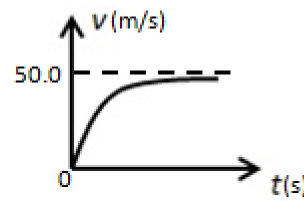
ACES – Academic Challenge
Physics Test (Sectional) – 2021

1. A 0.200-kg object slides on a horizontal surface in a straight line under friction. Its mechanical energy changes with position at a constant rate of -0.700 J/m. No other horizontal force or force component acts on the object. What is the coefficient of kinetic friction between the object and the surface?

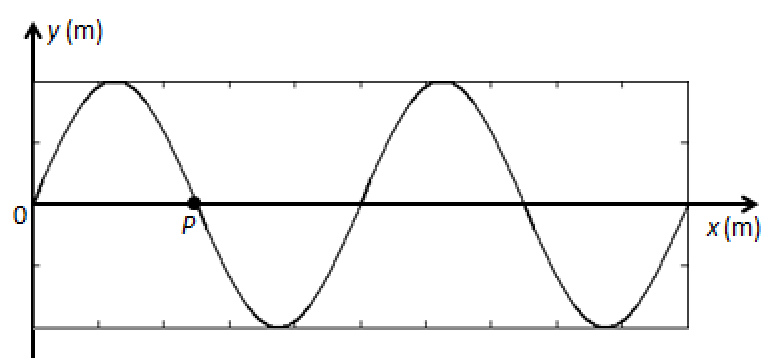
   a. 0.400
   b. 0.357
   c. 0.260
   d. 0.180
   e. 0.120

2. The speed versus time of a 70.0-kg bungee jumper during his fall (before the bungee cord becomes taut) is shown in the diagram below. If we model the air drag using the equation, $f_{air} = bv$, where f_{air} is the magnitude of the air drag, b is a coefficient, and v is the speed, what is the value for b?



   a. 1.40 kg/s
   b. 6.00 kg/s
   c. 10.5 kg/s
   d. 13.7 kg/s
   e. 15.6 kg/s

3. A transverse sinusoidal wave travels in the –*x* direction. Its waveform at $t = 0$ is shown in the diagram below. If T is the period of the wave, which statement below is true about the velocity and acceleration of point P at $t = T/4$?

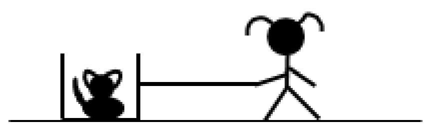


a. Both the velocity and acceleration are zero.
b. Both the velocity and acceleration are in the –y direction.
c. Both the velocity and acceleration are in the +y direction.
d. The velocity is zero but the acceleration is in the –y direction.
e. The velocity is zero but the acceleration is in the +y direction.

4. Which experiment demonstrates the wave nature of light?

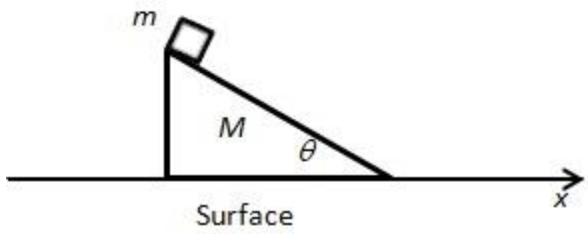
   a. The photoelectric effect
   b. Young's double-slit experiment
   c. Compton's X-ray scattering from an electron
   d. Davisson-Germer's experiment on electron diffraction by crystals
   e. Röntgen's experiment on the production of X-rays

5. Katie likes to play with her cat by giving him a ride in a box, as shown in the diagram. The box and cat (total mass 6.00 kg) move on a horizontal surface in a straight line at a constant speed of 2.00 m/s while Katie applies a horizontal force. If the coefficient of kinetic friction between the box and the surface is 0.200, how much power does Katie need to deliver to the box?



   a. 23.5 W
   b. 26.0 W
   c. 30.0 W
   d. 33.6 W
   e. 35.0 W

6. A wedge-shaped block of mass M = 0.400 kg sits on a frictionless, horizontal surface on the ground, as shown in the diagram. One side of the block is a frictionless, inclined plane with an inclination angle θ = 30.0°. An object of mass m = 0.200 kg is placed at the top of the inclined plane. At the moment when the object is released, both the block and object are at rest. At the instant when the object reaches the bottom of the inclined plane, the block moves in the –x direction with a speed of 0.500 m/s relative to the horizontal surface. At the same instant, what is the speed of the object in the x direction relative to the surface?

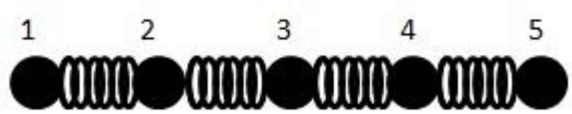


a. 0.250 m/s
b. 0.500 m/s
c. 0.866 m/s
d. 0.900 m/s
e. 1.00 m/s

7. In the situation described in problem 6, what is the speed of the object relative to the block when it reaches the bottom of the inclined plane?

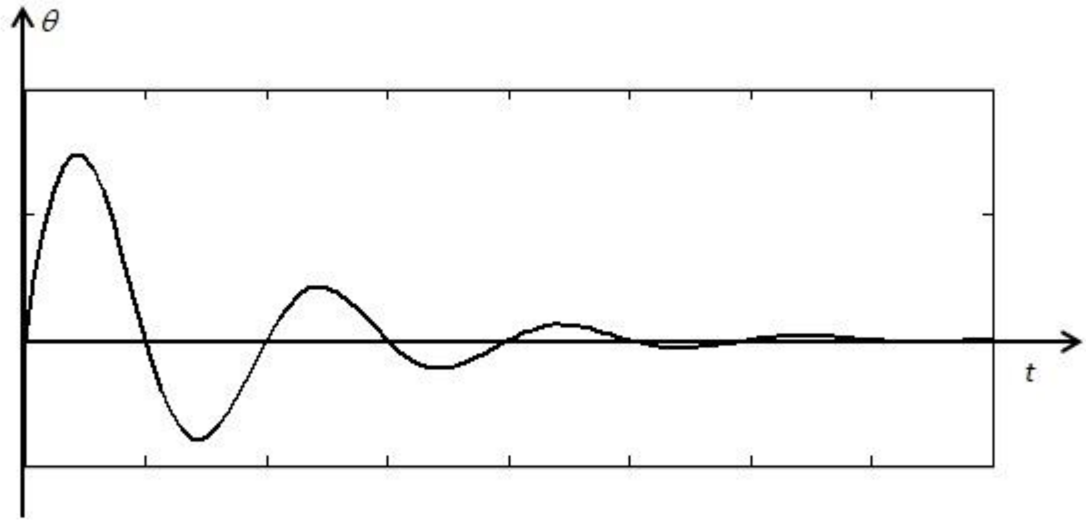
   a. 1.50 m/s
   b. 1.73 m/s
   c. 1.86 m/s
   d. 2.00 m/s
   e. 2.25 m/s

8. A mass-spring system consists of five equal point masses connected by identical, ideal springs of negligible mass, as shown in the diagram. The unstretched length and force constant of each spring are L_0 = 10.0 cm and k = 20 N/m, respectively. Each point mass is m = 50.0 g. If the mass-spring system is held stationary in the vertical direction with mass #1 at the top and mass #5 at the bottom, what is the length of the spring between mass #3 and #4?



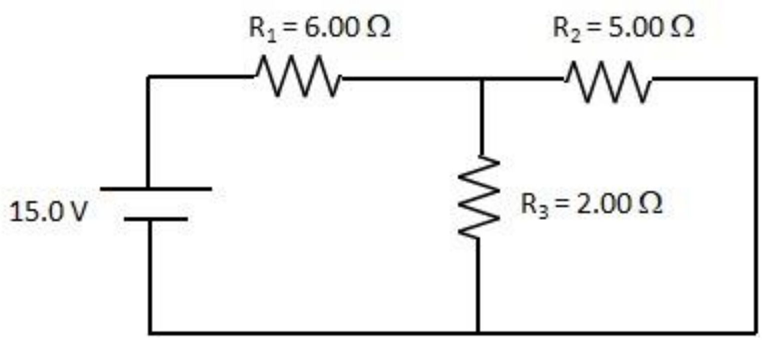
   a. 20.7 cm
   b. 18.5 cm
   c. 14.9 cm
   d. 11.0 cm
   e. 6.88 cm

9. A pendulum undergoes an oscillation, as shown in the diagram, where θ is angular displacement and t is time. What type of oscillation does the pendulum undergo?



a. A resonant oscillation
b. An under-damped oscillation
c. An over-damped oscillation
d. A critically-damped oscillation
e. An oscillation without damping

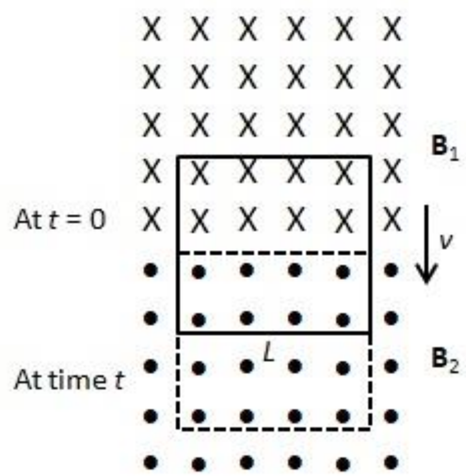
10. Determine the current that flows from the voltage source.



a. 2.02 A
b. 2.30 A
c. 3.66 A
d. 5.20 A
e. 8.86 A

11. A loop of coil in the shape of a square with side length L moves downward at a constant speed v between two uniform magnetic fields, $\mathbf{B}_1$ and $\mathbf{B}_2$, as shown in the diagram. The two magnetic fields are equal in magnitude but opposite in direction. The top and bottom sides of the coil are parallel to the boundary between the two magnetic

fields. The coil has resistance R. At $t = 0$, half of the coil is in $\mathbf{B}_1$ and half is in $\mathbf{B}_2$; at time t, the coil has just entered $\mathbf{B}_2$ completely. What is the direction of the induced current produced in the coil in the process from $t = 0$ to t?



a. Out of the page
b. Into the page
c. Counterclockwise
d. Clockwise
e. There is no induced current.

12. In the situation described in problem 11, if $B_1 = B_2 = 2.00$ T, $v = 5.00$ m/s, $L = 0.300$ m, and $R = 5.00\ \Omega$, what is the induced current produced in the process from $t = 0$ to t?

a. 0 A
b. 0.600 A
c. 1.20 A
d. 2.40 A
e. 3.60 A

13. In a physics laboratory, a ball launcher is placed at various heights h from the ground and a ball is launched horizontally at a fixed speed v_0. For each height h, students measure the corresponding range R. To find the initial speed v_0, students then plot R^2 on the vertical axis versus h (horizontal axis) and find the best fit line. What does the slope of the best fit line represent?

a. v_0^2/g
b. $2v_0^2/g$
c. v_0/g
d. $2v_0/g$

e. $2g/v_0^2$

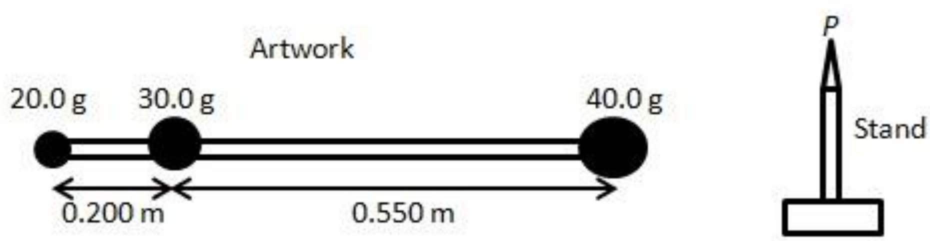
14. In the situation described in problem 13, if the slope of the best fit line is 3.27 m, what is the initial speed v_0 of the ball?

a. 32.0 m/s
b. 16.0 m/s
c. 5.66 m/s
d. 4.00 m/s
e. 2.45 m/s

15. The letters S and E in LASER stand for

a. Spontaneous Emission
b. Stimulated Emission
c. Spontaneous Emulsion
d. Stimulated Emulsion
e. Strange Emission

16. A piece of artwork consists of a long, light rod and three small spheres, as shown in the diagram. It is going to be displayed on a stand with pivot point *P*. Where should point *P* be placed along the rod so that the artwork does not tip over? Ignore friction.



a. 0.250 m to the left of the 40.0-g mass
b. 0.280 m to the right of the 20.0-g mass
c. 0.311 m to the right of the 30.0-g mass
d. 0.375 m to the left of the 40.0-g mass
e. 0.400 m to the right of the 20.0-g mass

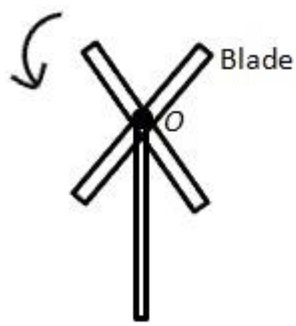
17. A sample of radioactive isotope *A* with a mean lifetime 30.0 s contains 6.00×10^{16} isotope *A* atoms. A sample of radioactive isotope *B* with a mean lifetime 50.0 s contains 2.00×10^{16} isotope *B* atoms. How much time will pass before the number of isotope *A* atoms is the same as the number of isotope *B* atoms? Note: neither isotope is a decay product of the other.

a. 82.4 s
b. 70.0 s
c. 56.8 s
d. 30.5 s
e. 27.7 s

18. On Christmas day, Flynn holds a silver ornament 25.0 cm from her face and sees her own image in the ornament. Consider the surface of the ornament as a convex mirror. Suppose the height of Flynn's face is 20.0 cm and the height of the image is 1.00 cm. What is the focal length of the ornament?

a. 1.00 cm
b. 1.19 cm
c. -1.32 cm
d. -1.56 cm
e. -2.45 cm

19. A pin wheel consists of two identical blades that can rotate freely without friction about point *O*, as shown in the diagram. Each blade has a moment inertia of 0.00200 kg·m^2 about *O*. Suppose that the wind causes the pin wheel to spin at a constant angular acceleration of 2.00 rad/s^2, what is the torque produced by the wind?



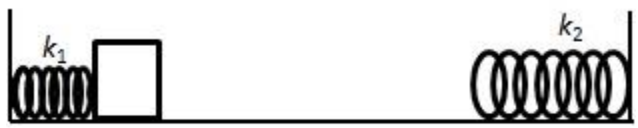
a. 0.00400 N·m
b. 0.00800 N·m
c. 0.0100 N·m
d. 0.0150 N·m
e. 0.0200 N·m

20. A fixed volume chamber contains 4.00 moles of ideal gas that have an initial temperature 30.0 °C and an initial absolute pressure 3.00 atmospheres. If the temperature rises to 50.0 °C and the absolute pressure rises to 8.00 atmospheres,

how many additional moles of the gas have been added to the chamber during this process?

a. 6.00 mol
b. 5.43 mol
c. 5.00 mol
d. 4.68 mol
e. 4.00 mol

21. A 0.200-kg block is pushed against (but not attached to) a compressed spring of force constant k_1 = 10 N/m, as shown in the diagram. The compression of the spring is 10.0 cm. The block is then released from rest. It moves on a frictionless horizontal surface and comes into contact with a second spring of force constant k_2 = 20 N/m. Both springs are ideal springs. What is the maximum compression of the second spring?



a. 3.68 cm
b. 5.00 cm
c. 6.32 cm
d. 7.07 cm
e. 20.0 cm

22. Two small objects collide on a frictionless surface. The first object has a mass of 0.500 kg and an initial velocity of 2.00 m/s, 30° clockwise from the +*x* axis. The second object has a mass of 0.400 kg and an initial velocity of 3.00 m/s, 30° counterclockwise from the +*x* axis. After the collision, what is the total momentum of the two objects? Set the +*x* axis to the right and the +*y* axis upward.

a. (1.20**î** – 0.300**ĵ**) kg·m/s
b. (-0.100**î** + 1.91**ĵ**) kg·m/s
c. (1.91**î** + 0.100**ĵ**) kg·m/s
d. (1.91**î** + 1.10**ĵ**) kg·m/s
e. (1.10**î** + 1.91**ĵ**) kg·m/s

23. A 15.0-kg suitcase is on a horizontal conveyor belt that moves at a constant acceleration. The coefficient of static friction between the suitcase and the conveyor belt is 0.200. If the suitcase is on the verge of sliding relative to the belt, what is the acceleration of the conveyor belt?

a. $1.28\ m/s^2$
b. $1.50\ m/s^2$
c. $1.66\ m/s^2$
d. $1.96\ m/s^2$
e. $3.00\ m/s^2$

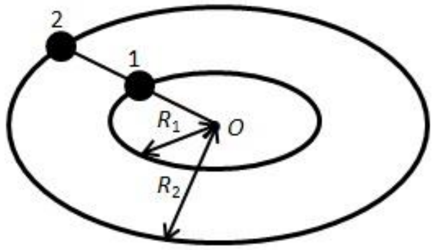
24. Classical physics has failed to predict a blackbody radiation curve that agrees with experimental results. The failure lies in the fact that according to the prediction of classical physics, the blackbody radiation increases to infinity when the wavelength approaches zero. What is the failure referred to historically?

a. The infrared catastrophe
b. The ultraviolet catastrophe
c. The X-ray catastrophe
d. The gamma-ray catastrophe
e. The visible catastrophe

25. The specific heat of water at 15.0 °C is 4186 J/(kg °C). If a 0.600-A current flows for 5.00 minutes through a 500-Ω resistor which is immersed in 600 grams of water initially at 15.0 °C, how much will the temperature of the water change, assuming that all of the heat goes to the water?

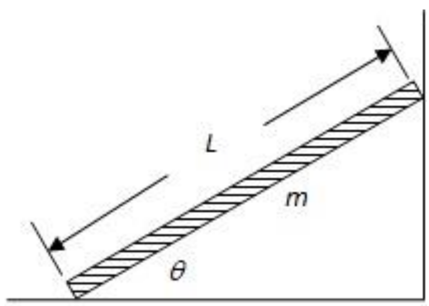
a. 0.0215 C°
b. 0.358 C°
c. 10.0 C°
d. 18.0 C°
e. 21.5 C°

26. Two small objects of equal mass are connected by strings of negligible mass. The two objects are in uniform circular motion about point *O* on a frictionless horizontal surface, as shown in the diagram. The tension in the string between point *O* and object 1 is T_1 and the tension in the string between object 1 and object 2 is T_2. What is the ratio, T_1/T_2? Assume $R_2 = 2R_1$.



a. 3/2
b. 2/3
c. 2/1
d. 1/2
e. 1

27. A ladder has one end leaning against a frictionless, vertical wall and the other end resting on a rough, horizontal floor, as shown in the diagram. The ladder has mass *m*, which is uniformly distributed along its length *L*, and makes an angle θ with the horizontal. If *L* = 2.00 m, *m* = 20.0 kg, and θ = 30.0°, what is the minimum requirement for the coefficient of static friction between the ladder and the floor so that the ladder does not slide?



a. 0.289
b. 0.470
c. 0.650
d. 0.866
e. 0.950

28. What is the definition of the atomic number of a nucleus?

a. The number of electrons in the nucleus
b. The number of neutrons in the nucleus
c. The number of protons in the nucleus
d. The number of protons and neutrons in the nucleus
e. The number of nucleons in the nucleus

29. If **A** = 2.00**î** - 3.00**ĵ** and **B** = -4.00**î** - 2.00**ĵ**, what are the magnitude and direction of **A** + 2**B**? Set the +*x* axis to the right and the +*y* axis upward.

a. 8.56 and 62.0° clockwise from the +*x* axis
b. 8.56 and 242° counterclockwise from the +*x* axis
c. 9.22 and 49.4° clockwise from the +*x* axis
d. 9.22 and 49.4° counterclockwise from the +*x* axis
e. 9.22 and 229° counterclockwise from the +*x* axis

30. Two small balls, ball 1 and ball 2, are thrown horizontally at two respective initial speeds, v_{01} and v_{02}, from two respective heights, h_1 and h_2, above the ground. The range of ball 1 is R_1, and that of ball 2 is R_2. If $h_2/h_1 = 4$ and $v_{02}/v_{01} = ½$, what is the ratio, R_2/R_1? Ignore air resistance.

   a. 2
   b. 1 *
   c. $\sqrt{2}$
   d. $1/\sqrt{2}$
   e. 1/2

31. A particle moves in a two-dimensional plane with a constant acceleration of (2.00**î** - 4.00**ĵ**) m/s^2. At t = 0, its velocity is (1.00**î** + 3.00**ĵ**) m/s. What is its velocity at t = 5.00 s?

   a. (1.00**î** + 3.00**ĵ**) m/s
   b. (1.00**î** - 3.00**ĵ**) m/s
   c. (8.00**î** + 5.00**ĵ**) m/s
   d. (11.0**î** – 17.0**ĵ**) m/s
   e. (16.0**î** + 4.00**ĵ**) m/s

32. Planet X has density ρ and radius R. Consider the planet as a spherical body with uniform density. What is the acceleration due to gravity at the planet's surface? G is the universal gravitational constant.

   a. $4\pi GR\rho/3$
   b. $4\pi GR/3\rho$
   c. $4\pi GR\rho$
   d. $\pi GR\rho/3$
   e. $4GR\rho/3$

33. An incompressible fluid flows through a pipe that has two sections with cross-sectional areas A_1 and A_2, respectively. The flow speeds through the two sections are v_1 and v_2, respectively. If $A_1/A_2 = 2$, what is v_1/v_2?

   a. 1
   b. 2
   c. 1/2
   d. 4
   e. 1/4

34. Quantity $X = Y_1Y_2Y_3$. The dimensions of Y_1, Y_2, and Y_3 are $[Y_1] = [L]^3[M]^{-1}[T]^{-2}$, $[Y_2] = [L]$, and $[Y_3] = [M][L]^{-3}$. What is the dimension of X? Note: $[L]$, $[M]$, and $[T]$ represent the dimensions of length, mass, and time, respectively.

a. $[L][T]^{-1}$
b. $[L]^2[T]$
c. $[L][T]$
d. $[L][T]^{-3}$
e. $[L][T]^{-2}$

35. A small object moves in a circle on a horizontal surface. It encounters kinetic friction with a constant magnitude of 0.300 N. An external force is applied to the object so that it maintains a constant speed. The radius of the circle is 0.500 m. If the object moves in the circle three times, how much work is done on the object by the external force?

a. 0 J
b. 0.45 J
c. 1.50 J
d. 2.83 J
e. 3.14 J