Chapter 2 Exercises

5. Why is it hard to start the wheel of a roulette table spinning, and what keeps it spinning once it’s started?
   E.5 The wheel has rotational inertia, as measured by its rotational mass, making it hard to start and stop spinning.

6. Why can’t you open a door by pushing its doorknob directly toward or away from its hinges?
   E.6 A force exerted directly toward or away from the axis of rotation produces zero torque about that axis of rotation.

7. Why can’t you open a door by pushing on its hinged side?
   E.7 A force exerted at the hinges produces no torque about them.

8. It’s much easier to carry a weight in your hand when your arm is at your side than it is when your arm is pointing straight out in front of you. Use the concept of torque to explain this effect.
   E.8 When you arm is pointing straight out in front of you, any weight force exerted on your hand is at right angles to the lever arm between your shoulder and hand and produces a large torque about your shoulder. On the other hand, when you arm is at your side, any weight force exerted on your hand is directed away from your shoulder and produces no torque about your shoulder.

9. A gristmill is powered by falling water, which pours into buckets on the outer edge of a giant wheel. The weight of the water turns the wheel. Why is it important that those buckets be on the wheel’s outer edge?
   E.9 The farther the water is from the water wheel’s pivot, the more torque its weight produces on the wheel.

10. How does the string of a yo-yo get the yo-yo spinning?
    E.10 The string pulls on the outside edge of the yo-yo's spindle and at right angles to the lever arm between the yo-yo's rotational axis and the point at which the force acts. As a result, it produces a torque on the yo-yo about its rotational axis and causes the yo-yo to undergo angular acceleration.

11. One way to crack open a walnut is to put it in the hinged side of a door and then begin to close the door. Why does a small force on the door produce a large force on the shell?
    E.11 Your force far from the hinges produces a large torque. To oppose this torque, the nut must exert a huge force near the hinges.

12. A common pair of pliers has a place for cutting wires, bolts, or nails. Why is it so important that this cutter be located very near the pliers’ pivot?
    E.12 The closer the wire is to the axis of pliers' axis of rotation, the less effective any force from the wire is at producing a torque on the pliers and stopping its rotation.

13. You can do push-ups with either your toes or your knees acting as the pivot about which your body rotates. When you pivot about your knees, your feet actually help you to lift your head and chest. Explain.
    E.13 The weights of your chest and your feet exert torques in opposite directions about your knees. They partially balance one another.

14. Tightrope walkers often use long poles for balance. Although the poles don’t weigh much, they can exert substantial torques on the walkers to keep them from tipping and falling off the ropes. Why are the poles so long?
    E.14 The longer the pole is, the greater its rotational mass and the more torque that is required to start it rotating significantly.
    E.14 When the pole has a large rotational mass, the tightrope walker can exert large torques on the pole without causing it to rotate quickly. The pole twists back on the tightrope walker and helps the tightrope walker remain upright.

15. Some racing cars are designed so that their massive engines are near their geometrical centers. Why does this design make it easier for these cars to turn quickly?
    E.15 It reduces the car’s rotational mass so that the car can undergo rapid angular accelerations and change directions quickly.

16. How does a bottle opener use mechanical advantage to pry the top off a soda bottle?
16. A modest force exerted far from the pivot produces an enormous force close to the pivot. Although the opener's handle must travel a long distance, it produces the huge force on the bottle cap that's required to pull that cap off the bottle.

17. A jar-opening tool grabs onto a jar's lid and then provides a long handle for you to turn. Why does this handle's length help you to open the jar?

18. When you climb out on a thin tree limb, there's a chance that the limb will break off near the trunk. Why is this disaster most likely to occur when you're as far out on the limb as possible?

19. How does a crowbar make it easier to lift the edge of a heavy box a few centimeters off the ground?

20. The basket of a wheelbarrow is located in between its wheel and its handles. How does this arrangement make it relatively easy for you to lift a heavy load in the basket?

21. Skiers often stop by turning their skis sideways and skidding them across the snow. How does this trick remove energy from a skier, and what happens to that energy?

22. A horse does work on a cart it’s pulling along a straight, level road at a constant speed. The horse is transferring energy to the cart, so why doesn't the cart go faster and faster? Where is the energy going?

23. Explain why a rolling pin flattens a piecrust without encountering very much sliding friction as it moves.

24. Professional sprinters wear spikes on their shoes to prevent them from sliding on the track at the start of a race. Why is energy wasted whenever a sprinter's foot slides backward along the track?

25. A yo-yo is a spool-shaped toy that spins on a string. In a sophisticated yo-yo, the end of the string forms a loop around the yo-yo’s central rod so that the yo-yo can spin almost freely at the end of the string. Why does the yo-yo spin longest if the central rod is very thin and very slippery?

26. As you begin pedaling your bicycle and it accelerates forward, what is exerting the forward force that the bicycle needs to accelerate?

27. When you begin to walk forward, what exerts the force that allows you to accelerate?

28. If you are pulling a sled along a level field at constant velocity, how does the force you are exerting on the sled compare to the force of sliding friction on its runners?

29. Why does putting sand in the trunk of a car help to keep the rear wheels from skidding on an icy road?
Additional Exercises:

1. What is rotational inertia? Rotational inertia depends on more than just the mass of the object. What is the other factor that contributes to an object’s rotational inertia?
   a. Rotational inertia is the resistance of an object to changes in angular velocity. It depends on mass and the size or shape of an object.

2. What is torque?
   a. Torque is a twisting action that causes objects to rotate.

3. Newton’s second law has an equation for rotational motion too. What is the equation? Explain each of the terms in the equation.
   a. \( \alpha = \frac{\tau_{\text{net}}}{I} \) The angular acceleration of an object is equal to the net torque acting on the object divided by its rotational inertia.

4. An electric motor is spinning a wheel. The motor provides a torque of 125 N·m to the wheel. The wheel has a rotational inertia of 18 kg·m². What angular acceleration will the wheel experience?
   a. Using the equation above \( \alpha = \frac{125 \text{ N} \cdot \text{m}}{18 \text{ kg} \cdot \text{m}^2} \) which is 6.94 rad/s².