2015 Academic Challenge

PHYSICS TEST - SECTIONAL

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} $C^2/(N \cdot m^2)$**
Electrostatic Constant	$k=(4\pi\varepsilon_0)^{-1}$	**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:

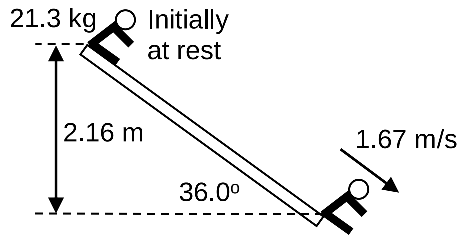
Acceleration due to gravity at Earth's surface: $g = 9.80$ m/s^2

0.00 ^oC = 273.15 K

1. Which of the following has dimensions of $\frac{1}{\text{time}}$?

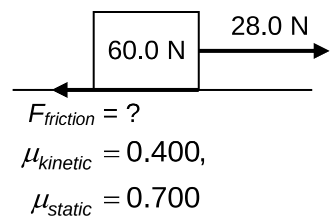
a. momentum / mass
b. momentum / force
c. energy / work
d. power / energy
e. energy / force

2. Beginning from rest, a 21.3 kg child drops a vertical distance of 2.16 m as she slides down a slide which is inclined at an angle of 36.0° to the horizontal. If her speed at the bottom of the drop is 1.67 m/s, what **magnitude** of work did friction do on her during the slide?



a. 737 J   b. 421 J   c. 235 J   d. 481 J   e. 391 J

3. A block having a weight of 60.0 N rests upon a horizontal surface (on Earth). The coefficient of static friction between the block and the surface is 0.700, while the coefficient of kinetic friction is 0.400. If you apply a horizontal force of 28.0 N to the initially resting block, the magnitude of the frictional force between the block and the surface will be

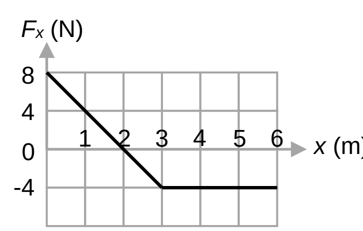


a. 0.00 N.   b. 28.0 N.   c. 42.0 N.   d. 24.0 N.   e. 4.00 N.

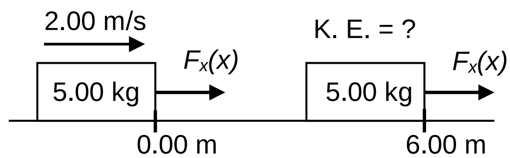
4. For the same situation as in problem 3, if a horizontal force of 44.0 N is suddenly applied to the initially resting block (instead of the 28.0 N force), how fast will the block be moving 2.40 s after the initiation of the 44.0 N force?

a. 0.784 m/s   b. 0.800 m/s   c. 1.66 m/s   d. 3.27 m/s   e. 7.84 m/s

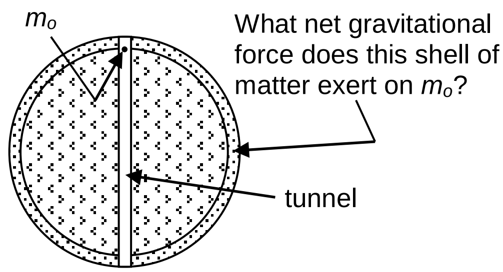
5. As a 5.00 kg object moves along the x-axis, it is acted upon by a single force that acts along the x-axis and varies with the object's position, as indicated in the graph to the right. If the velocity of the object is 2.00 m/s in the positive *x*-direction when the object is at *x* = 0.00 m, what will its **kinetic energy** be when it is at *x* = 6.00 m?



a. 4.00 J
b. 10.0 J
c. 16.0 J
d. 14.0 J
e. 28.0 J



6. Suppose that a straight-line tunnel runs through Earth from pole to pole. Assume that the Earth is a uniform sphere of radius R_E. If an object of mass m_o is located in this tunnel a distance of $0.900 R_E$ away from the center of the Earth, what gravitational force does Earth's matter in the radii range from $0.900 R_E$ to $1.00 R_E$ exert on the object? Note: This is NOT asking for the total gravitational force on the object, just the gravitational force on the object due to the shell of Earth's matter greater than $0.900 R_E$.
(In the following, g is 9.80 m/s^2.)



a. 0.100 $m_o g$ b. 0.900 $m_o g$ c. 0.123 $m_o g$ d. 0.111 $m_o g$ e. 0.00 $m_o g$

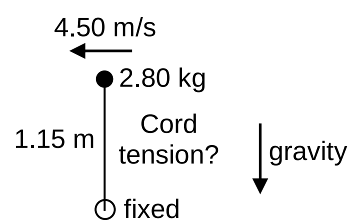
7. A baseball is thrown into the air from home plate toward center field. When the ball is 5.80 m above the ground, the velocity of the baseball is $\boldsymbol{v} = (8.50\,\boldsymbol{i} + 7.30\,\boldsymbol{j})$ m/s, where $\boldsymbol{i}$ and $\boldsymbol{j}$ are unit vectors in the horizontal and vertical directions, respectively. Ignoring air friction and assuming a horizontal playing field, what will be the maximum height reached by the baseball?

a. 11.2 m b. 13.2 m c. 9.49 m d. 8.52 m e. 12.2 m

8. For the same situation described in problem 7, how fast will the baseball be moving just before striking Earth?

a. 13.5 m/s b. 12.9 m/s c. 15.5 m/s d. 10.5 m/s e. 11.2 m/s

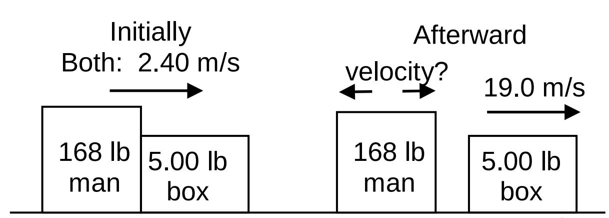
9. In a classroom on Earth, a small, 2.80 kg mass, which is attached to an inextensible cord, is being swung in a vertical circle which has a radius 1.15 m and a fixed center point. If the speed of the mass at the top of the circle is 4.50 m/s, what is the tension in the cord at the top of the circle?



a. 20.8 N b. 27.4 N c. 21.9 N d. 76.7 N e. 49.3 N

10. A 168 lb man, carrying a 5.00 lb box, is sliding with a velocity of 2.40 m/s East across a frozen, horizontal lake surface which has negligible friction. If the man heaves the box giving it a velocity of 19.0 m/s East relative to the Earth, what velocity will the man then have relative to the Earth? In the following, E denotes East, and W denotes West.

a. 1.83 m/s *W*
b. 1.83 m/s *E*
c. 1.85 m/s *E*
d. 1.78 m/s *W*
e. 1.91 m/s *E*



11. Two air track gliders, one of mass M and one of mass $2M$, are held stationary and close to one another on a horizontal, frictionless air track. Between the two gliders is a massless, horizontal spring which is pressing against both gliders, but only attached to one of them. If the spring has force constant, k, and an initial compression, x, what will the speed of the more massive glider be after the gliders are released from rest and the spring has zero remaining elastic potential energy?

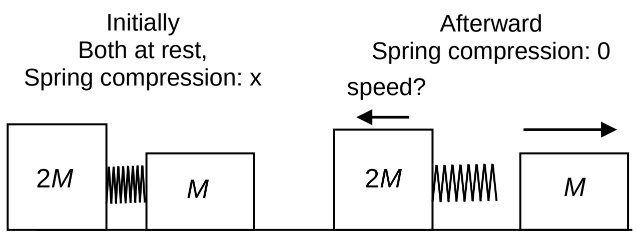
a. $\left(\sqrt{\frac{k}{6M}}\right)x$

b. $\left(\sqrt{\frac{k}{3M}}\right)x$

c. $\left(\sqrt{\frac{k}{M}}\right)x$

d. $\left(\sqrt{\frac{2k}{3M}}\right)x$

e. $\frac{kx^2}{3M}$



12. The angular velocity of a radial line on a wheel rotating about a fixed axle is given by $\omega = 3.00 + 0.400t + 29.0t^2$, where ω is in radians per second and t is in seconds. What is the average angular acceleration of the radial line between t = 0.000 ms and t = 5.000 ms?

a. 0.545 rad/s^2
b. 14.5 rad/s^2
c. 0.400 rad/s^2
d. 29.0 rad/s^2
e. 58.0 rad/s^2

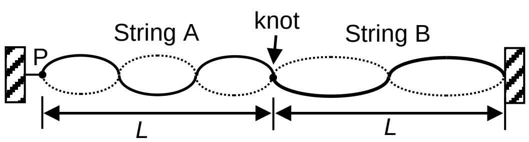
13. Atmospheric pressure at the Earth's surface is about 1.01×10^5 Pa. What is the pressure 6.00 m below the surface of a lake on Earth, assuming that the density of lake water is 1.00×10^3 kg/m^3?

a. 0.582 atm b. 0.0594 atm c. 1.02 atm d. 1.58 atm e. 1.06 atm

14. For the situation in problem 13, how much does the pressure change at the 6.00 m depth if a flat bottomed boat of mass 185 kg and with a bottom area of 3.20 m^2 is floating at rest over the point in question?

a. –567 Pa b. 60.4 Pa c. 567 Pa d. 0.00 Pa e. 57.8 Pa

15. Two strings of equal length, L, but different linear densities are knotted together and stretched between two supports. The frequency of the small amplitude vibrator at point P is adjusted until the standing wave pattern shown in the diagram is discovered. If μ_A and μ_B, are the densities of string A and string B, respectively, what is the ratio μ_A / μ_B? (Note that the tensions in each string are the same, $T = T_A = T_B$, as are the oscillation frequencies, $f = f_A = f_B$.)

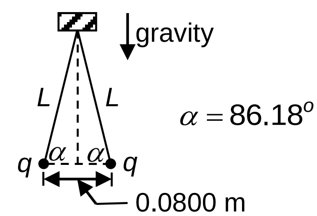


a. 0.444
b. 2.25
c. 1.50
d. 0.667
e. 1.22

16. The specific heat of water and ice are, respectively, 4186 J/(kg °C) and 2093 J/(kg °C), while the heat of fusion of water is 334×10^3J/kg. If a potential difference of 24.0 VDC is maintained across the terminals of a 6.00 Ω resistor which is imbedded in a 0.100 kg cube of ice initially at –10.00°C, how long will it take the ice to become water at 20.00 °C, assuming that all of the electrically generated heat goes to the ice/water?

a. 2.74×10^3 s b. 413 s c. 457 s d. 112 s e. 305 s

17. Two small metallic spheres of identical mass 0.0250 kg and identical charge q hang from insulating threads of length L, as shown. If the distance between the metallic spheres is 0.0800 m, and the angle α is 86.18°, what is the value of q? (Assume that the apparatus is located on Earth.)



a. 35.9 nC b. 1.62 μC c. 418 nC d. 153 nC e. 108 nC

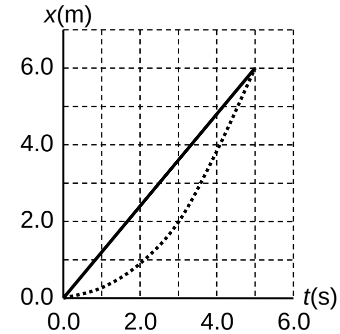
18. At what speed must an electron move to have a relativistic kinetic energy that is 3.00 times its rest mass energy? (c = the speed of light)

a. 0.938 c b. 0.968 c c. 1.07 c d. 0.943 c e. 0.889 c

19. An object in motion is not acted on by any forces. Which statement is true about the motion under this condition.

a. The object cannot speed up or slow down, but can change direction.
b. The object can speed up, but cannot change direction.
c. The object can speed up or slow down and change direction.
d. The object will move with constant speed, always in the same direction.
e. The object will always eventually come to rest, as that is the natural state of objects.

20. The plot shows the position versus time graph of two objects. The object which has its motion indicated by the solid line travels with constant velocity. What is the speed of that object?

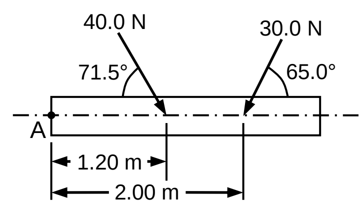


a. 0.83 m/s
b. 1.2 m/s
c. 1.5 m/s
d. 5.0 m/s
e. 6.0 m/s

21. In the previous problem, the object which has its motion indicated by the dotted line begins at rest at time zero and then moves with constant acceleration. What is the acceleration of that object?

a. 0.24 m/s^2 b. 0.48 m/s^2 c. 0.96 m/s^2 d. 1.2 m/s^2 e. 9.8 m/s^2

22. Regarding the massless rectangular bar in the diagram, what is the magnitude of the torque acting about point A as a result of the 40.0 N and 30.0 N forces acting on the bar?



a. 8.86 N·m
b. 40.6 N·m
c. 65.1 N·m
d. 99.9 N·m
e. 108 N·m

23. In the situation described in problem 22, how far from point A along the dash-dotted line should a fulcrum be placed so that the bar balances?

a. 0.33 m b. 1.38 m c. 1.41 m d. 1.53 m e. 1.66 m

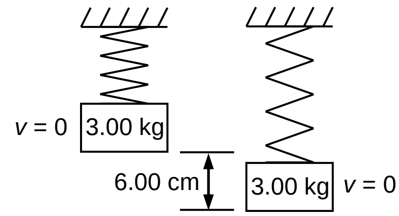
24. Two objects colliding with no external forces can result in different types of collisions. Sometimes the objects stick together, as when two lumps of clay collide. Other times the objects bounce off one another, as when two billiard balls collide. What determines whether momentum is conserved or is not conserved during these different types of collisions?

a. coefficient of elasticity
b. coefficient of friction
c. surface hardness
d. coefficient of compliance
e. Momentum is always conserved in these collisions.

25. Of the volumes listed, the best estimate of the volume occupied by a table tennis (ping pong) ball is

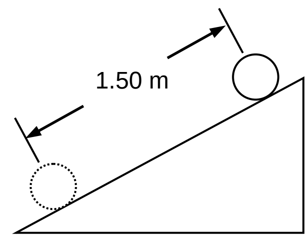
a. 3×10^{-2} m^3 b. 3×10^{-3} m^3 c. 3×10^{-4} m^3 d. 3×10^{-5} m^3 e. 3×10^{-6} m^3

26. In the left diagram, the spring shown is compressed 2.00 cm from its relaxed length. If the 3.00 kg mass attached to the spring is released from rest at the position in the left diagram, it drops 6.00 cm before momentarily coming to rest, as shown in the right diagram. What is the spring constant of the spring?



a. 4.90 N/cm b. 7.35 N/cm c. 9.80 N/cm d. 18.6 N/cm e. 29.4 N/cm

27. Located near the earth's surface, a ball of outer radius 15.0 cm, and radius of gyration about its center of 12.0 cm, rolls without slipping down a 30.0° incline. What is the speed of the center of mass of the ball when it has rolled 1.50 m down the incline after starting from rest?

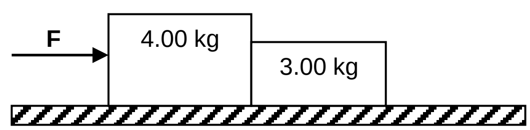


a. 2.12 m/s b. 2.99 m/s c. 3.83 m/s d. 4.48 m/s e. 8.96 m/s

28. Vector **A** points directly east and has a magnitude 4.00 m. Vector **B** points directly north and has a magnitude 3.00 m. What are the magnitude and direction of the sum of vectors A and B?

a. 7.00 m, 36.9° North of East
b. 7.00 m, 53.1° North of East
c. 5.00 m, 36.9° North of East
d. 5.00 m, 53.1° North of East
e. 1.00 m, East

29. Force **F** is applied horizontally to the 4.00 kg block which is in contact with the 3.00 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. $\frac{3}{7}|\mathbf{F}|$ b. $\frac{4}{7}|\mathbf{F}|$ c. $\frac{3}{4}|\mathbf{F}|$ d. $|\mathbf{F}|$ e. $\frac{4}{3}|\mathbf{F}|$

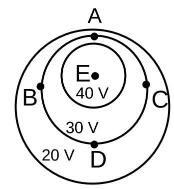
30. A 50.0 kg student ascends a flight of stairs at constant speed, undergoing a vertical displacement of 4.00 m. If the average power used to lift her body is 200.0 watts, how much time does she take to ascend the flight of stairs?

a. 5.14 s b. 6.60 s c. 9.80 s d. 12.1 s e. 15.7 s

31. A uniform density block in the shape of a rectangular prism has dimension 1.00 cm x 2.00 cm x 3.00 cm. The block floats stably in a liquid with a density 1.50 kg/m^3 with the bottom of the block 0.400 cm below the surface of the liquid. What is the density of the block?

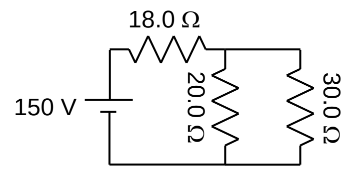
a. 0.400 kg/m^3 b. 0.600 kg/m^3 c. 0.800 kg/m^3 d. 1.20 kg/m^3 e. 1.67 kg/m^3

32. The circles in the diagram are equipotential lines with the indicated potentials. Near which of the labeled points is the average electric field magnitude the greatest?



a. A b. B c. C d. D e. E

33. Determine the current that flows through the 18 Ω resistor.



a. 8.33 A
b. 5.00 A
c. 3.95 A
d. 3.13 A
e. 2.21 A

34. For an object located 20.0 cm from a lens, the image is upright with a linear magnification 4.00. What is the focal length of the lens?

a. 14.8 cm b. 26.7 cm c. 33.3 cm d. 80.0 cm e. –80.0 cm

35. What are appropriate SI units for magnetic field?

a. $\frac{N \cdot s}{C \cdot m}$ b. $\frac{N \cdot m^2}{C^2}$ c. $\frac{N \cdot m}{A \cdot s}$ d. $\frac{N \cdot m}{A \cdot s^2}$ e. $\frac{N \cdot m^2}{C \cdot s}$