Merck State Science Day 2006 **Physics**

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question. **You may write on the test, but to be counted and earn credit, you must indicate your choice on the answer sheet provided. Unless otherwise indicated ignore friction with the air.**
Treat all problems as non-relativistic. Use 9.8 m/s^2 as the acceleration due to gravity on earth.

Use the following information for questions #1 and 2:
Given a ball made of a metal with a density of 4,000 kg per cubic meter. The ball has a radius of 0.30 meter. It has a hollow center with a radius of 0.20 meter.

1. When placed in a large wide tank 5 m tall filled with water, the ball ___

A) floats 2/3 out of water
B) floats 1/2 out of water
C) floats 4/9 out of water
D) sinks to about half way down
E) sinks to the bottom.

2. If a solid ball of the same material and outer radius had been made, its weight would have been approximately ___ N.

A) 4,380,000 **B)** 44,000 **C)** 14,600 **D)** 4,400 **E)** 140

Use the following information for questions #3 and #4:
Given: a horizontal pipe 0.20 m in diameter. The pipe enlarges to a larger horizontal section with a diameter of 0.40 m. An ideal incompressible liquid is flowing through the pipe. In the wider region the flow rate is 1.0 m^3/s . There is no turbulence.

3. The speed of the ideal liquid in the larger section of the pipe is approximately ___ m/s

A) 8 **B)** 0.04 **C)** 0.03 **D)** 0.004 **E)** 0.008

4. If the liquid had been a real liquid, then the speed of the liquid half-way between the center and the pipe itself would have been ___ its maximum value for that cross section.

A) 0.87 **B)** 0.75 **C)** 0.67 **D)** 0.50 **E)** 0.25

5. A marble is dropped from a 20 meter tall tower and falls to the ground. After release, but before reaching the ground, the marble's acceleration _____.

A) results from a forward force of motion and the pull of the earth.
B) increases, then is constant, and then decreases
C) is downward for half the distance and upward for the second half
D) is downward and increases at a constant rate during the fall
E) is downward and constant.

Use the following information for questions #6, 7 and 8:
Given: a record of position X in meters as a function of time in seconds for an object with rectilinear motion. Expressed as a power series in t, time, it requires terms as high as time cubed, t^3. Values shown are not rounded.

Time (s)	0	1	2	3	4	5	6	7	8	9	10
X (m)	10.0	8.3	7.6	8.5	11.6	17.5	26.8	40.1	58.0	81.1	110.0

6. The average speed of the object over the ten seconds was ___ m/s .

A) 22.1 **B)** 17.5 **C)** 11 **D)** 10 **E)** 9.3

7. The acceleration of the object __ .

A) is constant
B) is always positive
C) is always negative
D) is impossible to determine

8. The speed of the object when time was zero was ___ .

A) negative
B) zero
C) positive
D) impossible to determine

Use the following information for questions #9 and 10:
Given: a capacitor, resistance, ideal emf, and an open switch all arranged in series. The capacitance is 100 microFarad (10^{-4} F) . The resistance is 100,000 ohms (10^5 ohms). The ideal emf is 40 volts. At time t equals zero the switch is closed and the capacitor starts to charge.

9. The time constant for the RC circuit is ___ s .

A) 10^{-9} **B)** 0.0001 **C)** 10 **D)** 400 **E)** 10^9

10. The maximum current provided by the emf is ___ mA .

A) 1,000
B) 400
C) 2
D) 0.4
E) less than 0.01

11. A monochromatic beam of light, perpendicular to the plane of a single slit, shines on the slit. One does not observe any diffraction pattern as a result. An explanation for this is that the size of the slit width is ___ .

A) much larger than the wavelength
B) between 10 and 5 wavelengths wide
C) about equal to the wavelength
D) much smaller than the wavelength

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

A) equal to the object's weight
B) 1/2 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 previous answers

13. The phenomenon of beats occurs for two sound waves when the two superimposed waves have ___ .

A) frequencies that are a little different
B) the same frequency and amplitude but different phases
C) the same frequency but different amplitudes
D) frequencies where one has to be twice the other frequency.
E) none of the previous answers is correct.

14. Given an isotropic point sound source. At a distance of 9.0 m from the source the sound level intensity caused by the source is 60 dB. At a distance of 3.0 m, one-third the original distance, the dB reading caused by the source would be about ___ dB .

A) 180 **B)** 90 **C)** 70 **D)** 63 **E)** 20

15. Given a solid disk rolling without slipping on a horizontal plane. The translational speed of the center of the disk is 2.0 m/s. The instantaneous translational speed of the point on the outer edge of the disk at the bottom of the disk, and therefore in contact with the plane , is ___ m/s .

A) 0 **B)** 1.0 **C)** 2.0 **D)** 3.0 **E)** 4.0

16. Given four identical resistors. When placed in series the equivalent resistance of the four resistors is 12 ohms. The four resistors are placed in various combinations – parallel, series and parallel, etc -- . Which of the following five values could not be an equivalent resistance for the four resistors? ___

A) 0.75 **B)** 1.33 **C)** 3 **D)** 4 **E)** 7.5

17. 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 ___ .

A) is equal to the area under a Force vs. Distance curve only if F is constant
B) is equal to the area under a Force vs. Time graph only if F is constant
C) is equal to the area under a Force vs. Distance curve, even if F varies
D) is equal to the area under a Force vs. Time graph, even if F varies
E) can be determined only if the starting speed is zero.

Use the following information for questions #18 and 19:
Given: the measured values to the correct number of significant figures of the length, width, and height respectively of a rectangular box, 0.210, 1.34, and 0.043 m .

18. The area of the smallest face of the box expressed to the correct number of significant figures is __ meter^2 .

A) 0.009030 **B)** 0.00903 **C)** 0.0090 **D)** 0.009 **E)** 0.01

19. On the measuring instrument similar to a meter stick used to measure the 1.34 m width, the smallest marked interval on the measuring device was ___

A) meters **B)** decimeters **C)** centimeters **D)** millimeters **E)** tenths of mm

20. Given a basketball held at rest at a height h . A second but much smaller ball is placed on top of the basketball. For this discussion assume the balls have elastic collisions. The basketball is released from rest and the pair travel downward. Their speed downward just at collision is v . The magnitude of the rebound speed of the smaller ball is approximately ___ .

A) many, many v
B) 10 v
C) 5 v
D) 3 v
E) v

21. When a beam of monochromatic light passes from one medium to another, the ___ does not change.

A) amplitude **B)** speed **C)** wavelength **D)** frequency **E)** direction

Use the following information for questions #22, 23 and 24:
Given: a "massless" spring mounted horizontally on a horizontal flat frictionless surface. The left end of the spring is attached to a fixed rod. A 1.5 kg mass is attached to the right end of the spring. The mass is displaced horizontally and released with a starting speed to the left. The spring was stretched 0.10 m and released traveling at 0.15 m/s The mass vibrates on the horizontal surface in a very good approximation to Simple Harmonic Motion. The spring's constant of proportionality is 2.5 Newtons per meter.

22. The amplitude for the motion was approximately___ m .

A) 0.10 **B)** 0.15 **C)** 0.20 **D)** 0.25 **E)** 0.30

23. The frequency of the motion of the mass was ___ Hz .

A) 0.18 **B)** 0.21 **C)** 2.6 **D)** 4.9 **E)** 26

24. When the stretch of the spring was 0.05 m , the acceleration of the mass was __ m/s^2 .

A) 0.08 **B)** 0.12 **C)** 0.25 **D)** 1.25 **E)** 1.88

Use the following information for questions #25, 26 and 27:
Given: a spherical positive mirror (concave) with a 0.01 m tall object placed 0.30 m to the left of the mirror on the principal axis of the mirror. The mirror forms a virtual image of the object a distance of 0.45 m from the mirror.

25. The image is ___ m tall.

A) 0.005 **B)** 0.010 **C)** 0.015 **D)** 0.020 **E)** 0.025

26. 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

27. The index of refraction for water is about 1.33. If the mirror were under water, not in air, its focal length would be ___ times its focal length in air.

A) 1.33
B) 1 (the same as)
C) (1.33 – 1)
D) 1/1.33
E) (1.33 – 1)/1.33

Use the following information for questions #28 and 29:
Given: a "uniform" ladder inclined at 37 degrees with the horizontal. The ladder is 5.0 m long. It has a weight of 500.0 Newtons. The upper end is resting against a vertical wall. Assume the wall is frictionless. The lower end rests on a floor. A person who weighs 600.0 Newtons is on the ladder 2.0 m from the lower end (approx. 1.2 m above the floor).

28. The vertical component of the floor's force on the ladder is ___ N .

A) 1100 **B)** 500 **C)** 111 **D)** 51 **E)** 39

29. The outward force on the ladder from the wall is ___ N .

A) 368 **B)** 490 **C)** 653 **D)** 846 **E)** 1100

Use the following information for questions #30, 31 and 32:
Given: a very light taut string that is stretched horizontally and attached at its ends to rigid supports. The taut string is displaced a few centimeters downward at its center and released. The string vibrates at its fundamental frequency, 40 Hz. The length of the string that vibrates is 2.0 meters. Consider the speed of sound in the air as about 336 m/s.

30. The speed of a transverse wave on the vibrating string is ___ m/s .

A) 20 **B)** 40 **C)** 80 **D)** 160 **E)** 320

31. If the string were displaced downward at a point about 0.50 m from its left end, the wavelength for the string's fundamental would ___ the original value.

A) be one fourth
B) be half
C) remain the same as
D) be 1.4 times the original value
E) be double

32. If the tension in the string were four times the original value, the fundamental frequency would have been ___ Hz .

A) 160 **B)** 80 **C)** 56 **D)** 40 **E)** 20

33. Given a flat object in equilibrium in space. It has a center of mass at a point CM . Two forces are applied to the object. The object is still in total equilibrium. Therefore, the two forces ___

A) must be equal, anti-parallel, collinear and pass through CM
B) need not be equal but must be anti-parallel, collinear, and pass through CM
C) need only be equal, anti-parallel, and pass through CM
D) need only be equal, collinear, and pass through CM
E) none of these four

Use the following information for questions #34 and 35:
An astronaut is in space whirling a point mass around in a circle at a constant angular speed of 2.0 rad/s . The point mass has a mass of 0.20 kg . The radius of the circle is 1.5 m .

34. The total acceleration of the point mass is ___ m/s^2 .

A) zero **B)** 1.2 **C)** 6.0 **D)** 9 **E)** 12

35. The astronaut pulls the string in rather quickly, reducing the radius of the circle from 1.5 m to 1.0 m . The tangential speed of the point mass is now __ m/s .

A) 4.5 **B)** 4.2 **C)** 4.0 **D)** 3.5 **E)** 3

36. According to the ideal gas law a one liter volume of a gas at a gauge pressure of 15 pounds per square inch and a temperature of 27 degrees Celsius will have a volume of ___ liters if the gauge pressure becomes 30 pounds per square inch and the temperature becomes 54 degrees Celsius.

A) 1.4 **B)** 1.2 **C)** 1 **D)** 0.73 **E)** 0.54

37. Given a loop of wire in a uniform magnetic field. The field is directed upward out of the page and the field is increasing. The plane of the loop of wire coincides with the plane of the page, and therefore perpendicular to the magnetic field. The current induced in the loop, looking down on the page, is __ .

A) clockwise
B) counterclockwise
C) No current is induced in loop.

38. A concave lens (negative focal length) produces an image larger than its object when the object distance is __ .

A) less than a focal length
B) equal to a focal length
C) between one and two focal lengths
D) twice the focal length
E) never – the lens always forms reduced images.

Use the following information for questions #39, 40 and 41:
A projectile is launched at an angle of 39 degrees above the horizontal with a speed of 150 m/s . Assume no friction with the air.

39. The speed of the projectile at the highest point in its trajectory is __ m/s .

A) 0 **B)** 50 **C)** 94 **D)** 117 **E)** 121

40. The range of the projectile is ___ m .

A) 2245 **B)** 1935 **C)** 1492 **D)** 1123 **E)** 562

41. Using the same initial speed, the same range would be achieved with a launch angle of __ degrees.

A) almost 60 **B)** 51 **C)** 45 **D)** 41 **E)** 33

Use the following information for questions #42 and 43:
Given a uniform thin rod 2.00 m long. Assume it remains straight. Call its left end zero and its right end 2.00 m . In the laboratory here on earth when the rod is supported at the 1.50 m mark, an attached mass of 1.8 kg located at the 1.70 m mark puts the rod in equilibrium.

42. The mass of the rod is ___ kg.

A) zero **B)** 0.24 **C)** 0.72 **D)** 1.8 **E)** 2.4

43. If this experiment were performed on the moon where gravity is approximately one-sixth its value on earth, the determined mass would be ___ its value on earth.

A) 6 times **B)** 1.41 **C)** equal to **D)** 0.71 **E)** 1/6

44. Given four point charges at the corners of a square. At the center of the square the electric potential and electric field are both zero.
Which of the following cannot be true about the charges. The four charges ___ .

A) must sum to zero
B) may all have the same charge sign
C) must be situated with identical charges at the end of diagonals
D) may have opposite sign charges at adjacent corners of the square
E) that produce zero electric potential at the center will also produce zero electric potential at only four other points in the plane of the square .

Use the following information for questions #45 and 46:
A 2.0 kg mass is moving at 4.0 m/s to the right on a horizontal frictionless surface, and has a head-on collision with a 4.0 kg mass moving to the left at 3.0 m/s . (- means motion to the left; + means to the right)

45. If the two masses collide and stick together (perfectly inelastic collision), their speed after collision is __ m/s .

A) -3.67 **B)** -0.67 **C)** 0 **D)** 0.67 **E)** 3.67

46. If the collision of the two masses had been perfectly elastic, the magnitude of the speed with which the masses separated is ___ m/s .

A) 12 **B)** 7 **C)** 3.67 **D)** 1 **E)** 0.67

Use the following information for questions #47, 48 and 49:
Given: a 1.0 m layer of water on top of a transparent material. The water and material have a flat horizontal interface. A ray of light is incident on the interface at an angle of 30 degrees (measured with the normal). The ray is in the transparent material. It bounces off the interface back into the transparent material. Use 1.33 as the index of refraction for water.

47. The speed of the ray in the transparent material is approximately ___$X10^8$

A) 6
B) 3
C) 1.5
D) 0.75
E) impossible to determine

48. The speed of the ray in water is ___ $X10^8$

A) 3.39 **B)** 2.25 **C)** 1.33 **D)** 1.00 **E)** 0.5

49. If the beam were in the water and incident on the interface at 30 degrees, the angle the beam would make in the transparent material with respect to the normal would be ___ degrees.
A) 0
B) less than 30
C) 30
D) more than 30
E) could be more or less than 30

50. Given two transmission diffraction gratings which are used to produce Fraunhofer diffraction images. One has a line density of a few hundred lines per centimeter and is used first to produce a spectrum of a beam of light. Then it is replaced with a second grating that has a line density of a few thousand lines per centimeter. Examining the line pattern formed one would note that ___ .

A) the number of secondary maxima decreases
B) the width of the principal maxima increases
C) the grating spacing increases
D) the lines in the pattern change color
E) the angular positions of the maxima change.

51. An astronaut on earth with gear weighs 180 pounds. In orbit around the earth in a typical orbit of 200 miles above the earth, the astronaut floats about in the spaceship cabin.The gravitational pull on the astronaut from the earth is about ___ pounds.

A) 0 **B)** 10 **C)** 100 **D)** 160 **E)** 179

Use the following information for questions #52 and 53:
A 0**.**200 kg piece of metal is heated and placed in 0.500 kg of water. The temperature of the water rises from 18 degrees Celsius to 24 degrees Celsius. Assume no heat is gained nor lost to the environment. The experiment is repeated with a second, but different 0**.**200 kg metal sample and a 0**.**500 kg of water rises in temperature from 18 to 30 degrees.

52. The specific heat of the second metal is __ times that of the first metal.

A) 2.2 **B)** 2.0 **C)** 1.41 **D)** 1.1 **E)** 0.20

53. A liquid with a specific heat 1.5 times that of water is used instead. Using the first metal the rise in the temperature from 18 degrees Celsius would be about ___ Celsius degrees.

A) 12 **B)** 9 **C)** 6 **D)** 4 **E)** 2

Use the following information for questions #54 and 55:
A box weighing 250 N is on a 30 degree downward slope (30 degrees below the horizontal) . A "massless" string is attached to the box and is pulling on it downward along the slope with a force of 50 N . The box is sliding downhill at a constant rate of 0**.**4 m/s . The rope is parallel to the slope. Neglect the weight of the rope.

54. The coefficient of kinetic friction between the box and the slope is approximately ___ .

A) 0.8 **B)** 0.67 **C)** 0.5 **D)** 0.35 **E)** 0.25

55. If this motion takes place over a slope length of 10.0 m , the work done against friction will be __ J .

A) 1750 **B)** 1250 **C)** 750 **D)** 550 **E)** 400

Use the following information for questions #56, 57 and 58:
The equation:

$$Y = (0.01\ m)\ \text{Cos}\ (2\ \pi\ (\ 2.0\ X/m - 0.20\ t/s))$$

represents a traveling wave on a long, very light (massless) string. m and s stand for meter and second, respectively.

56. When x = 0.50 m and t = 5.0 s , then the magnitude of Y equals ___ m.

A) 0.2 **B)** 0.1 **C)** 0.02 **D)** 0.01 **E)** 0

57. The speed of the waveform along the string is ___ m/s .

A) 10 **B)** 0.4 **C)** 0.1 **D)** 0.01 **E)** 0.004

58. If the amplitude were halved, the speed of the waveform on the string would be ___ times the original speed.

A) 0.25 **B)** 0.50 **C)** 0.71 **D)** 1 **E)** 1.4

Use the following information for questions #59, 60, 61 and 62:
Given a parallel plate capacitor with air or a vacuum between the plates, oriented horizontally. The capacitor is connected to an ideal emf, positive to the upper plate and negative to the bottom plate. A uniform electric field is created in the space between the plates. The plates are 0.03 m apart. The magnitude of the electric field is seven hundred Newtons per Coulomb (700 N/Coul). The plates of the capacitor are positioned horizontally. A proton is moving horizontally toward the middle (0.015 m) of the space between the plates. The proton has a velocity of 50,000 m/s (5×10^4 m/s).

59. The potential difference across the plates is approximately ____ V .

A) 23,000 **B)** 2,000 **C)** 1,000 **D)** 700 **E)** 21

60. Assuming the moving charge remains in the electric field long enough to collide with the lower plate, its speed on impact with the plate will be approximately ___$x10^4$ m/s .

A) 46 **B)** 6.8 **C)** 6.2 **D)** 5.5 **E)** 2.1

61. If the potential difference which accelerated the proton from essentially rest to 50,000 m/s had been applied to an electron originally at rest, the electron's speed would have been approximately ___ m/s .

A) 92,000,000 **B)** 2,100,000 **C)** 1,000,000 **D)** 400,000 **E)** 220,000

62. If when the proton entered the electric field there had been a uniform magnetic field so positioned that the proton traveled through undeflected, the strength of that magnetic field would have been approximately ___ T .

A) 0.01 **B)** 0.1 **C)** 1 **D)** 10 **E)** 100

63. Given four double slit arrangements, -- I, II, III, and IV -- illuminated by plane light waves in a typical Fraunhofer set-up. Using monochromatic beams of light, interference patterns with uniformly spaced maxima are formed on screens 2 meters from the slits. The maxima in each pattern have essentially the same intensity (brightness). The slot size is the same for all four. The center-to-center separation of the slits is either d or 2d (double). The frequency of the light used is either f or 1.5f (one and one half times the original frequency). The table below summarizes which separation and which light frequency is used for a particular double slit.

Double Slit	Slit Separation	Frequency of Light Used
I	d	f
II	d	1.5f
III	2d	f
IV	2d	1.5f

Rank order the double slits on the basis of the center-to-center separation of the maxima in the interference patterns putting the largest first. Indicate a tie (equal values) with an = sign.

A) I,II,III,IV **B)** II,I,III,IV **C)** IV,II,III,I **D)** III,IV,I,II **E)** I,IV,III,II

64. At a temperature of zero degrees Celsius the root-mean-square speed, V_{rms} , of an oxygen molecule is approximately 460 m/s. If the temperature were 30 degrees Celsius, that speed would be approximately ___ m/s.

A) 430 **B)** 460 **C)** 485 **D)** 499 **E)** 511

65. A sound source emits a short duration sound which travels outward, bounces off a stationary object, and returns to the source. The entire trip took 0.6 second. About 10 minutes later the same sound is emitted, bounces off the same stationary object, and returns to the source. This time the total trip required 0.8 second. During the 10 minute interval the object had been moved from one position to the other, a distance of ___ m. Assume the speed of sound in air was 340 m/s.

A) 34 **B)** 68 **C)** 102 **D)** 136 **E)** 204

Answer Section

MULTIPLE CHOICE

1. ANS: E
2. ANS: D
3. ANS: A
4. ANS: B
5. ANS: E
6. ANS: D
7. ANS: B
8. ANS: A
9. ANS: C
10. ANS: D
11. ANS: D
12. ANS: A
13. ANS: A
14. ANS: C
15. ANS: A
16. ANS: B
17. ANS: D
18. ANS: C
19. ANS: B
20. ANS: D
21. ANS: D
22. ANS: B
23. ANS: B
24. ANS: A
25. ANS: C
26. ANS: E
27. ANS: B
28. ANS: A
29. ANS: C
30. ANS: D
31. ANS: C
32. ANS: B
33. ANS: E
34. ANS: C
35. ANS: A
36. ANS: D
37. ANS: A
38. ANS: E
39. ANS: D
40. ANS: A

41. ANS: B
42. ANS: C
43. ANS: C
44. ANS: E
45. ANS: B
46. ANS: B
47. ANS: E
48. ANS: B
49. ANS: B
50. ANS: E
51. ANS: D
52. ANS: A
53. ANS: D
54. ANS: A
55. ANS: A
56. ANS: D
57. ANS: C
58. ANS: D
59. ANS: E
60. ANS: B
61. ANS: B
62. ANS: B
63. ANS: A
64. ANS: C
65. ANS: A