Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

PHYSICS TEST – STATE

Physics Test Production Team

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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. 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
2019 State Physics Exam

1. A particle moves along the x-axis with constant acceleration 2.00 m/s^2. At t = 1.00 s, its position and velocity are 1.00 m and 5.00 m/s, respectively. What is its position at t = 2.00 s?

   a. 7.00 m b. 10.0 m c. 12.0 m d. 15.0 m e. 20.0 m

2. A swimmer is crossing a 54.9 m wide river with a current flowing at 0.70 m/s. The swimmer is able to swim with a speed of 1.80 m/s in still water. What is the minimum time that it will take for the swimmer to go directly across the river (landing without moving downstream)?

   a. 22.0 s b. 28.4 s c. 30.5 s d. 33.1 s e. 49.9 s

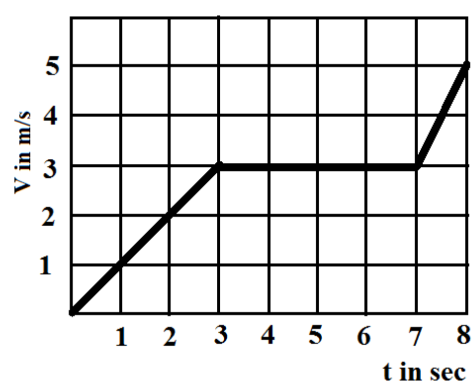
3. Vector $\vec{\boldsymbol{A}}$ has magnitude 3.47 and a direction of 132˚ from the +x axis. Vector $\vec{\boldsymbol{B}}$ is given by $1.80\hat{x} - 0.80\hat{y}$. What is the magnitude and direction of $\vec{\boldsymbol{A}} + \vec{\boldsymbol{B}}$?

   a. $1.85\ at\ 106^o$ b. $1.85\ at\ -73.7^o$ c. $5.38\ at\ -35.5^o$
   d. $5.44\ at\ 132^o$ e. $6.07\ at\ 38.9^o$

4. A ball is thrown straight upward with initial speed v_0. The magnitude of acceleration due to gravity is g. If we choose the origin to be the position at which the ball was initially thrown and the +y-axis to be directed straight downward, the correct equation that describes the ball's position y as a function of time t (time elapsed since the ball was thrown) is

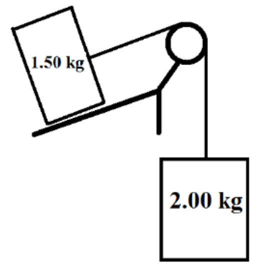
   a. $y = v_0t + (1/2)gt^2$ b. $y = v_0t - (1/2)gt^2$ c. $y = -v_0t + (1/2)gt^2$
   d. $y = -v_0t - (1/2)gt^2$ d. $y = v_0 - (1/2)gt$

5. Consider the velocity – time graph shown. The object starts at the origin at time 0.00. What is the position of the object at the time of 8.00 s?



   a. 0.60 m b. 5.00 m c. 8.50 m d. 20.5 m e. 24.0 m

6. A 1.50 kg mass is on a rough incline and attached to a string that passes over a pulley to a second mass of 2.00 kg. The coefficients of static and kinetic friction between the incline and the first mass are 0.20 and 0.12 respectively. The incline is at 20˚ to the horizontal. What is the acceleration of the hanging mass (considering downward to be positive) if the system is released from rest?

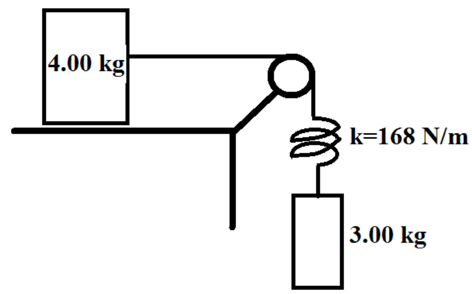


a. 0.00 m/s^2 b. 3.38 m/s^2 c. 3.69 m/s^2 d. 4.20 m/s e. 9.81 m/s^2

7. Considering the situation in problem 6 above, what is the tension in the string?

a. 0.0 N b. 8.2 N c. 12.2 N d. 12.9 N e. 19.6 N

8. Consider a mass of 4.00 kg attached to a string that passes over a frictionless, massless pulley to a massless spring of spring constant 168 N/m. The mass is on a flat frictionless surface. The other end of the spring is attached to a 3.00 kg mass. What initial extension of the spring if there are to be no oscillations in the spring after the two masses are released from rest?



a. 2.50 cm b. 10.0 cm c. 16.8 cm d. 17.5 cm e. 23.3 cm

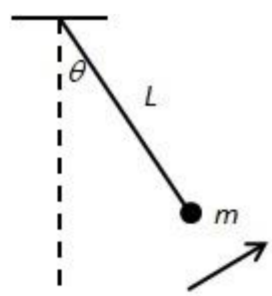
9. The bicycling land speed record is 183 mi/hr. How long would it take this rider to cover a 200 m test track at this speed?

a. 0.098 s b. 0.409 s c. 1.09 s d. 2.44 s e. 10.2 s

10. If the 65.1 kg rider of the bicycle in problem 9 above generates 1450 W of power what is the drag force that they overcome in this race?

a. 17.7 N b. 22.3 N c. 150 N d. 638 N e. 1150 N

11. A simple pendulum has length L = 1.00 m and a bob of mass m = 0.500 kg, as shown in the diagram. At the instant when the pendulum makes an angle θ = 10.0° with the vertical and swings away from its equilibrium position, what is the rate of change of its linear speed? Ignore air resistance and any other sources of friction.

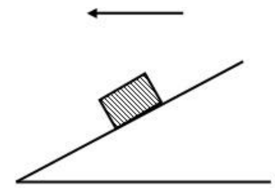


a. 0 m/s^2 b. –1.70 m/s^2 c. 1.70 m/s^2 d. –2.80 m/s^2 e. 2.80 m/s^2

12. In the situation described in problem 11, if at the instant when the pendulum makes an angle of 10.0° with the vertical, the tension in the string is 6.00 N, what is the linear speed of the bob at that instant?

a. 3.46 m/s b. 3.21 m/s c. 2.66 m/s d. 2.08 m/s e. 1.53 m/s

13. An inclined plane with a 1.00-kg block placed on it moves horizontally to the left with a constant acceleration of 2.00 m/s^2 relative to the ground, as shown in the diagram. In order for the block to remain at rest relative to the inclined plane, what should be the angle of the inclined plane relative to the horizontal? Ignore friction between the block and the inclined plane.



a. 10.0° b. 11.5° c. 20.0° d. 25.0° e. 30.0°

14. Given M = mass, L= Length, and T = time, the dimensions of angular momentum are

a. M·L^2/T. b. M·L/T^2. c. M·L^2/T^2. d. M^2·L^2/T. e. M^2·L^2/T^3.

15. An object of mass m_1 moving to the right with speed v_1 collides with another object of mass m_2 that is initially at rest. After the collision, m_1 moves to the right with speed v_1' and m_2 moves to the right with speed v_2'. If m_1 = 2.00 kg, m_2 = 1.00 kg, v_1 = 1.00 m/s, v_1' = 0.550 m/s, and v_2' = 0.900 m/s, what is the type of collision between the two objects?

a. Elastic.
b. Completely inelastic.
c. Inelastic, but not completely inelastic.
d. Partially elastic and partially inelastic.
e. A type of collision where momentum is not conserved.

16. Escape velocity in physics is defined as

a. The velocity such that the kinetic energy is equal to the gravitational potential energy.
b. The speed that will overcome the force of gravity.
c. The velocity that will be more than gravity.
d. The velocity needed to escape an electron.
e. The velocity such that the kinetic energy is equal to the opposite of the gravitational potential energy.

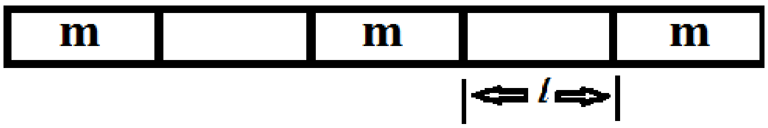
17. A 1550 kg car moving with a speed of 30.0 m/s in the x direction collides with a 1270 kg car moving with a speed of 22.0 m/s and angle of 55˚ above the x axis. The two cars lock bumpers during the collision and move away together. What is the velocity of the vehicles immediately after the collision?

a. 13.5 m/s at 36.9˚ b. 16.5 m/s at 55.0˚ c. 23.6 m/s at 20.1˚
d. 26.0 m/s at 0.0˚ e. 26.4 m/s at 27.5˚

18. How much mechanical energy is lost by the cars in the collision in problem 17?

a. 0.00 J b. 2.20 x 10^5 J c. 4.40 x 10^5 J d. 7.85 x 10^5 J e. 1.00 x 10^6 J

19. Consider a rod consisting of 5 equal length, *l*, parts. The first, third, and fifth parts have a mass *m* and the second and fourth are massless. The moment of inertia of a solid rod about an axis perpendicular to the rod and through its center is $\frac{1}{12}ml^2$. What is the moment of inertia about an axis through the center of this 5 part rod?



a. $\frac{3}{12}ml^2$ b. $\frac{5}{12}ml^2$ c. $\frac{1}{12}m(5l)^2$
d. $\frac{1}{12}m(5l)^2 - \frac{1}{12}m(3l)^2 + \frac{1}{12}m(l)^2$ e. $\frac{3}{12}m(l)^2 + 2m(2l)^2$

20. A fan is turned on and starts from rest. It has a constant angular acceleration of 34.1 rad/s^2. How much angle will it take to get the fan up to its operating speed of 10.3 rev/s?

a. 1.56 rad b. 3.31 rad c. 19.6 rad d. 61.4 rad e. 123 rad

21. Mollie the hamster runs on her exercise wheel. Mollie is running with a linear speed of 0.785 m/s. The angular velocity of the wheel is 1.67 rev/s. What is the radius of the wheel?

a. 0.0470 m b. 0.0587 m c. 0.0748 m d. 0.0824 m e. 0.470 m

22. A converging thin lens of focal length of 20 cm is placed between an object and a screen. The distance between the object and the screen is 100 cm. To form an enlarged image on the screen, what should be the distance between the object and lens?

a. 72.4 cm b. 70.0 cm c. 30.0 cm d. 27.6 cm e. 20.0 cm

23. A figure skater begins a spin with an angular speed 5.00 rad/s while the configuration of the skater's body has a moment of inertia 30.0 kg·m^2 about the vertical rotation axis. The skater increases the angular speed of rotation to 8.00 rad/s by a body reconfiguration which changes the skater's moment of inertia. If no external torque acts on the skater, how much work did the skater do to reconfigure her body?

a. 120 J b. 160 J c. 225 J d. 320 J e. 360 J

24. A simple pendulum with length *L* oscillates at small angles in air. The bob has mass *m* and is charged with charge +*Q*. An oscillating electric field with angular frequency ω is applied in the horizontal direction. The amplitude of the pendulum will reach its maximum value when ω is adjusted close to which value?

a. (Q/L)$^{1/2}$ b. (g/L)$^{1/2}$ c. (m/L)$^{1/2}$ d. (L/Q)$^{1/2}$ e. (Q/m)$^{1/2}$

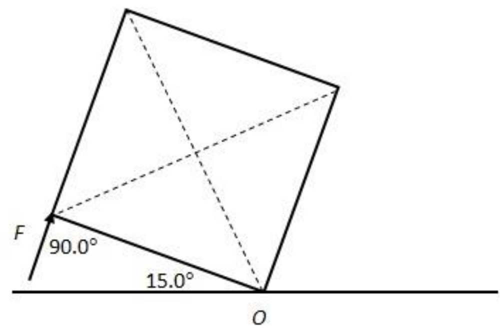
25. When a plane wave passes through an opening, it spreads out. This phenomenon is called

a. wave interference. b. wave superposition. c. wave diffraction .
d. wave amplification. e. wave function.

26. Two speakers send out sound waves at the same frequency. A person stands at a location 4.00 m from one speaker and 2.00 m from the other. What is the minimum frequency of the sound waves such that the person experiences a constructive interference of the two sound waves? Assume the two speakers are out of phase by π radians and sound travels in air at 344 m/s.

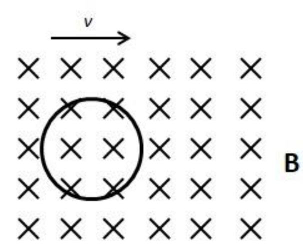
a. 86.0 Hz b. 172 Hz c. 260 Hz d. 300 Hz e. 344 Hz

27. A force of magnitude F is applied to a uniform object, as shown in the diagram. The object has mass 5.00 kg and has equal length on all sides. The object is in contact with the floor at point O and is in static equilibrium. What is F?



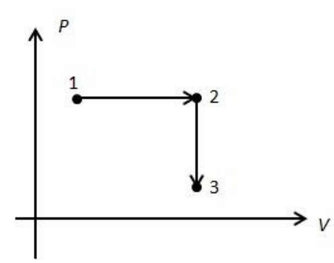
a. 49.0 N b. 30.0 N c. 24.5 N
d. 17.3 N e. 12.6 N

28. A metal ring of area A moves to the right with a constant speed v in a uniform magnetic field with strength B. The magnetic field is directed perpendicularly into the plane of the ring. If the magnetic field remains constant and the ring has a resistance R, what is the induced current in the metal ring?



a. $BAvR$ b. BA/R c. BAv/R d. BAv e. 0

29. A fixed amount of ideal gas changes its thermodynamic state from 1→2→3 according to the PV-diagram as shown. Which statement below is correct about the temperature of the gas?



a. $T_1 < T_2$ and $T_2 > T_3$ b. $T_1 = T_2 = T_3$ c. $T_1 = T_2$ and $T_2 > T_3$
d. $T_1 < T_2$ and $T_2 = T_3$ e. $T_1 < T_2 < T_3$

30. The energy of a photon is given by hf, where h is the Planck's constant and f is the frequency of light. If an atom makes a transition from a higher energy level E_2 to a lower energy level E_1, what is the frequency f of light emitted?

a. E_2/h b. E_1/h c. $(E_2 - E_1)/h$ d. $(E_2 + E_1)/h$ e. $(E_1 - E_2)/h$

31. To measure the speed of sound in air, a 440-Hz tuning fork is placed in front of a tube with a movable plunger. Two consecutive resonances are observed when the plunger changes it position along the length of the tube by 0.386 m. What is the speed of sound in air? Assume that the plunger reflects sound completely.

a. 320 m/s b. 330 m/s c. 340 m/s d. 344 m/s e. 350 m/s

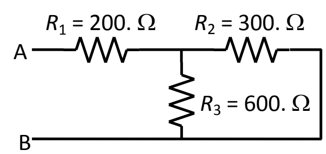
32. The half-life of a K meson is 9.80×10^{-9} s. A beam of K mesons is created with a speed of 0.85c according to an experimenter in the lab. What fraction of the original K meson beam remains after 1.7×10^{-8} s passes in the lab reference frame?

a. 100% b. 71.6% c. 53.1% d. 40.1% e. 7.20%

33. A thermodynamic system undergoes a process while the system is thermally isolated during which its entropy increases. Is it possible and, if so, how is it possible to decrease the entropy of the system to its original value?

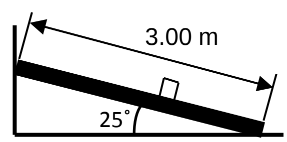
a. No. entropy never decreases.
b. Yes, reverse the process that took place, keeping the system thermally isolated.
c. Yes, allow the system to do positive work on the environment while thermally isolated.
d. Yes, allow the environment to do positive work on the system while thermally isolated.
e. Yes, allow heat to flow out of the system into the environment.

34. What is the equivalent resistance between nodes A and B of the network shown in the diagram?.



a. 100. Ω b. 164. Ω c. 400. Ω
d. 720. Ω e. 1100. Ω

35. A 3.00 kg board that is 3.00 m long rests with one end on the rough floor and the other end leaning against a frictionless wall. The board makes a 25˚ angle with the horizontal floor. An 8.0 kg crate sits on the board at a point 2.00 m from the end that is touching the wall. What is the magnitude of the normal force at the wall acting on the board?



a. 108 N b. 87.6 N c. 45.6 N d. 40.7 N e. 8.94 N