A total of three forces act on an object, two of which are shown. The object is in equilibrium.

1. What is the magnitude of the third force?
   a) 5 N
   b) 10 N
   c) 15 N
   d) 20 N
   e) none of the above answers are correct

2. How far from point P is the third force applied?
   a) 0 m
   b) 0.5 m
   c) 1.0 m
   d) 1.5 m
   e) more than one of the above answers is possible

3. A uniform 4 m, 40 N horizontal plank is shown with an 60 N weight resting on top, 1.0 m from the right end. The plank is in equilibrium. What is $F_1$?
   a) 30 N
   b) 35 N
   c) 40 N
   d) 45 N
   e) 50 N

(numbers 4-5) Callisto, one of Jupiter's moons, is the 3rd largest moon in our solar system. It has a mass of $1.08 \times 10^{23}$ kg and a radius of $2.41 \times 10^6$ m.

4. A 25 kg lunar rover is on Callisto's surface. How much does it weigh?
   a) 28.0 N
   b) 29.0 N
   c) 30.0 N
   d) 31.0 N
   e) 32.0 N

5. What is the escape speed from Callisto’s surface?
   a) $2.45 \times 10^3$ m/s
   b) $2.75 \times 10^3$ m/s
   c) $3.05 \times 10^3$ m/s
   d) $3.35 \times 10^3$ m/s
   e) $3.65 \times 10^3$ m/s
A 2 kg block hangs from a negligible mass string that wraps around a pulley wheel with a frictionless axle. The pulley wheel is a uniform cylinder of mass 3 kg and radius 0.5 m. When the system is released:

6. Find the magnitude of the block’s acceleration.
   a) 4.2 m/s²
   b) 4.7 m/s²
   c) 5.2 m/s²
   d) 5.7 m/s²
   e) 6.2 m/s²

7. Find the magnitude of the tension force pulling on the block.
   a) 6.6 N
   b) 8.6 N
   c) 10.6 N
   d) 12.6 N
   e) 14.6 N

8. An object travels along a curved path with initial and final velocities shown. This segment of motion takes 4 seconds. Find the magnitude of the object’s average acceleration during this segment.
   a) 1.0 m/s²
   b) 1.5 m/s²
   c) 2.0 m/s²
   d) 2.5 m/s²
   e) 3.0 m/s²

9. A block is released from rest from the top edge of a frictionless half-pipe. The block slides down along the curved surface. At the instant shown, which arrow may represent the block’s acceleration vector?
   a) arrow 1
   b) arrow 2
   c) arrow 3
   d) arrow 4
   e) none of the above arrows may be correct

(numbers 10-12) A projectile is launched at 60 m/s, 30 degrees above the horizontal. Neglect air resistance. After 3 seconds:

10. What is the height of the projectile?
    a) 25 m
    b) 30 m
    c) 35 m
    d) 40 m
    e) 45 m

11. What is the speed of the projectile?
    a) 0 m/s
    b) 37 m/s
    c) 42 m/s
    d) 47 m/s
    e) 52 m/s
12. What is the magnitude of the projectile’s acceleration?
   a) 4 m/s²
   b) 6 m/s²
   c) 8 m/s²
   d) 10 m/s²
   e) None of the above answers is correct

13. A 3 kg block is released from rest from the top of a curved slide. At the bottom, 2 m lower than the release point, the block moves at 4 m/s. If this segment of motion takes 4 seconds, find the average power exerted by kinetic friction on the block during the slide down.
   a) -3 W
   b) -6 W
   c) -9 W
   d) -12 W
   e) -15 W

14. The speed of the ring’s center is:
   a) 5.12 m/s
   b) 5.42 m/s
   c) 5.72 m/s
   d) 6.02 m/s
   e) 6.32 m/s

15. The acceleration of the ring’s center is:
   a) g/2, downward
   b) g, downward
   c) g, upward
   d) g/2, upward
   e) None of the above answers is correct

16. A ring of mass 3 kg and radius 0.4 m hangs from a nail. Calculate the ring’s rotational inertia about the nail.
   a) 1.68 kg-m²
   b) 1.44 kg-m²
   c) 1.20 kg-m²
   d) 0.96 kg-m²
   e) 0.72 kg-m²

17. A DVD initially rotating at 8 rad/s begins slowing down at a constant rate of 2 rad/s². How many radians does the DVD rotate through before coming to rest?
   a) 8 rad
   b) 12 rad
   c) 16 rad
   d) 20 rad
   e) 24 rad
18. A car travels at a constant speed of 20 m/s around a *horizontal circular track* of radius 100 m. The tires roll without slipping. We can conclude that the coefficient of static friction between the tires and track:
   a) may be 0.6
   b) must be 0.6
   c) may be 0.4
   d) must be 0.4
   e) more than one of the above answers is correct

19. Two 3 kg blocks are connected by a negligible mass string. An *upward tension force* of 96 N is applied. There is *nothing else touching the blocks*. Find the magnitude of the tension force that the lower string exerts on the bottom block.
   a) 30 N
   b) 36 N
   c) 42 N
   d) 48 N
   e) 54 N

(numbers 20-23) A 4 kg block is on a horizontal surface with coefficient of static friction = 0.5 and an unknown coefficient of kinetic friction. In all of the questions, the applied tension force is horizontal.

20. When a 24 N tension force is applied, the block *speeds up* at a constant rate of 2 m/s². What is the magnitude of the kinetic friction force?
   a) 4 N
   b) 8 N
   c) 12 N
   d) 16 N
   e) 20 N

21. The block continues to speed up at a rate of 2 m/s². Compared to the tension force that you apply to the block, the tension force that the block applies to you is:
   a) larger in magnitude
   b) smaller in magnitude
   c) equal in magnitude
   d) more information is needed to determine

22. While still sliding, the tension force is reduced to a value such that the block now *slows down* at a constant rate of 2 m/s². What is the magnitude of the tension force?
   a) 4 N
   b) 6 N
   c) 8 N
   d) 10 N
   e) 12 N
23. The block is now allowed to come to rest. After coming to rest, a 16 N tension force is applied. The surface below applies a _______ friction force of magnitude _____ Newtons.
   a) static, 14
   b) static, 16
   c) kinetic, 14
   d) kinetic, 16
   e) none of the above answers is correct

24. An ideal horizontal spring with spring constant 800 N/m is initially compressed 0.2 m. One end is attached to a wall and the other end touches a 4 kg block (not attached). The system is released from rest and the block slides 1.0 m from the initial position before coming to rest. The horizontal surface below has a uniform roughness. What can we conclude about the coefficient of kinetic friction between the surface and the block?
   a) it must be 0.4
   b) it may or may not be 0.4
   c) it must be 0.5
   d) it may or may not be 0.5
   e) none of the above answers is correct

25. What is the object's distance traveled for the full time segment, 0 – 4 seconds?
   a) 2 m
   b) 3 m
   c) 4 m
   d) 5 m
   e) 6 m

26. At which time is the object speeding up?
   a) 0.5 s
   b) 1.5 s
   c) 2.5 s
   d) 3.5 s
   e) none of the above answers is correct

27. A 200 kg roller coaster starts from rest. The ride reaches a maximum height of 30 m and a top speed of 30 m/s. 40 seconds after starting, the roller coaster is on a horizontal section of track at the same height as the starting position, but now moves at 5 m/s. There are no elastic (spring) forces involved. How much work was done on the roller coaster during this period by all of the nonconservative forces combined?
   a) 5500 J
   b) 4500 J
   c) 3500 J
   d) 2500 J
   e) 1500 J
28. What is the speed of the composite puck/bullet object after the collision?
   a) 10 m/s
   b) 15 m/s
   c) 20 m/s
   d) 25 m/s
   e) 30 m/s

29. How much kinetic energy was lost in the collision?
   a) 50 J
   b) 40 J
   c) 30 J
   d) 20 J
   e) 10 J

30. A uniform 50 kg iceboat of length 4 m is at rest on a frictionless, horizontal surface. A 50 kg person stands at rest on one end of the iceboat and a 100 kg person stands at rest on the other end. When the 100 kg person walks to the center, how far does the iceboat move relative to the surface below?
   a) 1.0 m
   b) 1.25 m
   c) 1.5 m
   d) 1.75 m
   e) 2.0 m

(numbers 31-32) A ring, cylinder, solid sphere, and hollow sphere are all released from rest from the same height on an inclined surface, at the same time. All four objects have uniform density, have the same mass, same radius, and roll without slipping.

31. Which one has the largest total kinetic energy at the bottom?
   a) ring
   b) cylinder
   c) solid sphere
   d) hollow sphere
   e) they all reach the bottom with the same total kinetic energy

32. Which one reaches the bottom last?
   a) ring
   b) cylinder
   c) hollow sphere
   d) solid sphere
   e) they all reach the bottom at the same time