Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

PHYSICS TEST – SECTIONAL

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

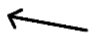
0.00 ^{o}C = 273.15

Academic Challenge
Physics Test (Sectional) – 2019

1. How many milliseconds in one 31 day month?

   a. 2.68×10^3 ms b. 1.12×10^5 ms c. 2.68×10^6 ms d. 1.12×10^8 ms e. 2.68×10^9 ms

2. Given vector A as  and vector B as , which of the following most closely shows A – B?

   a.  b.  c.  d.  e. 

3. If Galileo dropped a 7.50 kg mass from rest off of the Leaning Tower of Pisa from a height of 58.2 m above the ground, what would be the time it took the mass to reach the ground?

   a. 2.44 s b. 3.44 s c. 5.94 s d. 7.76 s e. 11.9 s

4. As a continuation of problem 3, what would be the speed of the object that Galileo dropped as it passes a window that is 2.45 m above the ground?

   a. 6.93 m/s b. 22.8 m/s c. 23.4 m/s d. 33.1 m/s e. 33.8 m/s

5. Daisy the dog is chasing a squirrel. The squirrel is running at his maximum speed of 2.78 m/s towards a tree. The squirrel is 5.25 m from the tree. Daisy is 9.68 m from the tree. At what constant speed must Daisy run in order to catch the squirrel at the tree?

   a. 1.65 m/s b. 2.35 m/s c. 3.31 m/s d. 4.43 m/s e. 5.13 m/s

6. Consider a car of total mass 675 kg on a circular unbanked bend in the road. The coefficient of static friction between the tires and the road is 0.835 and the coefficient of kinetic friction is 0.681. The radius of curvature of the bend is 45.2 m where the car is driving. What is the maximum speed that the car can travel and negotiate the bend without skidding?

   a. 12.5 m/s b. 15.9 m/s c. 17.4 m/s d. 19.2 m/s e. 21.0 m/s

7. Consider a cylinder rolling without slipping on a level surface. The cylinder has a mass of 2.47 kg and a radius of 7.50 cm. The speed with which this object moves across the surface is 2.15 m/s. What is the total kinetic energy of this object?

   a. 0.128 J b. 2.85 J c. 5.71 J d. 8.56 J e. 11.4 J

8. A bungee jumper of mass 62.1 kg drops from a height of 75.0 m above a river, attached to a cord of unstretched length 25.0 m. After she jumps, her lowest point is 11.2 m above the river. What is the spring constant of the cord?

   a. 19.1 N/m b. 24.3 N/m c. 31.4 N/m d. 51.6 N/m* e. 60.6 N/m

9. The position x of a particle moving along the x axis as a function of time t is given by $x = (1.00\text{ m}) + (3.00\text{ m/s})t - (2.00\text{ m/s}^2)t^2$. What is the acceleration of the particle?

   a. 3.00 m/s^2 b. -2.00 m/s^2 c. -4.00 m/s^2 d. 4.00 m/s^2 e. 0 m/s^2

10. In the situation described in problem 9, what is the instantaneous velocity of the particle at t = 1.00 s?

a. – 1.00 m/s b. – 4.00 m/s c. 1.00 m/s d. 3.00 m/s e. 0 m/s

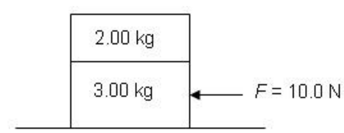
11. A grasshopper with a mass of 1.06 g and jumping legs that can produce a constant force over their 1.32 cm kick produces enough power to jump many times further than humans can jump for their size. The jump will launch the grasshopper horizontally with a velocity of 2.66 m/s. What is the power produced by the grasshopper during the launch?

a. 0.00151W b. 0.00375W c. 0.378W d. 1.51W e. 3.78W

12. A satellite is placed in circular orbit around the Moon. It is at an altitude of 60 km above the surface of the Moon. The mass of the Moon is 7.36×10^{22} kg and the radius of the Moon is 1.74×10^{6}m. What is the period of the orbit?

a. 29.0 min b. 85.5 min c. 1 hr 48 min d. 1 hr 54 min e. 13000 hr

13. Two blocks are placed on a frictionless surface, as shown in the diagram. A horizontal force of magnitude F = 10.0 N is applied to the block at the bottom. With this applied force, the two boxes are on the verge of sliding relative to each other. What is the acceleration of the two blocks?



a. 2.00 m/s^2 b. 2.50 m/s^2 c. 3.33 m/s^2 d. 4.00 m/s^2 e. 5.00 m/s^2

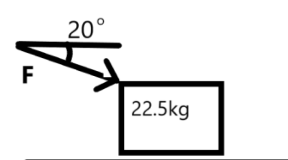
14. In the situation described in problem 13, what is the coefficient of static friction between the surfaces of the two blocks?

a. 0.150 b. 0.204 c. 0.268 d. 0.302 e. 0.400

15. A driver and car have a total mass of 950 kg and is traveling with a velocity of 26.8m/s. The driver applies the brakes and slows the car to 6.70 m/s in a distance of 300 m. What was the average net force acting on the car?

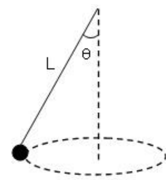
a. -2280N b. -1140N c. -1070N d. -2.24N e. 2130N

16. A 22.5 kg wooden crate is pushed across a wood floor. A force of 95.5N is applied to the crate in the direction shown. The coefficient of kinetic friction for wood on wood is 0.315. What is the acceleration of the crate across the floor?



a. 0.444 m/s^2 b. 0.901 m/s^2 c. 1.34 m/s^2 d. 3.99 m/s^2 e. 4.24 m/s^2

17. A small object is tied to a string and moves along a circle in a horizontal plane at a constant speed, as shown in the diagram. The string has length L and makes an angle θ with respect to the vertical. The magnitude of the acceleration due to gravity is g. What is the linear speed of the object?

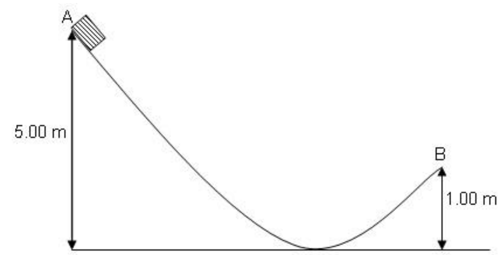


a. $(L \tan\theta)^{1/2}$ b. $(Lg)^{1/2}$ c. $(gL\cos\theta)^{1/2}$ d. $(Lg \tan\theta)^{1/2}$ e. $(Lg \sin\theta \tan\theta)^{1/2}$

18. The magnitude of a force on an object, F, is proportional to the ratio of the object's speed, v, and its cross-sectional area, A: $F = Cv/A$. What are the dimensions of the constant C?

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

19. A 1.00 kg-object starts from rest and moves from point A to point B along the path shown in the diagram. When it reaches point B, its speed is 5.00 m/s. Relative to the lowest point, the height of point A is 5.00 m and that of point B is 1.00 m. What is the work done by friction?



a. – 56.4 J b. – 40.5 J c. – 30.0 J d. – 26.7 J e. – 12.5 J

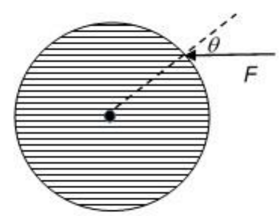
20. A bag of rice is thrown horizontally with an initial speed v onto a boat that is initially at rest. If the mass of the bag is m and that of the boat is M, what is the speed of the boat in the horizontal direction after the bag of rice lands? Ignore any air resistance and resistance between the boat and water.

a. 0 b. v c. $mv/(m + M)$ d. $(m + M)v/m$ e. Mv/M

21. A 0.200-kg bullet is fired horizontally to the right with a speed of 5.00 m/s into a 0.500-kg block that is initially at rest on a horizontal, rough surface. The coefficient of kinetic friction between the block and the surface is 0.400. The bullet is quickly stopped inside the block and the block (with the bullet inside) moves to the right. How far will the block move before coming to a rest?

a. 0.168 m b. 0.261 m c. 0.356 m d. 0.400 m e. 0.466 m

22. A force with a magnitude of F is applied on the rim of a round disk of radius R, as shown in the diagram. The disk can rotate about an axis through its center. What is the magnitude of the torque produced by this force about the axis?



a. $FR \sin\theta$ b. $FR \cos\theta$ c. FR d. $FR \tan\theta$ e. F

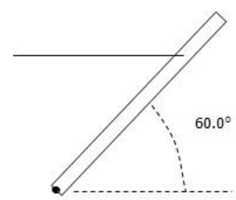
23. If an object is in static equilibrium,

a. the total force must be zero, but the total torque is not necessarily zero.
b. both the total force and total torque must be zero.
c. the total torque must be zero, but the total force is not necessarily zero.
d. the object cannot experience any external forces at all.
e. the object cannot experience any external torques at all.

24. According to Archimedes' Principle, the buoyant force F_b is given by $F_b = \rho g V$. Which statement below is correct regarding the quantities ρ and V?

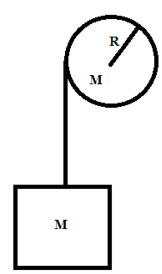
a. ρ and V represent the density and volume of the object, respectively.
b. ρ represents the density of the fluid and V represents the volume of the object.
c. ρ represents the density of the fluid and V represents the volume of the fluid displaced by the submerged object.
d. ρ represents the density of water and V represents the volume of the object.
e. ρ represents the density of water and V represents the volume of water displaced by the submerged object.

25. A uniform density board has weight 250 N and length 2.00 m. It is pinned at its lower left end and a horizontal string tied 0.500 m from the upper end of the board prevents the board from falling from the position shown. What is the tension in the string?



a. 289 N b. 250 N c. 180 N d. 125 N e. 96.2 N

26. A solid disk of radius R has a light string wrapped around the outside edge. A mass that is the same mass as the disk hangs from the string as shown. The disk can rotate freely on the axis through its center. The string is attached so that it does not slip on the disk as it unwinds. What is the acceleration of the mass if it is released from rest?



a. 0.00 b. $\frac{1}{2}g$ c. $\frac{2}{3}g$ d. $\frac{4}{5}g$ e. g

27. A centrifuge is operating at a constant speed of rotation. A particle that is 20.0 cm from the center of rotation experiences an acceleration of 600,000 m/s^2. What is the angular velocity of the centrifuge?

a. 276 rad/s b. 346 rad/s c. 1730 rad/s d. 2180 rad/sec e. $3.00\text{x}10^6$ rad/s

28. 2.00 moles of a monatomic ideal gas are sealed in a container at a temperature of 250˚C and an absolute pressure of 1.63 atm. If the volume of the gas remains constant, what will be the absolute pressure of the gas if the temperature increases to 600 ˚C?

a. 2.72 atm b. 3.91 atm c. 4.50 atm d. 4.80 atm e. 5.26 atm

29. A constant mass of monatomic ideal gas expands from 3.00 m^3 to 5.00 m^3 at a constant pressure 3.00×10^5 Pa. If the change in internal energy of the gas during this process is 8.00×10^5 J, how much heat was added to the gas during the process?

a. 2.00×10^5 J b. 12.0×10^5 J c. 14.0×10^5 J d. -14.0×10^5 J e. -6.00×10^5 J

30. A pipe is open at both ends. The length of the pipe is 1.00 m. The speed of sound in air is 344 m/s. What is the lowest resonant frequency of this pipe?

a. 150 Hz b. 172 Hz c. 186 Hz d. 260 Hz e. 344 Hz

31. In quantum mechanics, the wave function ψ for the lowest energy state of a particle in a box of length L is given by $\psi = (2/L)^{1/2} \sin(\pi x/L)$. Which statement below is correct regarding the absolute square $|\psi|^2$ of the wave function?

a. $|\psi|^2$ represents the probability of finding the particle at any given point in space.
b. $|\psi|^2$ represents the probability density of finding the particle at any given point in space.
c. $|\psi|^2$ represents the energy of the particle at any given point in space.
d. $|\psi|^2$ represents the kinetic energy of the particle at any given point in space.
e. $|\psi|^2$ represents the potential energy of the particle at any given point in space.

32. A single slit experiment has laser light of wavelength 514 nm falling on the slit. The detection screen is 1.34 m from the slit. The third interference minimum occurs at a distance of 2.75 cm from the central maximum. What is the width of the slit?

a. 7.51 μm b. 25.0 μm c. 75.1 μm d. 250 μm e. 751 μ

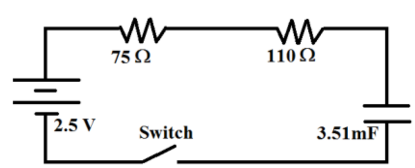
33. In a nuclear explosion 0.667 mg of mass was converted into energy. In a chemical explosion of 1000 kg of TNT 4.00×10^9 J of energy is released. How many kg of TNT would it take to make an explosion equivalent to the energy released in the nuclear explosion above?

a. 15.0 kg b. 15,000 kg c. 1.50×10^7 kg d. 6.00×10^9 kg e. 6.00×10^{15} kg

34. The first battery was constructed by layering zinc, copper and parchment that has been soaked in salt water. Who is credited with developing this first battery?

a. Benjamin Franklin
b. Alessandro Volta
c. Michael Faraday
d. Luigi Galvani
e. Aristotle

35. Consider the RC circuit to the right. The voltage source, the resistors, and the capacitor have the values shown. The switch is closed at time t=0.00. What is the charge on the capacitor after 0.158 s?



a. 1.90 mC b. 2.41 mC c. 2.94 mC d. 3.76 mC e. 3.96 mC