# The 58th Annual
# Merck State Science Day Competition
# May 20, 2008
# Physics

## Directions:
## PLEASE DO NOT OPEN THE EXAM BOOKLET UNTIL DIRECTED.

Be sure to fill in your name on the answer sheet both by printing it in the correct space, and by filling in the corresponding letter in the provided spaces.

**Use a #2 pencil only.**

Carefully erase any errors, and do not make any extraneous marks on the answer sheet. You may write on the test but all answers must be recorded on the Scantron answer sheet.

The test has 60 items that will be scored. You have **90** minutes in which to answer them.

There is only one correct answer per question. Do not spend too much time on any one question. Do the items you find easier first, and then go back to those you find more difficult or time consuming during the time you have remaining. Your individual score will be computed on the basis of the number of correctly answered items. Each question counts the same. No question is weighted. (There is no penalty for guessing)

There are important subject-specific items below that you may find useful in answering certain questions. Be sure to read them before you begin the test.

| | |
|---|---|
| **Proton mass** | $m_p = 1.67 \times 10^{-27}$ kg |
| **Electron mass** | $m_e = 9.11 \times 10^{-31}$ kg |
| **Magnitude of electron charge** | $q_e = 1.60 \times 10^{-19}$ C |
| **Speed of light** | $c_{\text{in a vacuum}} = 3.00 \times 10^{8}$ m/s |
| **Coulomb's law constant** | $k = 9.0 \times 10^{9}$ Nm$^2$/C$^2$ |
| **Universal gravitation constant** | $G = 6.67 \times 10^{-11}$ m$^3$/kg-s$^2$ |
| **Gravitational field near Earth** | g = 9.8 N/kg |
| | 1 mile = 1.609 km |
| **atmosphere pressure** | 1 atm= $1.0 \times 10^{5}$ N/m$^2$ = $1.0 \times 10^{5}$ Pa = 14.7 lb/in$^2$ |
| **Mean radius of the earth** | $R = 6.371 \times 10^{6}$ m |
| **Mass of the earth** | $m = 5.98 \times 10^{24}$ kg |
| **Vol of sphere** | $Vol_{sphere} = 4/3\ \pi R^3 = 1.33\ \pi R^3$ |
| **Surface area of a sphere** | Surface Area$_{sphere}$ = $4\ \pi R^2$ |

# Merck State Science Day 2008 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 SHEET.***

**Treat all questions as non-relativistic**. Unless otherwise indicated ignore friction with the air.

.

**1)** The dimensions of a rectangular solid are measured and recorded to the correct number of significant figures for the instruments used. Those values to the correct number of significant figures of the length, width, and height respectively of the solid are 1.112 m, 1.12 m, and 1.2 m . The volume of the solid to the correct number of significant figures is ____ $m^3$ .

A) 1.49453 B) 1.4945 C) 1.495 D) 1.49 E) 1.5

**2)** A measurement made and recorded to the correct number of significant figures is 0.01620. The correct number of significant figures is ___ .

A) 6 B) 5 C) 4 D) 3 E) 2

**3)** Given a closed container of "ideal" gas. Its volume is 2.0 liters. Its temperature is 100 degrees Celsius. It is under a gauge pressure of 15.0 pounds per square inch (absolute pressure is 30.0 psi). Then the volume of the gas is decreased to 1.0 liter and its gauge pressure is increased to 53.0 pounds per square inch (absolute pressure is 68.0 psi). Its new temperature is ___ degrees Celsius.

A) 423 B) 342 C) 212 D) 150 E) 123

**4**) Given a horizontal pipe. It "necks down" (reduces in diameter) from a 0.03 m radius to 0.01 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 0.02 m/s . In the smaller area section the speed of the liquid is __ m/s

A) 0.18 B) 0.12 C) 0.09 D) 0.062 E) 0.03

**5)** Given a 9.0 m tall cylindrical water tank. It is filled with water to a depth of 8.0 m. The upper end is open to the atmosphere. The tank is 3.0 m in radius. There is a round hole about 0.02 m in diameter in the side of the tank 2.0 m above the bottom. The speed of the water as it exits through the hole is ___ m/s .

A) 3.6 B) 4.2 C) 10.8 D) 12.5 E) 13.3

**Use the following information for # 6 and 7**

**6-7** Given a "flat bottomed boat". This boat has a rectangular bottom. It is 3.0 m by 4.0 m, and is 2.0 m tall. It is made of thin sheets of metal. It is in fresh water. Unloaded, it floats with 0.5 m under the water and 1.5 m above the water. It is loaded, and now floats so that 1.5 m is below the water level and 0.5 m out of the water.

**6)** The mass of the load is ___ times the mass of the boat.

A) 1 ( the same as) B) 2 C) 3 D) 4 E) 9

**7)** If the thickness of the sides and bottom of the boat is 0.01 m, then the density of the metal from which the boat was made is __ kg/m3 .

A) 15,000 B) 6,000 C) 3,000 D) 6 E) 3

**Use the following information for # 8-10**

**8-10**. Given two "point masses" moving along a straight line on a horizontal frictionless surface. At time equals zero, one has a mass 3.0 kg and is moving at 5.0 m/s to the right. At time equals zero, the second has a mass 5.0 kg and is moving to the right at 3.0 m/s. It is 3.0 meters to the right of the other. The two masses have a perfectly elastic collision

**8)** The total linear momentum in this system of two masses in this system of two particles before they collide is __ kg m/s.

A) 0 B) 8.0 C) 16.0 D) 24.0 E) 30.0

**9)** The velocity of the 3.0 kg particle after the collision was ___ .

A) 4.0 m/s to the left
B) 4.0 m/s to the right
C) 2.5 m/s to the left
D) 2.5 m/s to the right
E) zero (the mass is at rest)

**10)** Prior to the collision the magnitude of the velocity of the center of mass of the two masses was ___ m/s .

A) 5.0 B) 4.2 C) 4.0 D) 3.8 E) 2.0

**Use the following information for #11 - 12**

**11 - 12** A monochromatic beam of light with a frequency 5.0 X $10^{+14}$ Hz is incident upon a transmission diffraction grating producing Fraunhofer diffraction. The grating has 1,000,000 lines per meter.

**11)** The first order diffraction maximum of the light is at ___ degrees.

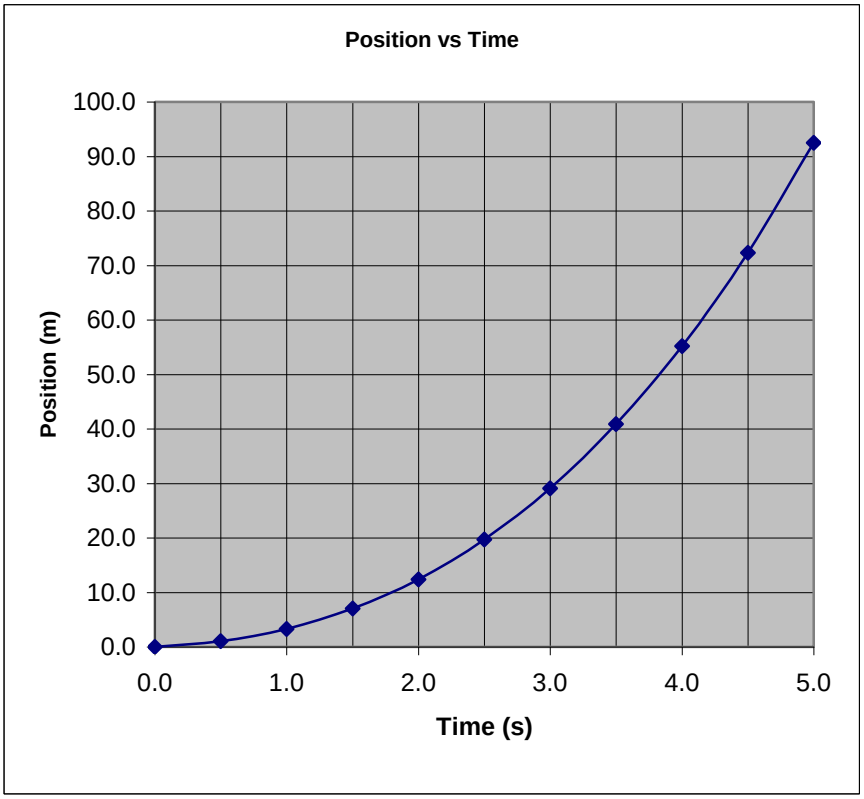
A) less than 5 B) 26.7 C) 36.9 D) 44.4 E) 60

**12**) If the frequency had been 6.65 X $10^{+14}$ Hz, one-third higher than the original, the first order maximum would be at ___ degrees.

A) less than 5 B) 26.8 C) 36.9 D) 44.4 E) 60

**Use the following information for # 13-16**

| Time | Position |
|---|---|
| s | m |
| 0.0 | 0.0 |
| 0.5 | 1.0 |
| 1.0 | 3.3 |
| 1.5 | 7.0 |
| 2.0 | 12.4 |
| 2.5 | 19.7 |
| 3.0 | 29.1 |
| 3.5 | 40.9 |
| 4.0 | 55.2 |
| 4.5 | 72.3 |
| 5.0 | 92.5 |




**13-16**. Given a record of Position, in meters, as a function of time, in seconds, for a small mass executing rectilinear motion.

**13**) Using the data, if the position, X, is represented by a power series of time,t

X = A + Bt + Ct^2 + Dt^3 + Et^4 etc

The highest power of t required would be ___ .

A) 5 B) 4 C) 3 D) 2 E) 1

**14**) The average velocity of the mass for the 5 second interval was __ m/s .

A) 11.5 B) 18.5 C) 22.5 D) 33.0 E) 46.2

**15**) The acceleration of the mass was ___ .

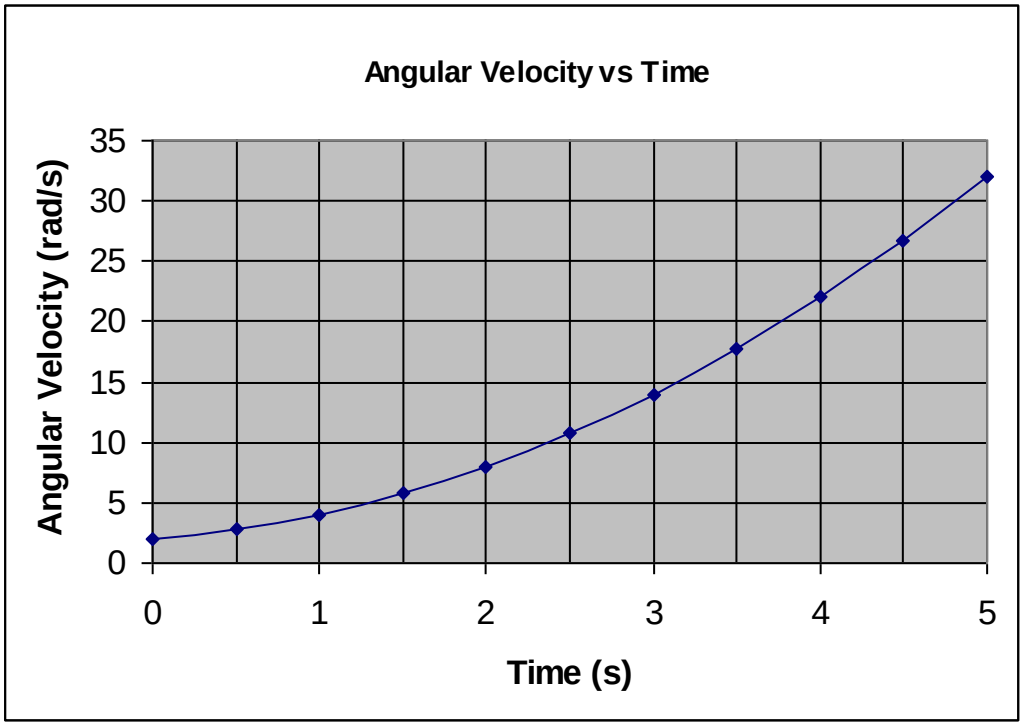
A) positive and increasing
B) positive and decreasing
C) negative and increasing
D) negative and decreasing

**16**) The velocity of the mass when time was 3.0 s was approximately __ m/s

A) 5 B) 15 C) 20 D) 24 E) 26

**Use the following information description and graph for # 17-20**

**17-20** Given a record of angular velocity in rad/s as a function of time in seconds for a small mass of 2.0 kg traveling in a circle of 3.0 m radius on a horizontal frictionless surface. When time was zero, the mass was at the zero radian mark.




**17**) The average angular velocity for the 5 second interval was ___

A) 32 B) 30 C) 21 D) 16 E) 13

**18**) If the changes in the motion continue as they had for the first five seconds, the angular velocity when time was 6.0 seconds would be ___ rad/s

A) 48 B) 44 C) 40 D) 36 E) 34

**19**) At time equals 2.0 s, the angular velocity of the mass was 8.0 rad/s and the kinetic energy of the mass was ___ J .

A) 576 B) 288 C) 192 D) 64 E) 24

**20**) When time was 2.0 s , the tangential force on the mass was ___ N .

A) 0 B) 5 C) 15 D) 30 E) 42

**Use the following information for # 21 and 22**

**21-22** Given a solid copper sphere 0.02 m in radius, and a larger solid copper sphere 0.06 m in radius. There is a charge of $10^{-10}$ Coulomb on the smaller sphere. The larger sphere is uncharged. The two spheres are brought into contact and then separated to 2.0 meters apart.

**21**) The electric potential inside the smaller sphere 0.01 m from its center is__ V.

A) 22 B) 15 C) 11.2 D) 7.5 E) 0

**22)** If you had only the smaller solid copper sphere, with its original charge, $10^{-10}$ Coulomb, the electric field strength, N/Coulomb, at a distance 0.08 m from the center of the small sphere would be ___ N/Coulomb .

A) 141 B) 70 C) 14 D) 7 E) less than one

**Use the following information for # 23 and 24**

**23-24** Given a 0.01 m tall object placed 0.30 m from a spherical mirror. The mirror forms a 0.03 m tall erect image of the object.

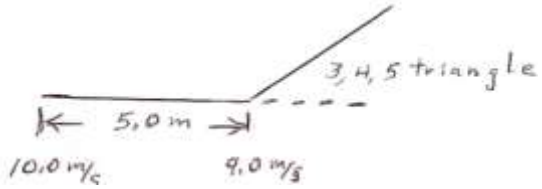
**23)** The magnitude of the radius of curvature of the mirror is __ m .

A) 0.90 B) 0.60 C) 0.45 D) 0.225 E) 0.15

**24**) If the mirror were used under water ( index of refraction of water is 1.33), its focal length would be ___ its focal length in air.

A) 4/3 B) 16/9 C) the same as D) 3/4 E) 9/16

**Use the following information for # 25 and 26**




**25-26** Given a small 5.0 N object. It is traveling along a horizontal level surface. It slows from 10.0 m/s down to 9.0 m/s while moving 5.0 m . After the 5.0 m the object moves up an incline, gradually coming to rest. The incline is at an angle of 36.9 degrees (sine is 0.60, cosine is 0.80, 3,4,5 triangle )The coefficient of friction between the incline and the object is 0.20 .

**25**) The coefficient of friction between the object and the horizontal surface is __ .

A) 0.19 B) 0.27 C) 0.38 D) 0.45 E) 0.54

**26**) The object travels __ m along the incline before it comes to rest.

A) 2.2 B) 5.4 C) 7.3 D) 8.1 E) 9.5

**27)** A 0.2 kg mass is moving in a circle 3.0 m in radius. At t = zero its speed is 2.0 m/s and its tangential acceleration is 2/3 $m/s^2$ . The magnitude of its net acceleration at that time is ___ $m/s^2$ .

A) 2.22 B) 2.00 C) 1.81 D) 1.49 E) 1.22

**Use the following information for # 28 and 29**

**28-29** A 1.0 kg "point mass" is projected at an angle of 59 degrees above the horizontal. At its launch the components of its velocity are 15.0 m/s horizontal and 25.0 m/s vertical. The mass lands at the same elevation from which it was projected.

**28**) The total time the mass is in the air is ___ seconds.

A) 1.5 B) 2.6 C) 3.1 D) 5.1 E) 8.2

**29**) When the mass was at a vertical height of 16.0 m on its way up, the net force on it was ___ N .

A) 14.7 B) 9.8 C) 6.5 D) 4.9 E) 0

**Use the following information for # 30, 31, and 32**

**30-32** Given a horizontal "massless spring". Its left end is attached to a rigid vertical support. A small 0.50 kg mass is attached to its right end. They are on a horizontal frictionless surface. The spring constant is 50.0 N/m (that is, the ratio of the force required to stretch produced (or compression produced) is 50.0 N/m). The mass is initially in equilibrium and at rest. The mass is displaced a distance 0.10 m to the right and released with a speed of 1.2 m/s to the left. The mass oscillates executing simple harmonic motion.

**30)** The amplitude for the motion is ___ m .

A) 0.29 B) 0.25 C) 0.20 D) 0.16 E) 0.10

**31**) When the mass was at 0.05 m, its acceleration was __ $m/s^2$ .

A) 5.0 B) 3.5 C) 1.7 D) 0.5 E) 0.35

**32**) If the velocity at release had been 1.2 m/s to the right instead of to the left, the amplitude for the motion would have been ____ .

A) almost double
B) larger, but not double
C) the same
D) half
E) smaller but not half

**33**) A 0.050 kg mass of a solid metal is heated to 250 degrees Celsius. The metal has a specific heat of 400 J/kg-Celsius degree . It is placed in 0.100 kg of water that is in a container that is equivalent to 0.015 kg of water. Assume no heat is gained from nor lost to the surroundings. The specific heat of water is 4,186 J/kg-Celsius degree . The original temperature of the water and container was 20.0 degrees Celsius. The final temperature of the water, container, and metal was __ degrees Celsius .

A) 35.8 B) 33.6 C) 31.7 D) 29.2 E) 22.5

**Use the following information for # 34, 35, and 36**

**34-36** Given the expression below for the vertical displacement, y , of points on a transverse wave traveling on a long, very light string along the horizontal axis, x . It gives y in meters when x is in meters and t is in seconds:

$$\mathbf{Y = (0.03\ m)\cos(2\Pi\,(x/0.5\ m - (0.25/s)\,t))}$$

$$\mathbf{Y = 0.03\cos(2\Pi(x/0.5 - 0.25\,t))}$$

**34)** The magnitude of the value of y for x = 2.0 m and t = 2.0 s is ____ m.

A) 0.00 B) 0.021 C) 0.025 D) 0.03 E) 0.04

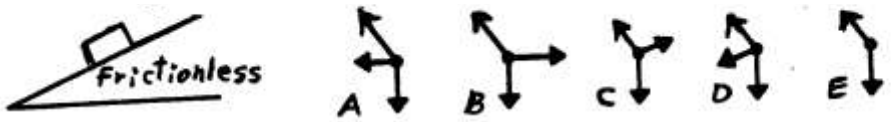
**35**) The speed of the wave is _____ m/s.

A) 8.0 B) 4.0 C) 2.0 D) 0.12 E) 0.08

**36**) The equation represents a ___ wave .

A) standing B) traveling C) resonance D) martinized E) beats

**37)** For a block sliding down a frictionless inclined plane, which of the following free-body diagrams best represents the forces on the block?




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

**Use the following information for # 38 and 39**

**38-39** At a point 3.0 m from an isotropic sound source the sound intensity level is $10^{-3}$ W/m$^2$ . The sound level in decibels is 90 dB.

**38)** At a distance 6.0 m from the source the sound level is ___ dB.

A) 30 B) 60 C) 78 D) 84 E) 135

**39**)The power of the source is ___ W .

A) 0.03 B) 0.11 C) 10 D) 30 E) 100

**40**) A sound source of 900 Hz is on an emergency vehicle approaching an observer at 22.0 m/s (49 mph). The observer is at rest. The observer receives a sound with a frequency of ___ Hz . Speed of sound in air is 343 m/s .

A) 54 B) 62 C) 846 D) 918 E) 961

**Use the following information for # 41 and 42**

**41-42** Given a one meter long plank weighing 40.0 N. Using hanging masses three downward forces are applied to the plank. The forces are: 100.0 N at the left end of the plank ( the zero mark), 100.0 N at the 0.40 m mark ( 0.40 m from the left end), and 120.0 N at the 0.90 m mark ( 0.90 m from the left end). The plank with forces is supported by an upward force at the center of the plank ( the 0.50 m mark) . The plank is in equilibrium.

**41**) The center of gravity of the plank is at the __ m on the plank.

A) 0.8 B) 0.7 C) 0.5 D) 0.30 E) 0.1

**42**) The net upward force applied at the 0.50 m mark is ___ N .

A) 360 B) 320 C) 180 D) 40 E) 0

**Use the following information for # 43 and 44**

**43-44** Given a uniform ladder resting against a vertical wall. The ladder has a weight of 400.0 N, is 4.0 m long, and touches the wall 3.0 m off the ground. It is inclined at a 48.6 degree angle with the horizontal. The coefficient of static friction between the base of the ladder and the ground is 0.55 . There is a 100.0 N load on the ladder. It is 3.0 m up the ladder ( 2.25 m off the ground)

**43)** The force due to friction on the ladder is ___ N .

A) 275 B) 242 C) 232 D) 212 E) 201

**44)** The angle with the horizontal that is made by the force from the ground on the ladder is ___ degrees.

A) 64.2 B) 61.2 C) 48.6 D) 40.8 E) 25.8

**Use the following information for # 45 and 46**

**45-46** A very light thin string is in vibration and forms a standing wave with 4 loops ( 5 nodes). The string is 3.0 m long. One end is attached to a small transverse vibrator which is vibrating at 40.0 Hz. The other end is attached to a rigid support.

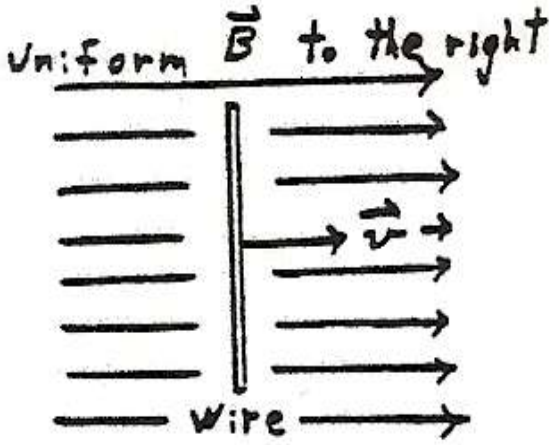
**45)** The wave speed on the string is __ m/s .

A) 120 B) 90 C) 60 D) 40 E) 3

**46)** The frequency of the vibrator is changed and results in a different standing wave. The standing wave has 5 loops (6 nodes) . The frequency of the vibrator is ___ Hz .

A) 60 B) 50 C) 47 D) 45 E) 42

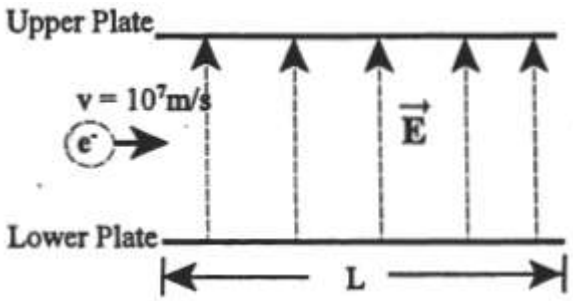
**47**) Given a straight wire segment moving to the right with speed v in a uniform magnetic field pointing to the right as shown. The wire is perpendicular to the magnetic field.




The positive charges in the wire will experience a magnetic force directed __

A) to the left
B) to the right
C) toward the top of the page
D) toward the bottom of the page
E) none of these, no force produced

**Use the following information for #48-49**




**48-49** Given an electron moving at $10^{+7}$ m/s. It enters a uniform electric field at the middle of the field formed by a parallel plate capacitor. The plates are horizontal. The plate separation is 0.02 m. The electron's velocity is horizontal. The electric potential across the plates is 100.0 volts. Treat problem as non-relativistic.

**48)** The acceleration of the electron in the field is approximately ___ $m/s^2$ .

A) $10^{+6}$ B) $10^{+8}$ C) $10^{+11}$ D) $10^{+13}$ E) $10^{+15}$

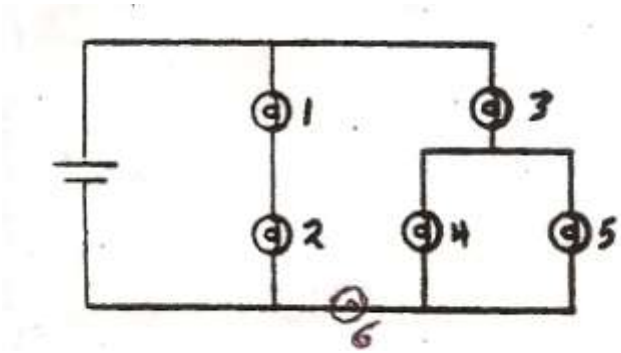
**49)** The potential difference that accelerated the electron from essentially at rest to $10^{+7}$ m/s was approximately ___ volts.

A) 1700 B) 300 C) 170 D) 17 E) 0.30

**50)** When a sound travels from a medium in which it has a speed v into a medium in which its speed is twice as large, the frequency of the sound is ___ its value in the first medium.

A) one-fourth B) one half C) the same as D) double E) four times

**51**) Given six identical light bulbs attached to an ideal emf as shown. Assume that the current in each light bulb is sufficient for all the bulbs to light. Rank order the bulbs on the basis of how bright a bulb will light with the brightest first. Indicate a "tie" with an equals sign. The correct ranking is




A) 1=2=3=4=5=6
B) 4=5, 3, 1=2=6
C) 1=2, 4=5, 3=6
D) 1=2, 3=6, 4=5
E) 3=6, 4=5, 1=2

**Use the following information for # 52 and 53**

**52 – 53** A small particle enters a uniform magnetic field at a right angle to the field. The particle has a mass of $10^{-25}$ kg . Its velocity is $10^{+6}$ m/s in the plane of this page. Its charge is 3.2 X $10^{-19}$ Coulomb. The magnetic field is perpendicular to the plane of the page and pointing upward. The strength of the magnetic field, B, is 0.1 Tesla.

**52**) The radius of the particle's path is approximately ___ m .

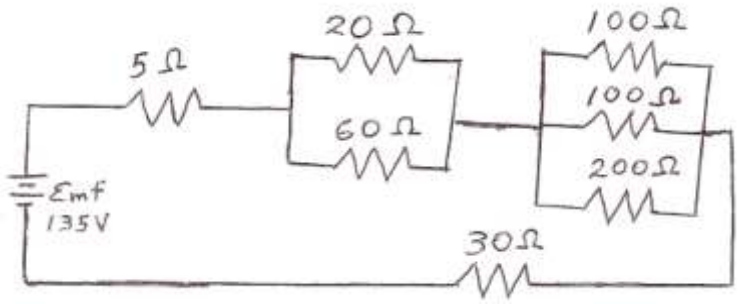
A) less than 0.01 B) 0.03 C) 0.50 D) 1.5 E) 3.1

**53**) If the particle had twice the charge, the radius would have been ___ the original radius .

A) twice B) 1.41 times C) the same as D) 0.71 times E) half

**Use the following information for # 54 and 55**

**54-55** Given seven ohmic resistors arranged as shown in the figure below. The combination is connected to a 135 V ideal emf.



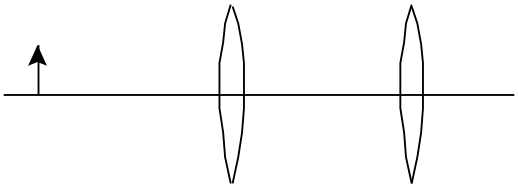

**54)** The current in the 5 ohm resistor is ___ A .

A) 1.5 B) 1.75 C) 2.0 D) 2.4 E) 83

**55)** The power used by the 200 ohm resistor is ___ times the power used by the 20 ohm resistor.

A) 0.38 B) 0.71 C) 1.4 D) 2.7 E) 10

**Use the following information for # 56 and 57**



**56-57** Given two thin positive lenses positioned so that their centers of curvature fall on a straight line. The focal length of lens 1, F1,(the left lens) is 0.30 m and the focal length of lens 2, F2, (the right lens) is 0.45 m. The lenses are 0.15 m apart. A small object is located 0.10 m to the left of lens 1. It is located on the principal axis of the lenses and is 0.01 m tall. It is erect.

**56**) The image formed by lens 2 is ___ .

A) real and erect
B) real and inverted
C) virtual and erect
D) virtual and inverted
E) no image is formed

**57**) The image formed by lens 2 is ___ m tall.

A) no image formed B) 0.90 C) 0.30 D) 0.22 E) 0.045

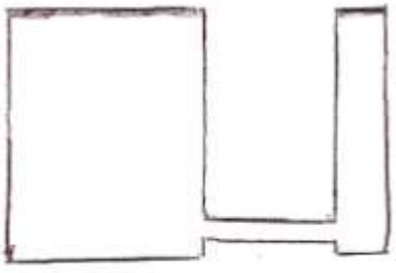


**Illustration for #58**

**58**) Given a Pascal's Principle device, a hydraulic lift. Two circular cylinders stand next to each other and are joined by tubing at their bottoms. The cylinders are 0.15 m tall. They are filled with oil. They each have a friction free "massless" piston at their tops. The one on the left has a radius of 0.02 m , and has a weight of 10.0 N placed on the piston. The radius of the one on the right is 0.005 m , and has a weight on it to offset the weight placed on the left to set the system in equilibrium. In the larger cylinder the increase in pressure 0.01 m above the bottom is __ Pa.

.

A) zero B) $4 \times 10^{-4}$ C) $6 \times 10^{+2}$ D) $8 \times 10^{+3}$ E) $10^{+4}$

**Use the following information for #59-60**

**59-60** Given a Fraunhofer Young's double slit interference apparatus. The center-to-center separation of the two slits is $8.0 \times 10^{-5}$ m . The slits are the same size. The slit width is $3.0 \times 10^{-5}$ m each. There is a screen 3.0 m from the plane of the double slits. A monochromatic beam of light with wavelength $5.0 \times 10^{-7}$ m illuminates the slits and an interference pattern appears on the screen.

**59)** The distance between adjacent maxima in the pattern is __ m .

A) 0.21 B) 0.11 C) 0.027 D) 0.023 E) 0.019

**60**) If one slit were covered and a single-slit diffraction pattern were on the screen, the width of the central maximum would be ___ m .

A) 0.05 B) 0.10 C) 0.18 D) 0.24 E) 0.33

The End