The 64th Annual
Merck State Science Day Competition
May 19, 2014

Physics

DIRECTIONS

The "answer panel" at the bottom of the window is pre-set to show 10 answer boxes per page.

1.The current question has a black border.
2. Enter your answer choice using the keyboard.
3. Click Confirm to record your answer.
4. Questions that have been answered will be tinted Green
5. Any answer can be edited. Confirm the correction.
6.> moves to the next set of questions (<moves back)
7.Click on any number to answer that question.
8. Confirm all entries. Each answer is recorded only when Confirm is used.
9. When finished, use FINISHED TEST in lower left.

Hint: The size of the lettering in the bottom answer panel can be adjusted using CTRL + to magnify the browser view.

There is subject-specific information on the next page that you may find useful in answering certain questions. Be sure to view it before you begin the test.

General Information:

Proton mass, $m_P = 1.67x10^{-27}\,kg$	**Electron charge,** $e = 1.60x10^{-19}\,C$
Electron mass, $m_e = 9.11x10^{-31}\,kg$	**1 electron volt,** $1eV = 1.60x10^{-19}\,J$
Avogadro's Number, $N_o = 6.02x10^{23}\,mole^{-1}$	**Speed of light,** $c = 3x10^8\,{}^{m}\!/\!_{s}$
Universal gas constant, $R = 8.31\,{}^{J}\!/\!_{(mol\cdot K)} = 0.0821\,{}^{atm\cdot liter}\!/\!_{(mole\cdot K)}$	**Universal gravitation constant,** $G = 6.67x10^{-11}\,{}^{m^3}\!/\!_{(kg\cdot s^2)}$
Boltzmann's constant, $k_B = 1.38x10^{-23}\,{}^{J}\!/\!_{K}$	**Acceleration due to gravity at Earth surface:** $g = 10\,{}^{m}\!/\!_{s^2}$
$1cal = 4.184J$	

Unified atomic mass unit, $u = 1.66x10^{-19}\,kg = 931\,{}^{MeV}\!/\!_{c^2}$
Planck's constant, $h = 6.60x10^{-34}\,J\cdot s = 4.14x10^{-15}\,eV\cdot s$
Coulomb's Law constant, $k = 9x10^9\,{}^{N\cdot m^2}\!/\!_{C^2}$
1 earth atmosphere pressure, $1atm = 1.0x10^5\,{}^{N}\!/\!_{m^2}$

***Equations*:**

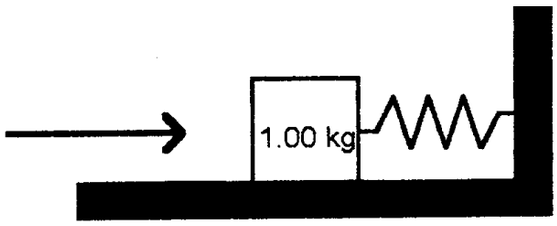
$v_f = v_i + at$	$2ad = v_f^2 + v_i^2$
$d = v_i t + \frac{1}{2}at^2$	$\Sigma F = ma$
$a_c = \frac{v^2}{r}$	$K = \frac{1}{2}mv^2$
$P_g = mgh$	$W = Fd$
$P = \frac{W}{t} = \frac{\Delta E}{t}$	$F_g = G\frac{M_1 M_2}{R^2}$
$F_B = DVg$	$A_1 v_1 = A_2 v_2$
$P + Dgy + \frac{1}{2}Dv^2 =$ ***Constant***	$v = \lambda f$
$n_i \sin i = n_r \sin r$	$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
$f = \frac{R}{2}$	$E = hf = pc$
$\Delta E = \Delta mc^2$	$Q = mc\Delta T$
$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$	$PV = nRT$
$V = IR$	$P = VI$

Merck State Science Day 2014 Physics

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question and ***place your selection ON THE ANSWER PANEL then "Confirm."***

Treat all questions as non-relativistic. Unless otherwise indicated ignore friction with the air. Figures are not drawn to scale.

The following figure and discussion are for question 1.



1. Given a block of mass 1.0 kg at rest on a horizontal frictionless surface. The block is attached to a rigid support by a spring that is horizontal. An arrow of mass 0.10 kg and speed 15.0 m/s embeds itself into the block. The arrow and block move to the right compressing the spring, and coming to rest. The spring constant for the spring is 180.0 N/m. The maximum amount that the spring compresses is ___ m .
A) 0.11 B) 0.14 C) 0.17 D) 0.20 E) 0.25

2. Given an automobile which travels 50.0 km at a rate of 50.0 km/hour. It then travels 50.0 km at a rate of 1.0 km/hour. The average speed for the automobile for the entire trip of 100.0 km was ___ km/hour.
A) 1.0 B) 2.0 C) 14.1 D) 20.0 E) 141.0

3. An object weighs 600.0 N on a homogeneous solid planet P . Given a second homogeneous solid planet, planet Q, with three times the mass and three times the radius of planet P. On the surface of planet Q the objects weighs ___ N.
A) 900.0 B) 707.0 C) 600 D) 400.0 E) 200.0

4. A point mass is projected horizontally at 10.0 m/s from the roof of a building 30.0 m tall. When the mass reaches the ground, the magnitude of its speed is
__ m/s .
A) 20.0 B) 24.7 C) 26.6 D) 28.2 E) 30.0

5. Given: a rigid body of mass M with rectilinear motion. It is acted upon by a net force F for a time T. The net force F is constant in direction but not magnitude. The body moves a distance X in a time T. The impulse received by the mass is represented by the area under a Force vs. ___ .

A) Distance graph only if F is constant B) Time graph only if F is constant
C) Distance graph, even if F varies D) Time graph, even if F varies

The following discussion is for questions 6 and 7.
A small ball of mass 0.65 kg rests on an inclined plane. It is given a push and rolls up the plane. It slows to a stop and rolls back down the plane.

6. After the push, but while the ball is rolling up the plane, the direction of the acceleration of the ball is ___ .
A) upward along the plane
B) downward along the plane
C) vertically downward
D) vertically upward
E) zero (there is none)

7. When the ball reaches its highest point on the plane, the acceleration of the ball is _____ .
A) upward along the plane
B) downward along the plane
C) vertically downward
D) vertically upward
E) zero (there is none)

8. A small box is pushed by a constant horizontal force across a horizontal surface at a constant speed of 1.0 m/s. The weight of the box is 500.0 N . The coefficient of kinetic friction between the box and the surface is 0.20 . The constant applied force was ___ N .
A) 71 B) 100 C) 141 D) 200 E) 1,000

9. A point mass is dropped from rest from the roof of a 30.0 m tall building. At the end of 1.0 s the mass has fallen ___ m .
A) 1.4 B) 2.5 C) 3.3 D) 4.9 E) 9.8

The equation below and the description are for questions 10 and 11
Given the following equation which represents a transverse traveling wave on a long, very light (massless) string, as a function of position, x, and time , t.
m and s stand for meter and second, respectively. Y is in meters.

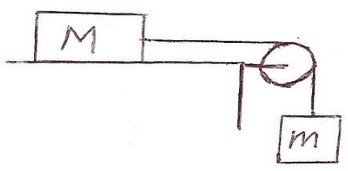
$$Y = 0.050 \text{ Cos } (2 \pi (0.2 x - 0.2 t))$$

10. When x = 8.0 m and t = 8.0 s , then the magnitude of Y equals ___ m.
A) 0.050 B) 0.045 C) 0.025 D) 0.012 E) 0.000

11. The speed of the waveform along the string is ___ m/s .
A) 10.0 B) 2.0 C) 1.4 D) 1.0 E) 0.2

12. Given a soap bubble illuminated by light. The interference colors you see are indicative that ___ .
A) a monochromatic beam of light was used
B) only one reflecting surface is involved
C) the bubble walls are very thick
D) the light from the bubble is polarized
E) the light used has multiple colors

The following description and figure are to be used for questions 13, and 14



Given two masses, M and m, attached at the ends of a very light cord (massless) which passes over a pulley as shown to the left. The larger mass, M, has a mass of 20.0 kg . The lighter mass, m, has a mass of 10.0 kg. M is on a flat horizontal surface. The cord passes from M horizontally, then over the pulley and then vertically downward to the mass m. The axle of the pulley is frictionless. Neglect the mass of the cord. The pulley acts as a circular solid disk that may be neglected except that it changes the direction of the tension The solid disk of the pulley has a radius of 0.10 m and a moment of inertia about its axis of rotation of 0.15 kg-m^2. At time equals zero the pulley and masses are held at rest.

13. While at rest, the tension in the cord is approximately ___ N.
A) 58 B) 71 C) 88 D) 100 E) 141

14. The objects are released from rest. Mass m descends and mass M moves to the right. Mass m descends with an acceleration of 1.6 m/s^2 . The tension in the cord is approximately ___ N.
A) 40 B) 58 C) 82 D) 100 E) 141

The description below is for questions 15 and16.
Given a system of two "point masses". One has a mass 4.0 kg. It is moving to the right at 4.0 m/s. The second has a mass of 5.0 kg . It is moving to the left at 1.0 m/s. When time is zero, they are separated by 10.0 m .

15. If the two masses have a perfectly **inelastic** collision (stick together), the magnitude of the change in kinetic energy of the 4.0 kg particle as a result of the collision would be __ J .
A) 35.6 B) 34.5 C) 29.0 D) 22.2 E) 19.8

16. If the two particles had a perfectly **elastic** collision, the magnitude of the speed of the 5.0 kg mass after the collision would be ____ m/s .
A) 3.4 B) 3.2 C) 3.0 D) 2.7 E) 2.4

17. Given a horizontal pipe. It "necks down" (reduces in diameter) from a 0.06 m radius to 0.02 m radius, but still remains horizontal. It is filled with an ideal incompressible liquid. In the larger area section of the pipe the speed of the fluid is 0.08 m/s . In the smaller area section the speed of the liquid is __ m/s
A) 0.72 B) 0.36 C) 0.24 D) 0.03 E) 0.009

The following description is for questions 18 and 19.
Given a uniform ladder 6.0 m long with a weight of 500.0 N. A 100.0 N object hangs from the ladder at a point 2.0 m up the ladder, i.e. 1.6 m above the horizontal floor. The ladder is inclined against a frictionless vertical wall, touching a point on the wall 4.8 m above the floor (The sine of the angle of inclination of the ladder is 4.8/6.0 or 0.80). The coefficient of static friction between the base of the ladder and the floor is 0.45

18. The normal component of the force from the floor on the ladder is ___ N
A) 141.0 B) 444.0 C) 550.0 D) 600.0 E) 840.0

19. The angle that the force from the floor on the ladder makes with the floor is approximately ____ degrees.
A) 70 B) 66 C) 53 D) 45 E) 37

The following description is used for questions 20 and 21
Monochromatic coherent light passes through a double slit forming on a screen an interference pattern with maximums 0.04 m apart.

20. If light with twice the frequency had been used, the maximums would have been ___ m apart.

A) 0.12 B) 0.08 C) 0.04 D) 0.02 E) 0.01

21. If the original light were used but the screen was twice as far away, the separation between interference maximums would ____.

A) double
B) increase but less than double
C) be the same
D) be halved
E) decrease but not halved

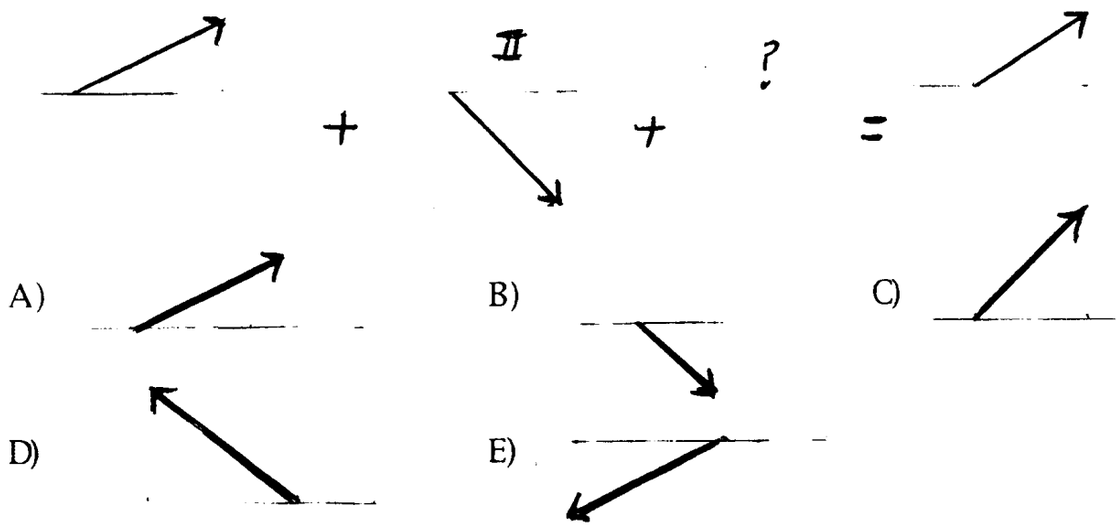
The description below is for questions 22 and 23.
A 30.0 kg block is pushed for a distance of 10.0 m up an inclined plane by a constant force of 250.0 N parallel to the inclined plane. The 10 m point is 7.07 m above the elevation of the 0 m mark. (The plane is inclined at an angle of 45.0 degrees.) The force of friction on the sliding block is 100.0 N . The block is initially moving up the plane at 10.0 m/s at the 0 m mark.

22. The work done by the 250.0 N force in moving the block from the 0.0 m mark to the 10.0 m mark on the incline was approximately __ J .
A) 2800 B) 2500 C) 1800 D) 1200 E) 200

23. The speed of the block at the 10.0 m mark is approximately ___ m/s .
A) 16.3 B) 12.5 C) 10.8 D) 7.7 E) 2.3

The following description and figure are to be used for question 24

24. Given that three vectors add to give a fourth. You are given the first two of the three vectors and the sum, the fourth. Of the five vector choices, A through E, which represents correctly the third, the ?, the vector which when added to the two best yields the sum, the fourth? The vectors in this question are to scale.



25. Given a cylindrical water tank. It is 10.0 m tall and filled with water to a depth of 9.0 m. The upper end of the tank is open to the atmosphere. The tank is 4.0 m in radius. There is a round hole about 0.02 m in diameter in the side of the tank 1.0 m above the bottom. The speed of the water as it exits through the hole is ___ m/s .

A) 8.9 B) 9.4 C) 12.5 D) 13.3 E) 157

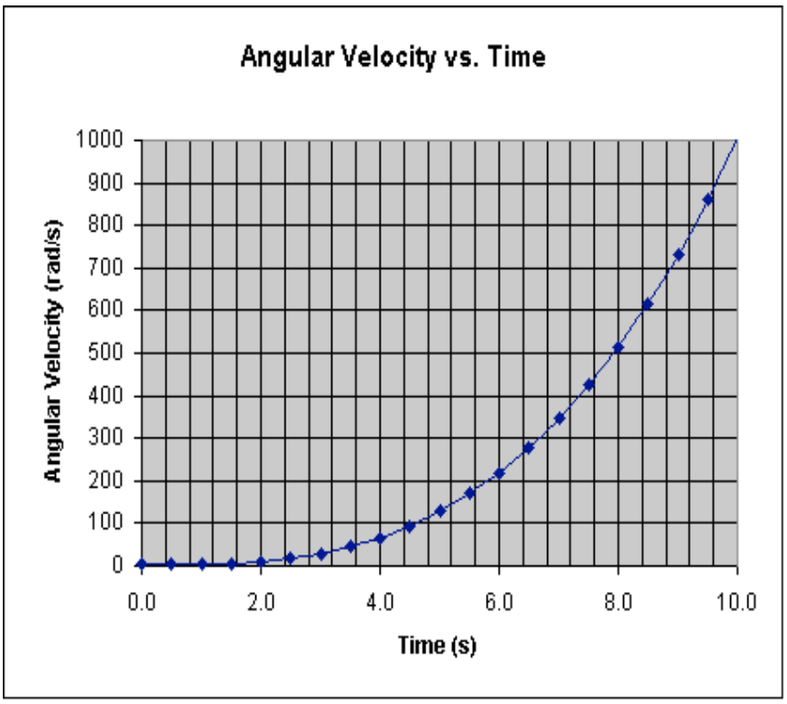
26. Given a glass of water with ice cubes in it. If the ice melts, the water level in the glass ___

A) rises B) does not change C) lowers

27. A solid block of metal is suspended by a very light cord attached to a scale so that it is entirely under the surface of a liquid, but not resting in any way on the bottom of the container. When the liquid is water, the apparent mass of the block indicated by the scale is 1.0 kg . The water is replaced by a liquid with a density of 900 kg/m^3 . The apparent mass of the block indicated by the scale is 1.1 kg . The volume of the metal block is approximately ___ m^3

A) 1 B) 0.1 C) 0.01 D) 0.001 E) 0.0001

The following graph, and description are used for questions 28 and 29.



Given a graph of angular velocity in rad/s as a function of time in seconds for a circular disk rotating about its axle. At the beginning of the time interval the angular velocity of the disk was 3.0 rad/s . The radius of the disk is 2.0 m .

28. The average value of the angular velocity for the 10 second time interval was approximately ___ rad/s .
A) 500 B) 400 C) 350 D) 300 E) 250

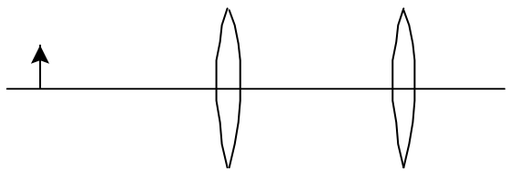
29. If the motion continued, the angular velocity when t was 11 s was approximately ___ rad/s
A) 1500 B) 1400 C) 1300 D) 1200 E) 1100

30. Given a diver at a depth of 9.0 m in a calm tank of water. The density of the water is 1,000 kg/m^3 The diver releases bubbles of air. The radius of a bubble is 0.005 m when released. If the temperature of the water is constant, the radius of the bubble as it reaches the surface is ___ m . The pressure at the surface of the water is 1.01X 10^{+5} Pa (one atmosphere).

A) 0.0062 B) 0.052 C) 0.10 D) 0.14 E) 0.15

The following description and figure are for questions 31 and 32.

A small arrow object is placed 0.225 m to the left of a thin positive lens of focal length 0.15 m. A second thin positive lens with a focal length of 0.20 m, is placed 0.60 m to the right of the first lens. The lenses and the object are in air. The principal axes of the lenses coincide. The small object is on that principal axis.



31. The final image formed by this combination of lenses compared with the original small object is ____.
A) real and inverted
B) real and erect
C) virtual and inverted
D) virtual and erect
E) no image is formed

32. The magnitude of the distance of the final image from the right hand lens is__ m.

A) None is formed B) 0.90 C) 0.60 D) 0.30 E) 0.15

The following description is used for questions 33 and 34.
A beam of light consisting of two frequencies is incident upon a transmission diffraction grating producing Fraunhofer diffraction. The wavelengths in air of the two light components are 6×10^{-7} m and 6.5×10^{-7} m. The first order diffraction maximum of the 6×10^{-7} m light is at 29.9 degrees.

33. The second order maximum for 6×10^{-7} m light will be at approximately ____ degrees.

A) 86 B) 74 C) 60 D) 44 E) 36

34. When light of these two wavelengths meet in space, they combine (interfere) to form a wavelength of __. m

A) 0.5×10^{-7} B) 6.25×10^{-7} C) 13.5×10^{-7} D) 39×10^{-7} E) none-they do not interfere

35. Given a 0.400 kg block of metal. The block is heated to 500.0 degrees Celsius and placed in 0.400 kg of water. The temperature of the water rises from 18 degrees Celsius to 30 degrees Celsius. Assume no heat is gained nor lost to the environment. The experiment is repeated with a second, but different 0.400 kg metal block, also raised in temperature to 500.0 degrees Celsius. A 0.400 kg of water rises in temperature from 18.0 to 24.0 degrees Celsius. The specific heat of the second metal is __ time(s) the specific heat of the first metal.

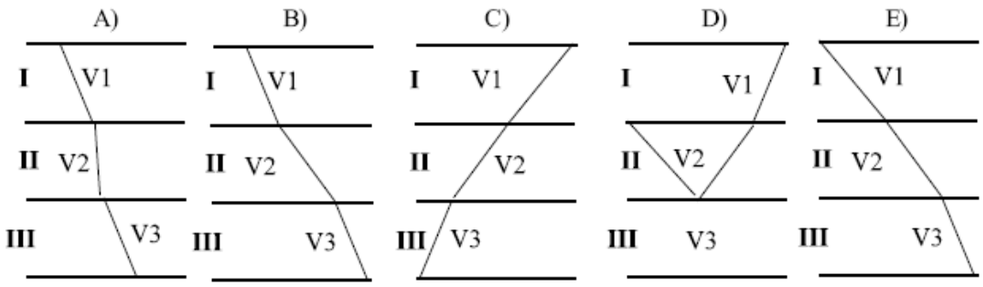
A) 0.25 B) 0.50 C) 1.00 D) 1.41 E) 2.00

The following description and figure are for question 36.

36. Given three homogeneous media with flat interfaces and in which the speeds of a wave of a particular wavelength are represented by V1, V2, and V3. Which of the five ray diagrams below represents media in which the speed in medium I is less than the speed in medium II, and the speed in medium II is less than the speed in medium III?

V1 < V2 and V2 < V3

A) A B) B C) C D) D E) E



37. Given solid metal cube that is 0.12 m on a side. Its temperature is raised from 10 degrees Celsius to 260 degrees Celsius. The coefficient of linear expansion of the metal is 20.0×10^{-6}/degree Celsius. Each of the 0.12 m edges is increased in length by __ %.

A) 0.06 B) 0.50 C) 0.8 D) 1.2 E) 1.8

The description below is for questions 38, 39, and 40.

Given a string vibrating in its fundamental mode (one loop). 1.50 meters of string are in vibration. The vibration rate is 200.0 Hz .

38. The frequency of the note in the air produced by the vibrating string is ___ Hz

A) 50.0 B) 75.0 C) 100.0 D) 150.0 E) 200.0

39. The speed of the wave on the string is ____ m/s .

A) 600.0 B) 400.0 C) 300.0 D) 250.0 E) 200.0

40. The frequency required to produce a standing wave of two loops is ___ Hz .

A) 71.0 B) 100.0 C) 200.0 D) 282.0 E) 400.0

41. The buoyant force on an object floating in water is ___ .

A) Equal to the object's weight
B) Half the weight of the displaced water
C) More than the weight of the object
D) More than the weight of the displaced water
E) None of the above answers

42. A very small (point) sound source of only one frequency is radiating equally in all directions. The intensity 4.0 m from this "point source" is 0.04 W/m^2 .
The intensity 2.0 m from the source is approximately___ W/m^2 .

A) 0.002 B) 0.08 C) 0.012 D) 0.16 E) 0.20

43. Given a stationary source of sound and a sound observer moving toward the source at a speed of 29.0 m/s (65 miles/hour). The source emits a 3,000 Hz sound as detected by an observer on the source. The speed of sound in the air is 343 m/s. The moving observer hears a frequency of approximately ____ Hz .

A) 4000 B) 3750 C) 3500 D) 3250 E) 2750

44. Given a column of air that is closed at one end and open at the other end. It resonates at the following frequencies: 240.0 Hz, 400.0 Hz, and 720.0 Hz . If these frequencies are integral multiples of the tube's fundamental frequency, the fundamental frequency might be ___ Hz .
A) 360.0 B) 180.0 C) 120.0 D) 80.0 E) 60.0

The description below is for questions 45, 46, and 47.
Given a horizontal "massless spring". Its left end is attached to a rigid vertical support. A small 0.40 kg mass is attached to its right end. They are in equilibrium on a horizontal frictionless surface. The spring constant is 60.0 N/m. At time equals zero the mass is displaced a distance 0.20 m to the right of equilibrium and released with a speed of 2.0 m/s to the right away from the equilibrium point. The mass oscillates, executing simple harmonic motion.

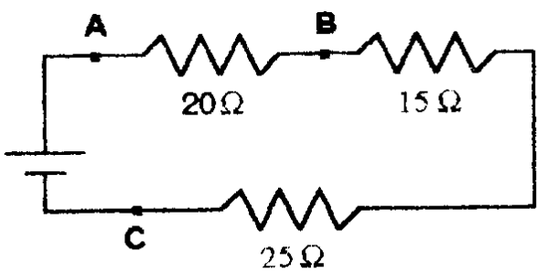
45. The amplitude for the simple harmonic motion is ___ m .
A) 0.26 B) 0.20 C) 0.14 D) 0.10 E) 0.07

46. The oscillation frequency is _ Hz.
A) 2.0 B) 1.25 C) 1 D) 0.8 E) 0.4

47. The acceleration of the mass when the spring is stretched 0.1 m is ___ m/s^2.
A) 0.0 B) 2.0 C) 6.0 D) 9.0 E) 15.0

48. In an isobaric process ___ .
A) the pressure remains constant.
B) the volume remains constant
C) the temperature remains constant
D) no heat is transferred between a system and its surroundings
E) heat must be transferred between a system and its surroundings

The following figure and discussion are for question 49.



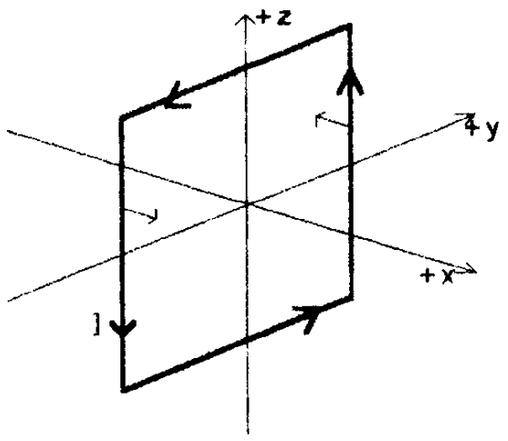
49. Given three resistors, 20.0, 15.0, and 25.0 ohms, in a series circuit with an ideal emf. The potential difference across A-C is 30.0 volts. The potential difference across B-C is ___ volts.

A) 14.1 B) 20.0 C) 22.5 D) 23.0 E) 28.3

The following figure and discussion are for question 50.

50. Given a conducting loop in the Y-Z plane. The loop has a current I as shown by the arrows. The direction of the magnetic field that will cause the loop to experience a torque about the positive Z-axis (vertically upward) is ___ .

A) +Z B) +Y C) -Y D) +X E) -X



51. Given a wire with a resistance of 20.0 ohms . The wire is 200.0 m long. The wire is stretched uniformly to a length of 400.0 m . The resistance of the wire becomes ___ ohms.

A) 160.0 B) 120.0 C) 80.0 D) 40.0 E) 20.0

52. Given two point electric charges separated by a distance of 0.15 m . The force between the two charges is 10^{-7} N. If they were 0.30 m apart and their charges were doubled, the force between them would ___ .

A) be 4 times as large
B) double
C) not change
D) be halved
E) be one fourth as large

53. Given two identical uncharged hollow metal masses 0.02 m in diameter and 0.05 kg in mass. Each is attached to a 1.0 m long thread, and suspended from the same point, as two simple pendula. A charge of +Q is placed on one and a charge twice +Q is placed on the other. They repel each other. The +Q charge forms an angle of 22.0 degrees with the vertical. The +2Q charge forms an angle of ___ degrees with the vertical.

A) 44.0 B) between 25 and 35 C) 22.0 D) 11.0 E) < 11

The following description and figure are used for questions 54, 55, and 56.
Given a parallel plate capacitor with air or a vacuum between the plates. The plates of the capacitor are vertical. They are squares, 0.06 m on a side , and are thin. An ideal emf is attached to the capacitor fully charging the capacitor. The plus terminal of the emf is attached to the left plate of the capacitor, and the negative terminal is connected to the right plate. The emf is removed once the plates are fully charged. Assume the resulting electric field in the space between the plates is uniform. Ignore any fringing. The plates are 0.02 m apart (2.0 cm). The magnitude of the uniform electric field between the plates is three thousand Newtons per Coulomb (3,000 N/C). A tiny particle is projected vertically downward at 500,000 m/s (0.5×10^{6} m/s) between the plates just to the right of the left plate. The tiny particle has a charge of $+8 \times 10^{-19}$ Coulomb. The mass of the particle is 10^{-17}kg.

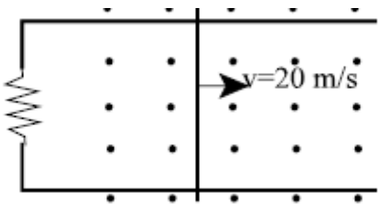
54. The particle is deflected to the right as it moves in the electric field. The horizontal component of its velocity when it impacts the right plate is approx. ___ m/s

A) 1,000 B) 630 C) 42 D) 3 E) never hits; it escapes

55. The particle had been accelerated from rest to the 500,000 m/s velocity. The potential difference that produced this velocity was approximately ___ volts.
A) 10^{+4} B) 10^{+6} C) 10^{+8} D) 10^{+10} E) 10^{+12}

56. A uniform magnetic field is applied in the region of the electric field to offset the deflection by the electric field and allow the particle to move vertically undeflected through the fields. The magnetic field would be approximately __ T
A) 0.006 B) 0.02 C) 0.2 D) 5.0 E) 14.1

The following description and figure are used for question 57.
57. Given a 0.02 kg wire rod moving to the right at a speed of 20.0 m/s on a pair of horizontal parallel frictionless metal rails. The rails are 2.0 m apart . There is a magnetic field in the region pointing vertically upward, and perpendicular to the velocity of the rod (upward and out of the page). The magnitude of the magnetic field is 5.0 Tesla. A resistance of 800.0 ohms joins the two rails. While the rod is moving , the current in the 800.0 ohm resistor is approximately ___ A .



A) 0.05 B) 0.10 C) 0.25 D) 0.50 E) 20.0

58. Given four point charges of equal magnitude, each of the four located at the corner of a square. Two are positive and two are negative. The two positive charges are at the end of one diagonal and the two negative charges are at the ends of the other diagonal. (Going around the square they are +, -, +, -). At the center of the square which of the following five choices is true? (E represents electric field and V represents electric potential)

A) E is not zero. V is positive
B) E is not zero. V = zero
C) E = zero. V = zero
D) E = zero. V is positive
E) E = zero. V is negative

59. Given a closed container of "ideal" gas. Its temperature is 100 degrees Celsius. It is under a gauge pressure of 10.0 pounds per square inch (absolute pressure is 25.0 psi). Its volume is 4.0 liters. The volume of the gas is increased to 8.0 liter and its gauge pressure is increased to 50.0 pounds per square inch (absolute pressure is 65.0 psi). Its new temperature is approximately ___ degrees Celsius.
A) 2,000 B) 1,700 C) 1,500 D) 1,300 E) 1.000

60. Given: a spherical positive mirror (concave) with a 0.04 m tall object placed 0.20 m in front of the mirror on the principal axis of the mirror. The mirror forms a virtual image of the object a distance of 0.30 m from the mirror. The magnitude of the radius of curvature of the mirror is ___ m .
A) 0.36 B) 0.67 C) 0.90 D) 1.2 E) 1.8

End of Test