenna points straight up. But when the car is moving rapidly down a highway, the antenna arcs toward the rear of the car. What force is bending the antenna?
   E.22 Pressure drag is pushing the antenna backward.

23. To drive along a level road at constant velocity, your car’s engine must be running and friction from the ground must be pushing your car forward. Since the net force on an object at constant velocity is zero, why do you need this forward force from the ground?
   E.23 It balances the backward force due to air drag.

24. Racing bicycles often have smooth disk-shaped covers over the spokes of their wheels. Why would these thin wire spokes be a problem for a fast-moving bicycle?
   E.24 The spokes experience pressure drag because they produce turbulent wakes as the wheel spins.

25. A bullet slows very quickly in water but a spear doesn’t. What force acts to slow these two objects, and why does the spear take longer to stop?
   E.25 Both objects are slowed by similar pressure drags. But the spear’s larger mass and momentum keep it from slowing as quickly.

26. If you hang a tennis ball from a string, it will deflect downwind in a strong breeze. But if you wet the ball so that the fuzz on its surface lies flat, it will deflect even more than before. Why does smoothing the ball increase its deflection?
   E.26 Smoothing the ball prevents its fuzz from "tripping" the boundary layer in the air flowing past it. As a result, the wet ball creates a larger turbulent wake and experiences more pressure drag.

27. Explain why a parachute slows your descent when you leap out of an airplane.
   E.27 It increases pressure drag and reduces your terminal velocity.

28. Bicycle racers sometimes wear teardrop-shaped helmets that taper away behind their heads. Why does having this smooth taper behind them reduce the drag forces they experience relative to those they would experience with more ball-shaped helmets?
   E.28 The teardrop shape assists air in flowing around the back of the helmet and delays flow separation. The resulting turbulent wake is smaller.

29. If you want the metal tubing in your bicycle to experience as little drag as possible while you’re riding in a race, is cylindrical tubing the best shape? How should it be shaped?
   E.29 An airfoil, round in front and tapered behind, would be better.

30. In 1971, astronaut Alan Shepard hit a golf ball on the moon. How did the absence of air affect the ball’s flight?
   E.30 In the absence of air, the ball traveled in a simple parabolic arc. It could not fly the way a golf ball with backspin does in the earth's atmosphere.

31. A water-skier skims along the surface of a lake. What types of forces is the water exerting on the skier, and what is the effect of these forces?
   E.31 Lift supports the skier and drag pulls the skier backward.

32. How would a Frisbee fly on the airless moon?
   E.32 The Frisbee would fly in a simple parabolic arc, the same way a rock would.
33. You can buy special golf tees that wrap around behind the ball to prevent you from giving it any spin when you hit it. These tees are guaranteed to prevent hooks and slices (i.e., curved flights). But how do these tees affect the distance the ball travels? Why?
   E.33 Without backspin, the ball can’t obtain lift and won’t go as far.

34. A hurricane or gale force wind can lift the roof off a house, even when the roof has no exposed eaves. How can wind blowing across a roof produce an upward force on it?
   E.34 When wind blows horizontally across a pointed roof, it undergoes an inward bend. The pressure at the surface of the roof drops below atmospheric pressure and the speed of the air there rises. With normal atmospheric pressure below the roof and less than atmospheric pressure above it, the roof experiences a net upward pressure force.

35. A skillful volleyball player can serve the ball so that it barely spins at all. The ball dithers slightly from side to side as it flies over the net and is hard to return. What causes the ball to accelerate sideways?
   E.35 Small disturbances in the airflow around the sides of the nonspinning volleyball produce lift forces that push the ball to the side.

36. Why does an airplane have a “flight ceiling,” a maximum altitude above which it can’t obtain enough lift to balance the downward force of gravity?
   E.36 The higher the airplane goes, the less dense the air becomes and the harder it gets for the plane to transfer enough downward momentum to the air to keep itself aloft. At a certain height, the plane can only just obtain enough upward momentum from the air to keep from falling.

37. If you let a stream of water from a faucet flow rapidly over the curved bottom of a spoon, the spoon will be drawn into the stream. Explain this effect.
   E.37 The water speeds up around the curve and its pressure drops. The resulting pressure imbalance pushes the spoon into the stream.

38. If you put your hand out the window of a moving car, so that your palm is pointing directly forward, the force on your hand is directly backward. Explain why the two halves of the airstream, passing over and under your hand, don’t produce an overall up or down force on your hand.
   E.38 When your palm is pointing forward, the two airstreams (over and under your hand) are symmetric. Although both airstreams experience pressure drops as they arc inward around your hand’s edges, the pressure drops are symmetric and there is no net up or down pressure force on your hand.

39. If instead of holding your hand palm forward (see Exercise 38), you tip your palm slightly downward, the force on your hand will be both backward and upward. How is the airstream exerting an upward force on your hand?
   E.39 Air travels faster over your hand than under it, so the pressure above your hand is less than the pressure under your hand.

40. When a hummingbird hovers in front of a flower, what forces are acting on it and what is the net force it experiences?
   E.40 The hovering hummingbird experiences zero net force: the upward aerodynamic force it experiences exactly balances its downward weight.

Additional Questions:

1. Name the two types of drag forces and describe them.
   a. Viscous Drag – a frictional force between air molecules and the object
   b. Pressure Drag – a force due to a pressure imbalance around an object.

2. What does it mean if airflow over an object is said to be “turbulent”?
   a. The streamlines of air separate at the back of an object, resulting in a low pressure wake behind the object.

3. Sketch Figure 6.3.2 (c) and label the areas of high and low pressure.
   a. High pressure will be along the entire bottom side of the wing. Low pressure will be present on the top of the wing, at the front. The imbalance of pressure pushes the wing up.
4. Explain what it means when a wing “stalls” and what affect is has on pressure drag.
   a. When a wing stalls, airflow becomes blunt. That is, there is boundary layer separation
      and a wake is formed on top of the wing.
5. What is the benefit of a streamlined shape when it comes to airflow?
   a. It eliminates/reduces the amount of pressure drag.
6. On airplanes, what is meant by the “angle of attack”?
   a. The angle of attack is the angle between the wing of an airplane and a horizontal line.
7. On airplanes, what is the purpose of “slats” and “flaps”?
   a. Slats and flaps increase the curvature of a wing. It causes more lift to be generated by
      the wing.