Worldwide Youth in Science and Engineering

2014 Academic Challenge

PHYSICS TEST - STATE

This Test Consists of 35 Questions

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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. Only 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 *****

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·m^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·m^2/kg^2
Universal gas constant	R	8.3145 J/(mol·K)
Stefan-Boltzmann constant	σ	5.6703×10^{-8} W/(m^2·K^4)

Other information:

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

0.00 ^{o}C = 273.15 K

WYSE – Academic Challenge
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1. Which of the following relationships is correct if acceleration is not constant?

   a. $x = x_0 + v_0 t + \frac{1}{2} a t^2$
   b. $v = v_0 + at$
   c. $v^2 - v_0^2 = 2a(x - x_0)$
   d. $\bar{v} = \frac{x - x_0}{t}$
   e. $x = x_0 + \frac{1}{2}(v + v_0)t$

2. What are the physical dimensions of mechanical work? [L] = length, [M] = mass, [T] = time

   a. $\frac{[M][L]}{[T]}$ b. $\frac{[M]^2[L]}{[T]}$ c. $\frac{[M][L]}{[T]^2}$ d. $\frac{[M][L]^2}{[T]}$ e. $\frac{[M][L]^2}{[T]^2}$

3. A bicyclist starts from rest at the top of a hill with a uniform slope. The bicyclist rolls with constant acceleration a distance 120. m downward along the slope in 10.0 s. What is the magnitude of the average acceleration of the bicyclist during this motion?

   a. 2.40 m/s^2 b. 6.00 m/s^2 c. 9.80 m/s^2 d. 12.0 m/s^2 e. 24.0 m/s^2

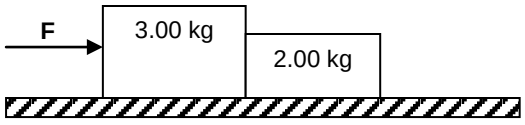
4. In problem 3, what was the average speed of the bicyclist during the motion described?

   a. 2.40 m/s b. 6.00 m/s c. 9.80 m/s d. 12.0 m/s e. 24.0 m/s

5. Three forces act on an object. The first force has a magnitude 20.0 N and is directed toward the north. The second force has a magnitude 30.0 N and acts toward the east. The third force has a magnitude 60.0 N and acts toward the south. What is the magnitude of the net force acting on the object?

   a. 50.0 N b. 70.0 N c. 90.0 N d. 100.0 N e. 110.0 N

6. Force **F** is applied horizontally to the 3.00 kg block which is in contact with the 2.00 kg block. If the blocks are sliding along a frictionless, level surface, what is the magnitude of the force of contact between the two blocks?

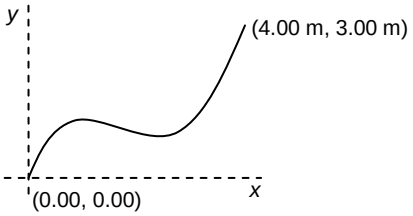


   a. $\frac{2}{5}|\mathbf{F}|$ b. $\frac{3}{5}|\mathbf{F}|$ c. $\frac{2}{3}|\mathbf{F}|$ d. $\frac{4}{5}|\mathbf{F}|$ e. $|\mathbf{F}|$

7. A pilot flies a plane 400. miles in 2.00 hours in a direction 60.0° north of east to reach an intermediate destination. Then the pilot flies the plane 200. miles in 1.00 hour in a direction 30.0° south of east to the final destination. What is the magnitude of the average velocity of the plane for the entire trip?

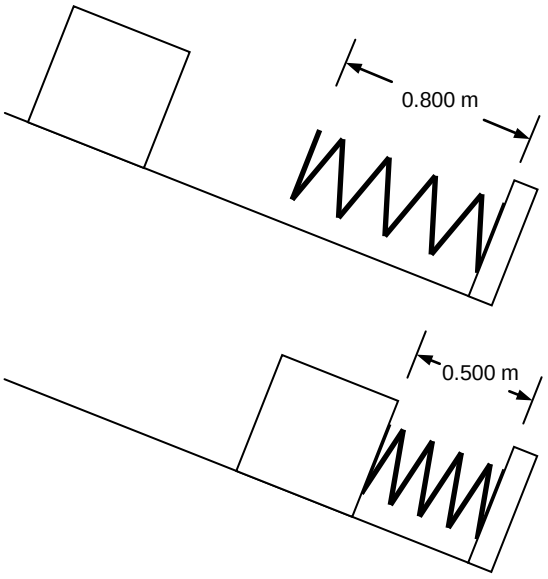
   a. 149. miles/hour
   b. 200. miles/hour
   c. 220. miles/hour
   d. 250. miles/hour
   e. 300. miles/hour

8. A constant force of 20.0 N in the positive *x*-direction acts on an object as it moves along the path shown, with endpoints at coordinates (0.00, 0.00) and (4.00 m, 3.00 m). The length along the path is 6.00 m. What is the work done by the 20.0 N force as the object moves from (0.00, 0.00) to (4.00 m, 3.00 m) along the given path?



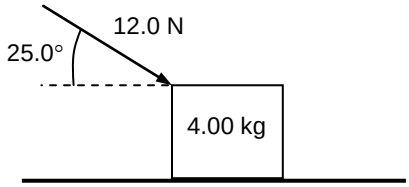
   a. 0.00 J b. 60.0 J c. 80.0 J d. 100. J e. 120. J

9. A 6.00 kg block is released form rest from the position shown in the upper diagram. The block slides down the frictionless surface and contacts the initially relaxed spring. The block comes to rest in the position shown in the lower diagram. If the spring constant of the spring is 300. N/m, what is the change in gravitational potential energy as the block slides down the slope?



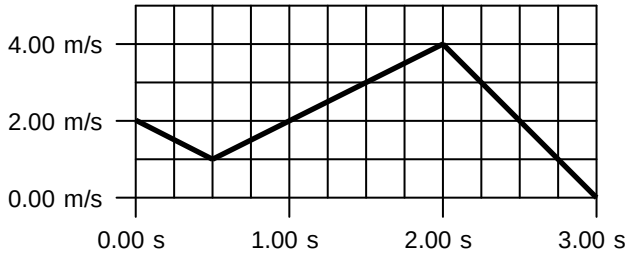
   a. −27.0 J
   b. −13.5 J
   c. +13.5 J
   d. +27.0 J
   e. +40.0 J

10. As the 12.0 N force acts on the 4.00 kg block, the block slides along the level surface of the earth with an acceleration of 2.00 m/s^2. What is the coefficient of kinetic friction between the block and the level surface?



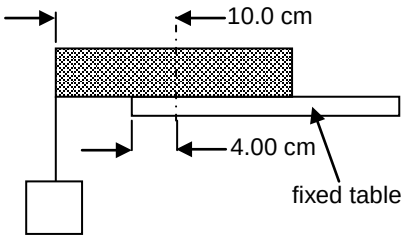
   a. 0.0650 b. 0.0734 c. 0.204 d. 0.322 e. 0.567

11. A plot of the *x*-component of the velocity of an object as a function of time is shown in the graph. What is the *x*-component of the displacement of the object between 0.00 s and 3.00 s?



a. −2.00 m b. +2.00 m c. 6.00 m d. +6.50 m e. +8.50 m

12. A 2.00 kg uniform block of length 20.0 cm rests on the edge of a fixed table such that its center is 4.00 cm from the edge of the table. A second block is suspended from the end of the first block, as shown. What is the greatest mass for the suspended block which will not cause the first block to tip and fall off of the table?

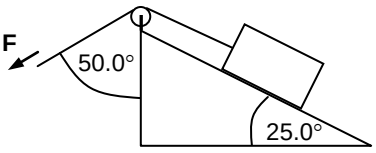


a. 0.800 kg b. 1.33 kg c. 2.50 kg d. 3.00 kg e. 5.00 kg

13. A 5.00 kg mass is attached to a 3.00 kg mass. Between the two masses is a massless, compressed spring. The combined object has a velocity of 2.00 m/s east as it slides on a level, frictionless surface. When the connection between the objects is broken, the spring pushes the objects apart, and the 3.00 kg mass ends up with a velocity of 1.00 m/s west. What is the final velocity of the 5.00 kg mass?

a. 2.60 m/s east
b. 3.80 m/s east
c. 4.00 m/s east
d. 4.20 m/s east
e. 5.00 m/s east

14. A block of weight *w* remains at rest on a frictionless surface that is inclined 25.0° from horizontal, while force **F** is applied to the rope that passes over the frictionless pulley. The rope has negligible mass. What is the magnitude of force **F**?



a. *w* cos 25.0°
b. *w* sin 25.0°
c. *w* cos 25.0°/cos 50.0°
d. *w* cos 25.0°/sin 50.0°
e. *w* sin 25.0°/cos 50.0°

15. The center of mass of an object is at rest. The object explodes and splits into three fragments. The first fragment has a mass 2.00 kg and an initial velocity after the explosion (300. m/s, 200. m/s, 100. m/s). The second fragment has a mass 1.00 kg and an initial velocity (−400. m/s, 400. m/s, 200. m/s). The third fragment has a mass 3.00 kg. What is the initial velocity of the third fragment after the explosion?

a. (−66.7 m/s, −267. m/s, −133. m/s)
b. (−200. m/s, −800. m/s, 400. m/s)
c. (100. m/s, −600. m/s, −300. m/s)
d. (−100. m/s, 600. m/s, 300. m/s)
e. (−33.3 m/s, −200. m/s, −100. m/s)

16. A spring obeys Hooke's Law. The length of the spring is 20.0 cm when stretched by a force 100. N, and the length of the spring is 30.0 cm when stretched by a force 200. N. What is the relaxed length of the spring when no forces are stretching it?

a. 0.00 cm b. 6.00 cm c. 8.00 cm d. 10.0 cm e. 12.0 cm

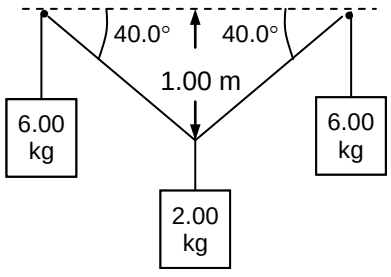
17. During a certain 8.00 s time interval, the potential energy of a system changes from 20.0 J to 80.0 J and the kinetic energy of the system changes from 70.0 J to 40.0 J. What is the average power applied to the system by external forces during the specified time interval?

a. 2.50 W b. 3.75 W c. 5.00 W d. 5.00 hp e. 11.3 W

18. A figure skater starts a spin at a relatively low rotation rate. Which law or principle can be most directly applied to the situation to explain how the skater can increase the rotation rate of the spin?

a. Ideal Gas Law
b. Law of Conservation of Energy
c. Bernouli's Principle
d. Law of Conservation of Angular Momentum
e. Archimede's Principle

19. The two outer blocks of mass 6.00 kg and the center block of mass 2.00 kg, which are connected by strings, are simultaneously released from rest from the symmetric positions shown. The connecting strings have negligible mass as do the frictionless pins over which the strings pass. What will the speed of the center block be when the strings connected to it are horizontal? (Hint: When the strings are horizontal, the velocity of the two outside blocks will be zero.)



a. 1.05 m/s b. 2.58 m/s c. 3.33 m/s d. 4.82 m/s e. 6.89 m/s

20. A satellite in a circular orbit of radius 1.00*R* about a planet has an orbital period of 30.0 h. What is the orbital period of a satellite in a circular orbit of radius 8.00*R* about the same planet?

a. 4.25 h b. 84.9 h c. 240. h d. 679. h e. 1.92×10^{3} h

21. A disk is rotating with a constant angular velocity 6.00 revolutions per second about a fixed axis. What is the speed of a point A on the disk that is a distance 20.0 cm from the center of the disk?

a. 60.0 cm/s b. 120. cm/s c. 314. cm/s d. 628. cm/s e. 754. cm/s

22. During a particular cyclic process that a system undergoes, 200.0 J of heat flows into the system from a reservoir which is at 800. °C, and 100.0 J of heat flows out of the system into a reservoir which is at 200. °C. What is the minimum increase in entropy of the system and reservoirs that occurs during a cycle of this process?

a. 0.0111 J/K b. 0.0250 J/K c. 0.324 J/K d. 0.407 J/K e. 2.56 J/K

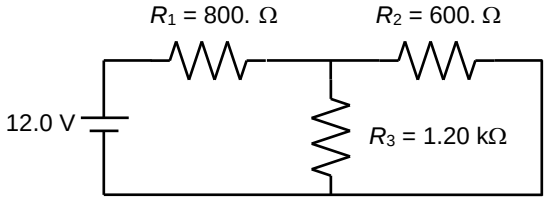
23. In problem 22, how much work does the system do on the environment during one cycle of the process?

a. 0.0 J
b. 100. J
c. 200. J
d. 300. J
e. The answer depends on other factors not given.

24. A 200. kg solid wooden raft floats on water with 50.0% of its volume submerged. Two 80.0 kg people climb onto the raft. What percentage of the raft's volume is submerged with the two people on top?

a. 60.0% b. 70.0% c. 80.0% d. 90.0% e. 100.%

25. What is the rate at which the battery delivers power to the rest of the circuit?



a. 0.120 W
b. 0.150 W
c. 0.200 W
d. 0.333 W
e. 0.566 W

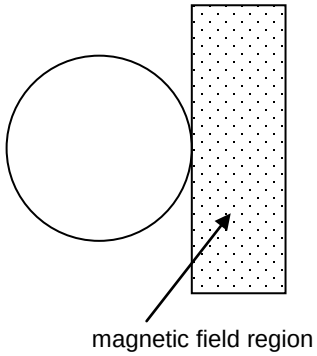
26. A thin lens is used to form a real image of a 1.00 cm long ant that is oriented perpendicularly to the optic axis. A sharp image is formed on a screen that is 3.00 m away from the lens, and the image of the ant is 20.0 cm long. What is the focal length of the lens?

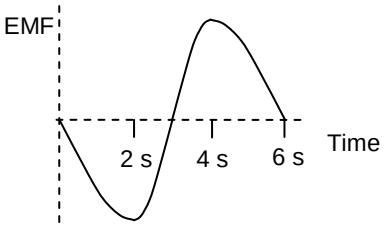
a. 6.67 cm b. 13.3 cm c. 14.3 cm d. 15.0 cm e. 20.0 cm

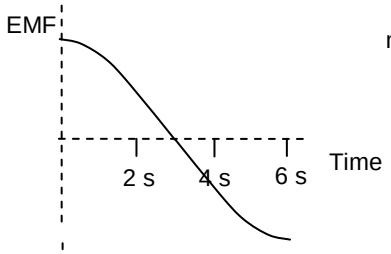
27. Terry has come up with a possible solution to the energy crisis and loss of polar ice rolled into one. There is plenty of internal energy stored in polar ice. Terry's idea is to extract the energy from the ice, thus cooling the ice to help the polar temperatures freeze yet more ice. The extracted energy can be used in place of carbon fuels, with the waste heat going back into the environment which would eventually find its way back to the poles to be extracted once again. What law of physics does Terry's plan definitely violate?

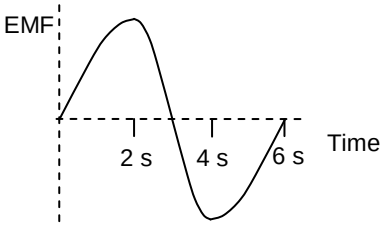
a. Newton's Second Law
b. The Law of Conservation of Momentum
c. The Law of Conservation of Energy
d. The Law of Conservation of Baryon Number
e The Second Law of Thermodynamics

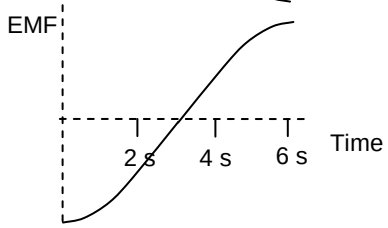
28. A 0.500 m radius circular hoop lying in the plain of the page is pulled at a constant speed of 0.250 m/s to the right through a region with a uniform magnetic field of 2.00T. The magnetic field points out of the page, and the width of the field region is 0.500 m. If the induced electromotive force in the hoop is measured in the clockwise direction, which graph best represents the induced electromotive force as a function of time?

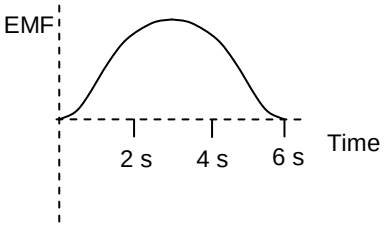


a.


b.


c.


d.


e.


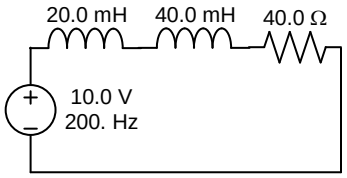
29. An electron moves through a uniform magnetic field of magnitude 6.00 T with an 80.0 km/s velocity component perpendicular to the magnetic field. What is the radius of curvature of the trajectory of the electron?

a. 7.58×10^{-8} m
b. 1.33×10^{-4} m
c. 4.62×10^{-2} m
d. $1.33 \times 10^{+1}$ m
e. $1.33 \times 10^{+4}$ m

30. In the situation described in problem 29, if the only force acting on the electron is due to the magnetic field, what is the component of the acceleration of the electron in the direction parallel to the magnetic field?

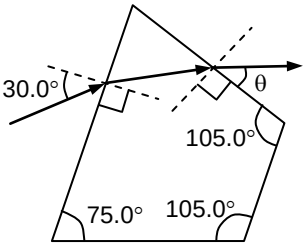
a. 0.00 m/s^2 b. 0.444 m/s^2 c. 3.44 m/s^2 d. 9.80 m/s^2 e. $8.44 \times 10^{+16}$ m/s^2

31. A 10.0 V amplitude, 200. Hz, sinusoidal voltage source is connected across the series combination of a 20.0 mH inductor, a 40.0 mH inductor, and a 40.0 Ω resistor as shown in the diagram. What is the amplitude of the voltage across the resistor?



a. 0.00 V b. 3.47 V c. 4.00 V d. 4.69 V e. 10.0 V

32. A ray of light traveling in air (n = 1.00) enters a block of material (n = 1.20) at the angle indicated in the diagram, passes through the block, and exits in the direction shown. What is angle θ?



a. 44.0°
b. 33.6°
c. 28.8°
d. 25.5°
e. 22.4°

33. An observer on the earth measures a spaceship passing by to have a length of 20.0 m in the direction it is traveling. If the speed of the spaceship relative to the earth is 0.500c, what would be the length of the spaceship as measured by someone traveling on the spaceship?

a. 14.1 m b. 15.0 m c. 17.3 m d. 20.0 m e. 23.1 m

34. The emission spectrum of atomic hydrogen contains light of wavelength 1280 nm. Given that Rydberg's constant is 1.0974×10^7 m^{-1} and that the initial state of the atom has principle quantum number $n_{initial}$ = 5, what is the final state principle quantum number that results in light emitted at this wavelength?

a. 1 b. 2 c. 3 d. 4 e. 6

35. A radioactive isotope sample contains 2.00×10^{12} nuclei. If the halflife of this isotope is 2000. s, what will be the initial activity of this sample?

a. 2.55×10^6 decays/s
b. 2.55×10^7 decays/s
c. 6.67×10^8 decays/s
d. 6.93×10^8 decays/s
e. 1.00×10^9 decays/s