Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

PHYSICS TEST – REGIONAL

Physics Test Production Team

Steven Daniels, Eastern Illinois University – Author/Team Leader
Jie Zou, Eastern Illinois University – Author
Don Pakey, Eastern Illinois University – Reviewer

GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. One oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

Be sure ovals are marked as ● , not ⊙ , ◐ , ◑ , etc.

If you wish to change an answer, erase your first mark completely before marking your new choice.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

Time: 40 Minutes Number of Questions: 35

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Fundamental Constants

Quantity	Symbol	Value
Avogadro's number	N_A	6.022×10^{23}/mol
Boltzmann's constant	k	1.381×10^{-23} J/K
Electron charge magnitude	e	1.602×10^{-19} C
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ T·m/A
Permittivity of free space	ϵ_0	8.854×10^{-12} $C^2/(N \cdot m^2)$
Electrostatic Constant	$k = (4\pi\epsilon_0)^{-1}$	8.988×10^9 $N \cdot m^2/C^2$
Planck's constant	h	6.626×10^{-34} J·s
Electron mass	m_e	9.1094×10^{-31} kg
Neutron mass	m_n	1.6749×10^{-27} kg
Proton mass	m_p	1.6726×10^{-27} kg
Speed of light in vacuum	c	2.9979×10^8 m/s
Universal gravitational constant	G	6.673×10^{-11} $N \cdot m^2/kg^2$
Universal gas constant	R	8.3145 J/(mol·K)

Other information:

Acceleration due to gravity at Earth's surface: g = 9.80 m/s^2

0.00 ^oC = 273.15 K

Academic Challenge
Physics Test (Regional) – 2019

1. Given that 1 liter is 1000 cubic centimeters, that 1 inch is 2.54 centimeters, and that 12 inches is 1 foot, by what factor would you multiply 0.5 cubic feet to obtain the number of liters in 0.5 cubic feet?

   a. 1.76×10^{-3} b. 3.53×10^{-3} c. 14.2 d. 28.3 e. 56.6

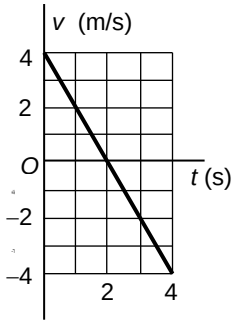
2. A person makes a journey of two parts. The first part they travel north 150 m. What was the magnitude of the second part if their final position is (46.0 m East, 23.0 m South)?

   a. 81.0 m b. 107 m c. 135 m d. 179 m e. 197 m

3. The amount of heat Q that flows through a rod of length L and cross-sectional area A in time t is given by $Q = \kappa A(\Delta T/L)t$, where κ is the thermal conductivity of the rod and ΔT is the temperature difference across the length of the rod. Which set of SI units below would be appropriate for measuring thermal conductivity?

   a. J/(m·K)
   b. W·m/K
   c. W/(m·K)
   d. $W/(m^2 \cdot K)$
   e. W/(m·K·s)

4. The graph shows velocity v versus time t for a particle moving along the x axis. What is the overall displacement of the particle from 0.00 s to 4.00 s?



   a. 4.00 m
   b. – 4.00 m
   c. 8.00 m
   d. – 8.00 m
   e. 0 m

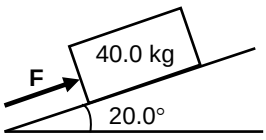
5. In the situation described in problem 4, what is the total distance covered by the particle from 0.00 s to 4.00 s?

   a. 2.00 m b. 4.00 m c. 4.47 m d. 8.00 m e. 8.94 m

6. A 0.200-kg object is attached to a light, non-stretchy string that hangs straight from the ceiling of an elevator. The elevator starts from rest going up with an acceleration of 0.700 m/s^2. During that acceleration, what is the tension in the string?

   a. 0 N b. 1.96 N c. 2.10 N d. 4.90 N e. 6.86 N

7. A box is placed on an inclined plane. To prevent the box from sliding down, a force **F** is applied parallel to the inclined plane, as shown in the diagram. What is the minimum value for the magnitude of force **F**? Assume the mass of the box is 40.0 kg, the angle between the inclined plane and the horizontal is 20.0°, and the coefficient of static friction between the box and the inclined plane is 0.300.



   a. 23.6 N
   b. 110 N
   c. 134 N
   d. 368 N
   e. 0 N

8. Consider the following table of information about planets. According to the data in the table which planet is the most dense?

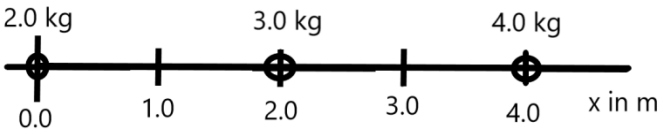
Planet	Mass	Radius
Mercury	$3.18\text{x}10^{23}$ kg	$2.44\text{x}10^{6}$ m
Earth	$5.98\text{x}10^{24}$ kg	$6.37\text{x}10^{6}$ m
Mars	$6.42\text{x}10^{23}$ kg	$3.39\text{x}10^{6}$ m
Jupiter	$1.90\text{x}10^{27}$ kg	$7.14\text{x}10^{7}$ m
Neptune	$1.03\text{x}10^{26}$ kg	$2.48\text{x}10^{7}$ m

a. Mercury b. Earth c. Mars d. Jupiter e. Neptune

9. A 20.0-kg object is pulled along a horizontal surface. The coefficient of kinetic friction between the object and the surface is 0.180. The pulling force has a magnitude of 100 N and is applied at an angle of 20.0° above the horizontal. How much work does the pulling force do in moving the object 6.00 m?

a. 564 J b. 405 J c. 300 J d. 175 J e. 125 J

10. Consider the masses shown spaced as shown in meters. Where is the center of mass of the system?

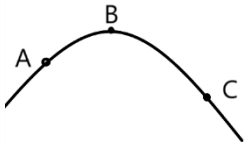


a. 1.17 m b. 2.00 m c. 2.44 m d. 3.14 m e. 4.00 m

11. In the situation described in problem 10 what is the magnitude of the gravitational force that the 3.00 kg mass feels from the other two masses (G is the universal gravitational constant and the results are all in Newtons)?

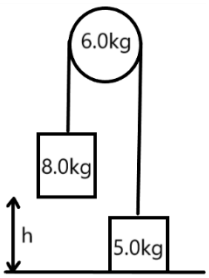
a. $\frac{3}{2}\text{G}$ b. 2G c. 4G d. $\frac{9}{2}\text{G}$ e. 6G

12. A ball is thrown so that it follows the trajectory shown in the figure. At the highest point, B,



a. the velocity is zero and the acceleration is zero.
b. the velocity is not zero and the acceleration is zero.
c. the velocity is not zero and the acceleration is not zero.
d. the speed is more than at A and less than at C.
e. the speed is the same as at A and at C.

13. Consider the system shown in the figure. The pulley (a uniform disk) has a mass of 6 kg and rotates freely about an axis through its center. The system is released from rest with the 8 kg mass at a height of *h*. What is the speed of the 5 kg mass when the 8 kg mass reaches the ground?

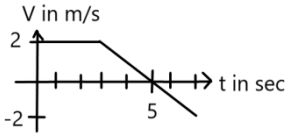


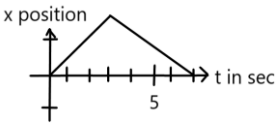
a. $\sqrt{\frac{3}{16}gh}$ b. $\sqrt{\frac{3}{13}gh}$ c. $\sqrt{2gh}$ d. $\sqrt{\frac{3}{8}gh}$ e. $\sqrt{\frac{5}{8}gh}$

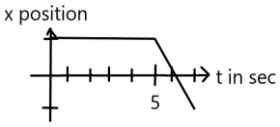
14. Considering the system shown in problem 13 and assuming that the 5 kg mass has an upward speed of *v* when the 8 kg mass hits the floor, what is the maximum height, above the floor, that the 5 kg mass reaches?

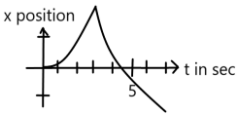
a. $h_{max} = \frac{v^2}{2g} + h$ b. $h_{max} = \frac{v^2}{2g}$ c. $h_{max} = \frac{v^2}{g}$ d. $h_{max} = \frac{v^2}{g} + h$ e. $h_{max} = \frac{mgh}{2v}$

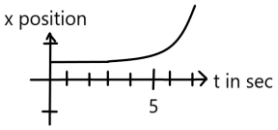
15. The velocity of a particle that starts at the origin is shown as a function of time on the graph to the right. What graph is the proper shape for the position of this particle as a function of time?

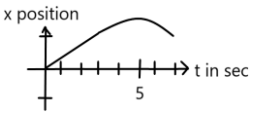


a. 

b. 

c. 

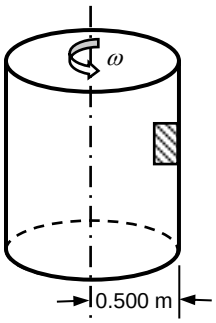
d. 

e. 

16. In the Earth's orbit around the Sun the path is an ellipse. The point in the orbit at which the Earth is farthest from the Sun is called the

a. aphelion b. perihelion c. focus d. ecliptic e. keplerian

17. An object is placed against the inside wall of a cylindrical container and spins together with the container at a constant angular speed ω about the center axis, as shown in the diagram. The radius of the inside wall is 0.500 m. The coefficient of static friction between the object and the inside wall is 0.200. What is the minimum value for ω so that the object does not slide down?



a. 4.95 rad/s b. 9.90 rad/s c. 12.6 rad/s d. 28.4 rad/s e. 30.0 rad/s

18. Which statement is correct about collisions?

a. During an inelastic collision, neither the total momentum nor the total kinetic energy of a system is conserved.
b. The total momentum of a system is conserved only in an elastic collision, but not in an inelastic collision.
c. During a collision, the individual momentum of each object involved is conserved.
d. During a collision, elastic or inelastic, the total momentum of a system is conserved.
e. During a collision, the total momentum of a system is not conserved because there are forces acting on the objects in the system.

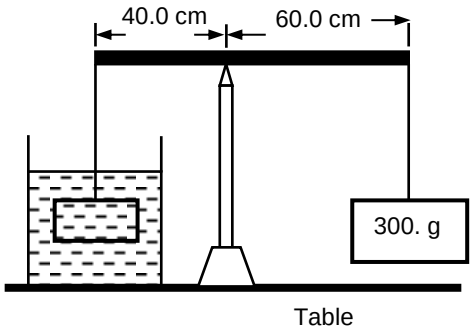
19. A 7.00-kg bowling ball traveling at 4.00 m/s collides head on with a 2.00-kg stationary bowling pin. Immediately after the collinear collision the ball is measured to have a speed of 3.00 m/s. What is the speed of the pin after the collision?

a. 2.00 m/s b. 2.50 m/s c. 3.11 m/s d. 3.25 m/s e. 3.50 m/s

20. To open a revolving door, a lesser force is required if you push farther away from the axis of rotation. The concept best demonstrated by the statement would be:

a. Inertia
b. Moment of Inertia
c. Torque
d. Angular acceleration
e. Center of mass

21. A rigid stick of negligible mass rests horizontally on a stand. On the left end of the stick hangs a 500-g block that is completely submerged in water and on the right end of the stick hangs a 300-g block in air, as shown in the diagram. If the fulcrum is 40.0 cm away from the left end of the stick and 60.0 cm from its right end, what is the tension in the string attached to the 500-g block? (The density of water is 1.00×10^3 kg/m^3 and the mass of the strings is negligible.)

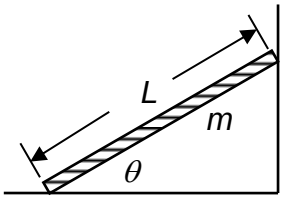


a. 2.00 N b. 4.41 N c. 4.90 N d. 5.00 N e. 6.20 N

22. In the situation described in problem 21, what is the volume of the 500-g block?

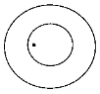
a. 30.0 cm^3 b. 40.0 cm^3 c. 50.0 cm^3 d. 60.0 cm^3 e. 70.0 cm^3

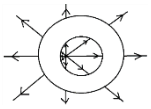
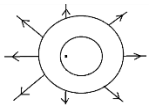
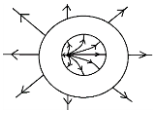
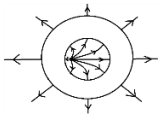
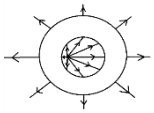
23. A ladder has one end leaning against a frictionless, vertical wall and the other end resting on a rough, horizontal floor, as shown in the diagram. The ladder has mass m, which is uniformly distributed along its length L, and makes an angle θ with the horizontal. What is the minimum requirement for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



a. $\sin\theta$ b. $\cos\theta$ c. $\sin\theta/\cos\theta$ d. $\cos\theta/\sin\theta$ e. $\cos\theta/(2\sin\theta)$

24. Consider a positive charge placed inside of a hollow spherical shell of conducting material as shown. What do the electric field lines look like?



a.  b.  c.  d.  e. 

25. A window washer's platform has a uniformly distributed mass of 25 kg and a length of 2.1m. The platform is supported at each end by a rope and is stationary and level. The window washer has a mass of 78 kg and is situated 0.5 m from one end of the platform. What is the tension in the rope at the other end of the platform?

a. 31.0 N b. 151 N c. 305 N d. 505 N e. 1480 N

26. A 1.00 kg particle is moving with a velocity of 0.75 m/s in a direction 45˚ below the x axis. Another particle with mass 1.30 kg is moving with a velocity 0.65 m/s in a direction 45˚ above the x axis. The two particles collide in a perfectly inelastic collision. What is the angle that the final velocity vector makes with the x axis?

a. 0.00˚ b. 3.41˚ c. 7.43˚ d. 48.4˚ e. 85.6˚

27. A beam of blue light of wavelength 480 nm travels from air into glass with index of refraction 1.48. As the beam goes from the air to the glass the beam will

a. slow down and increase frequency.
b. slow down and decrease frequency.
c. maintain frequency but increase wavelength.
d. maintain frequency but decrease wavelength.
e. not be changed.

28. The specific heat of water at 15.0 °C is 4186 J/(kg °C). If a 0.800 A current flows for 3.00 minutes through a 400-Ω resistor which is immersed in 500 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. 22.0 C° b. 0.0220 C° c. 0.0184 C° d. 18.4 C° e. 0.367 C°

29. One of the laws of thermodynamics can be expressed as $\Delta U = Q - W$, where U is the internal energy of a system, Q is the heat, and W is the work. This law is known as

a. The Zeroth Law of Thermodynamics
b. The First Law of Thermodynamics
c. The Second Law of Thermodynamics
d. The Third Law of Thermodynamics
e. The Fourth Law of Thermodynamics

30. The tagline in the original poster for the movie, *Alien*, was: "In space, no one can hear you scream." This tagline is consistent with which physical fact?

a. There is no source of sound in space.
b. Physical systems cannot vibrate in space.
c. Sound intensity decreases too fast with distance in space.
d. Sound cannot travel in a vacuum.
e. Sound vibrates at too low a frequency in space.

31. In the photoelectric effect, for a given metal, the frequency of the incident light must exceed a certain minimum value (the cutoff frequency) in order for electrons to be ejected from the metal. If the work function for a metal surface is 3.00 eV, what is the cutoff frequency of this metal surface?

a. 7.25×10^{14} Hz
b. 7.25×10^{15} Hz
c. 8.00×10^{14} Hz
d. 6.78×10^{33} Hz
e. 7.00×10^{19} Hz

32. Because it is confined to be inside of a certain atom, the uncertainty in the position of an electron in the atom is the size of the atom or 5.12×10^{-11}m. The minimum uncertainty in the velocity of this electron is

a. 1.03×10^{-24} m/s
b. 1.29×10^{-23} m/s
c. 1.13×10^{6} m/s
d. 2.26×10^{6} m/s
e. 1.42×10^{7} m/s

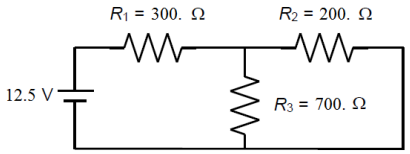
33. Consider a three turn coil of wire of radius 0.350 m that has a magnetic field directed perpendicular to the plan of the coil. The magnitude of the magnetic field is given in tesla by the equation:

$$B = 2t^3 - 5t + 1$$

with t given in seconds. What is the emf generated in the coil at a time of 2.00 sec?

a. 2.69V b. 6.98V c. 7.31V d. 8.08V e. 21.9V

34. What is the rate at which the battery delivers power to the circuit?



a. 0.0274W b. 0.130W c. 0.156W d. 0.343W e. 1.00W

35. A sample of material contains a single radioactive isotope with a half-life 25.0 minutes. At the time the activity of the sample is 2.30 μCi, how many atoms of the radioactive isotope are present? (1.0 Ci = 3.7×10^{10} decays/s)

a. 3.07×10^{6} b. 1.28×10^{8} c. 1.84×10^{8} d. 1.28×10^{14} e. 1.84×10^{14}