The 55th Annual Merck State Science Day Competition May 17, 2005 Physics

PLEASE DO NOT OPEN 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.

The test has 68 items. 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. (There is no penalty for guessing, and items each count 1/68 of the final score.)

There are additional subject specific important items below. Be sure to read them first.

Current means traditional current, the flow of positive charges.

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	$c = 3.00 \times 10^{8}$ 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 atmosphere pressure	1 atm = 1.0×10^{5} N /m^2 = 1.0×10^{5} Pa

Although you may want to circle your chosen answer on this test paper, you must also indicate your choice on the answer sheet provided in order to earn credit. There will be NO penalty for guesses.

1. A solid block of metal is suspended so that it is entirely under the surface of a liquid, but not resting in any way on the bottom of the container. Its apparent mass is 0.250 kg when the liquid is water and 0.263 kg in a liquid with a density of 850 kg/m^3 The volume of the metal block is approximately ____ m^3

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

2. Given a horizontal pipe 0.05 m in radius. The pipe reduces to a horizontal section 0.03 m in radius. An ideal incompressible liquid flows through the pipe. The flow rate through the reduced section is 0.0015 m^3/s . The speed of ideal liquid in the larger section is approximately ___ m/s .

   A) 0.0004 B) 0.0015 C) 0.2 D) 1 E) 6

The following situation applies to items 3 and 4. *Given two thin spherical lenses 25 cm apart. Their principal axes coincide. The focal length of the lens on the left is 50 cm. A small object is placed 30 cm to the left of the left lens, on the principal axis line. The focal length of the lens on the right is 50 cm.*

3. The final image formed by this arrangement of lenses and object is ____ .
A) inverted and 100 cm to the right of the 50 cm focal length
B) erect and 100 cm to the right of the 50 cm focal length
C) inverted and 33 cm to the right of the 50 cm focal length
D) inverted and 33 cm to the left of the 50 cm focal length
E) erect and 33 cm to the right of the 50 cm focal length

4. If the lenses had been placed in contact to form a crude compound lens, its focal length would have been approximately ___ cm .

   A) 0 B) 20 C) 25 D) 50 E) 100

The following situation applies to items 5 and 6. *A launching device releases a ball traveling horizontally at a speed of 40 m/s from a height of 10.0 m. Assume no friction with the air. The horizontal distance between the launcher and the vertical plane of a target is 40.0 m.*

5. When the ball arrives at the target, the magnitude of the velocity of the ball is approximately ___ m/s

   A) 10 B) 9.8 C) 20.2 D) 41.2 E) 45.1

6. If the motion had taken place on a recently discovered moon where the acceleration due to gravity is twice the value on earth (approximately 20.0 m/s^2), the vertical displacement of the ball during its travel toward the target would be approximately___ m

   A) 10.0 B) 7.5 C) 5.0 D) 2.5 E) 1.2

The following situation applies to items 7 and 8. *A solid disk is rotating about an axis perpendicular to its face at its center. Its moment of inertia about the axis is 0.50 kg-m^2. Its angular velocity is 12 rad/s .The radius of the disk is 1 m .*

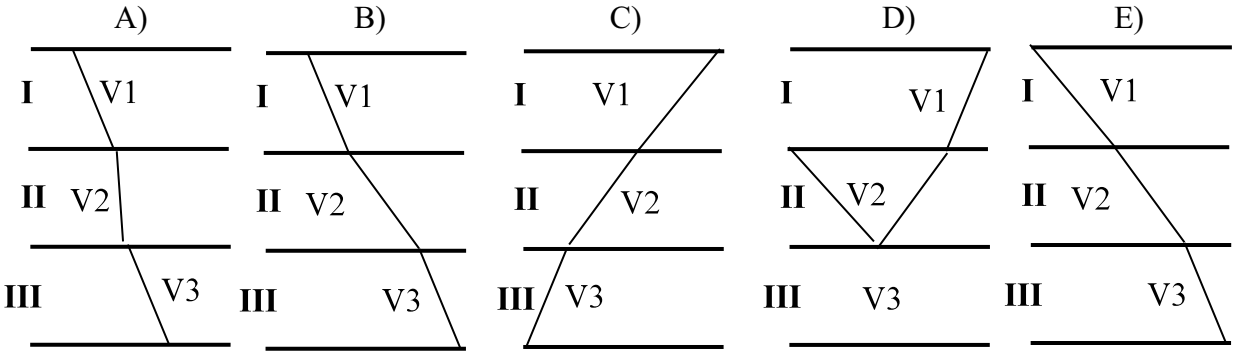
7. If its angular velocity changes from 12 rad/s to 6 rad/s , then its rotational kinetic energy is reduced by ___ J .

A) 36 B) 27 C) 9 D) 6 E) 3

8. Given a second solid disk similar to the first except that it has a 0.5 m radius hole drilled at its center making that disk resemble a "washer" . The masses of the two disks are the same. When both disks have angular velocities of 12 rad/s , the rotational kinetic energy of the second disk will be ___ times that of the first disk.

A) 1.6 B) 1.25 C) 0.75 D) 0.62 E) 0.5

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



The following situation applies to items 10 and 11. *Given a very light taut string stretched horizontally between two rigid supports. The length of the string free to vibrate is 1.5 meter. The string is displaced slightly at its center, is released, and vibrates at its fundamental frequency. The speed of sound in the air is about 336 m/s.*

~~**10.** The frequency of the vibrating string is ___ Hz.~~

~~A) 112 B) 168 C) 224 D) 280 E) 336~~

11. If the linear density of the string (mass per unit length) were doubled, the wavelength for the fundamental would ___ .

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

12. Two small particles initially at rest near each other are released. As they move, the acceleration they experience due to electrical force between them increases. Therefore..

A) both particles must be charged, and the charges are opposite.
B) both particles must be charged, and the charges are the same.
C) only one particle must be positively charged.
D) only one particle must be negatively charged.
E) only one particle must be charged, either negatively or positively.

The following situation applies to items **13 and 14.** *A 2 cm tall object is located 25 cm to the left of a spherical mirror. The spherical mirror forms an erect image 50 cm from the mirror.*

13. The image is ___ cm tall.

A) 0.50 B) 1.0 C) 2 D) 4 E) 5

14. The magnitude of the radius of curvature of the mirror is ___ cm.

A) 50/3 B) 25 C) 100/3 D) 50 E) 100

15. If a measured length using a device similar to a meter stick were given as 1.0 m to the correct number of significant figures, the smallest unit marked on the measuring device was ___ meter.

A) 0.001 B) 0.01 C) 0.1 D) 1 (just whole meters)

The following situation applies to items 16 and 17. *A "massless" spring is mounted horizontally on a horizontal frictionless surface. The left end is attached to a fixed rod. A 1.0 kg mass is attached to the right end of the spring. The mass is displaced horizontally so that the spring is stretched 8.0 cm and released. At the time of release the mass is traveling at 10 cm/s away from the rod. The mass vibrates horizontally in a very good approximation to Simple Harmonic Motion. The spring's constant of proportionality is 2.0 Newtons per meter.*

16. The maximum speed of the mass was approximately___ m/s.

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

17. The period of the motion was ___ s.

A) 0.11 B) 0.22 C) 2 D) 4.44 E) 9.05

18. A rock is thrown straight up in the air. <u>After</u> it is released from the thrower's hand, ___.

A) it speeds up at first and then slows down as it rises.
B) it slows down continuously until it reaches the top where its acceleration is zero and it falls back.
C) the net force on it is greater than its weight so it slows down.
D) the net force on it is less than its weight so it slows down.
E) the change in its velocity is directed downward toward the earth.

The following situation applies to items **19 and 20.** *A vehicle has a mass of 800 kg and is accelerated at a constant rate of 2 meters per second per second. When time is 5 seconds, the vehicle is traveling at 14 m/s . (*Assume the weight is evenly distributed over the four tires.)

19. The minimum coefficient of friction between the tires and the road is approximately ___
A) 0.15 B) 0.2 C) 0.25 D) 0.3 E) 0.35

20. In the five second interval the vehicle travels ___ m.
A) 70 B) 45 C) 35 D) 25 E) 20

21. A 10 kg brick and a 1 kg brick are dropped in a vacuum here on earth. The force of gravity on the 1 kg brick is ____ .

A) equal to the force of gravity on the 10 kg brick
B) zero
C) one-tenth as large as the force of gravity on the 10 kg brick
D) ten times as large as the force of gravity on the 10 kg brick

22. A block that weighs 100 N is at rest on the floor of an elevator. The elevator is moving downward at a constant velocity of 2 m/s . The net force on the block is approximately ___ N .

A) 120 B) 100 C) 80 D) 20 E) 0

The following situation applies to items 23 and 24. *A box weighing 200 N is held in place on a frictionless 37 degree slope (with the horizontal) by a light rope attached to a stake at the top. The rope is parallel to the slope. Neglect the weight of the rope.*

23. The tension in the rope is approximately ___ N.

A) 200 B) 160 C) 120 D) 100 E) 80

24. If there were friction, with a static coefficient of 0.8 and a kinetic coefficient of 0.2, the tension in the rope would be approximately ____ N .

A) 160 B) 128 C) 120 D) 64 E) 0

25. A tennis racket hits a tennis ball with a force of 600N. The ball exerts a reaction force on the racket _____.

A) much, much less than 600N B) of about 60 N C) of 600 N
D) of about 1200 N E) much, much greater than 600 N

26. If the measured sides of a rectangular block are 9.12 cm , 3.150 cm and 22.5 cm, then the area of the largest side , given to the correct number of significant figures, is _____ cm^2 .

A) 205 B) 205.20 C) 70.9 D) 28.73 E) 28.728

The following situation applies to items **27 through 29.** *Given a horizontal uniform board 8.00 m long. It has a weight of 30.0 N. A weight of 30.0 N is attached to the left end and one of 20.0 N is 6.00 m from the left end, both acting downward. A fourth force is applied and puts the board in equilibrium.*

27. About the left end the moments will sum to zero. About the center of gravity of the board the sum of the moments will be ___ .

A) positive B) negative C) zero also

28. The magnitude of the moment of the attached 30.0 N force about the center of gravity of the board is ___ Nm .

A) 240 B) 120 C) 60 D) 30 E) 0

29. The location of the fourth force is approximately ____ m from the left end.

A) 1.0 B) 1.5 C) 2.5 D) 3 E) 4

30. The force exerted on the tires of a car that directly pushes it along a road is exerted by the ___ .

A) engine B) driver C) road D) tires E) air

31. If a , V , X , and t represent respectively acceleration, velocity, distance and time, then which of the equations is dimensionally correct?

A) $a = Vt$ B) $V = a/t$ C) $X = V/t$ D) $a = V^2X/X$ E) $t = \sqrt{(X/a)}$

The following situation applies to items 32 and 33. *Three balls are projected at the same speed from the same height above a horizontal plane. Ball U is projected straight upward. Ball V is projected vertically downward. Ball H is projected horizontally.*

32. The ball to hit the plane below first is ball ___ .

A) U B) V C) H D) they hit at the same time

33. The ball that hits the plane with the largest velocity is ____ .

A) U B) V C) H D) they hit with the same velocity

34. When light goes from a medium in which its speed is v into a medium in which its speed is v/2, its frequency _____.

A) doubles B) is the square root of 2 times its original value C) is halved
D) equals its original frequency divided by the square root of 2 E) remains the same

35. The image formed by a single negative (diverging) lens (or convex mirror) is always ____ .

A) real and enlarged B) virtual and inverted C) real and reduced
D) virtual and reduced E) virtual and enlarged

36. The dB level one meter from a source radiating equally in all directions is 50 dB. At a point twice as far from the dource, 2 meters, the dB level from that source will be ____ dB .

A) 50/4 B) 25 C) 50/1.41 D) 44 E) 47

37. The phenomenon that indicates "light" is a transverse wave is _____ .

A) refraction B) interference C) diffraction D) reflection E) polarization

The following situation applies to items 38 through 40.. *Given the equation:* $Y = (0.1m)\cos\left[2\pi\left(\frac{2X}{m} - \frac{t}{0.001s}\right)\right]$ *(where m represents meters and s represents seconds) representing a transverse wave moving on a light string.*

38. The wave's frequency is approximately ___ Hz.

A) 2000 B) 1000 C) 0.05 D) 0.02 E) 0.001

39. The wave speed on the string is approximately ___ m/s

A) 500 B) 400 C) 200 D) 50 E) 2

40. The equation represents a ____ wave.

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

The following situation applies to items **41 through 43.** *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 X 10^{-7} m and 6.5 x 10^{-7} m. The first order diffraction maximum of the 6 x 10^{-7} m light is at 30.0 degrees.*

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

A) 90 B) 84 C) 60 D) 45 E) 36

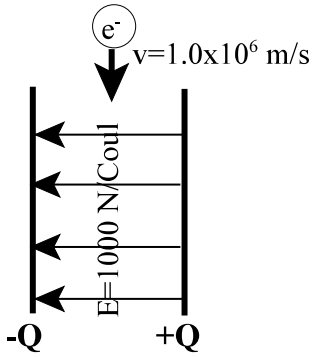
42. When these two wavelengths meet in space, they combine (interfere) to form a wavelength of ____ x 10^{-7} m

A) 0.5 B) 6.25 C) 39 D) 79 E) none-they do not interfere

43. The frequency of the 6 x 10^{-7} m light is approximately ____ x 10^{12} Hz .

A) 0.00015 B) 0.039 C) 5 D) 500 E) 1800

The following situation applies to items **44 through 46.** NEGLECT RELATIVISTIC CORRECTIONS. *Given a parallel plate capacitor with air or a vacuum between the plates. The capacitor is charged and then removed from the charging source. The electric field in the space between the plates is uniform. There is an excess of plus charge, + Q, on the plate to the right and an excess of negative charge , - Q , on the left hand plate. The plates are 10 cm (0.10 m) apart. The magnitude of the electric field is one thousand Newtons per Coulomb (1000 N/Coul). An electron is moving downward toward the middle of the gap between the plates as shown. The electron has a velocity of 1,000,000 m/s (10^6 m/s).*



44. The potential difference across the plates is _____ V .

A) 10 B) 100 C) 1,000 D) 10,000 E) 100.000

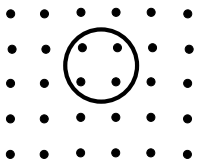
45. The potential difference which accelerated the electron from essentially rest to 1,000,000 m/s was approx. __ V.

A) < 0.5 B) 2.8 C) 5.7 D) 11 E) > 500

46. 1,000 N/Coul expressed in Volts per meter would be ___ V/m .

A) 10 B) 100 C) 1,000 D) 10,000
E) none of these (V/m cannot be used)

47. Given a loop of wire in a uniform magnetic field. The plane of the loop of wire is perpendicular to the magnetic field, as shown to the right The field is directed upward out of the page and the field is increasing. The current induced in the loop is ____ .



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

The following situation applies to items **48 and 49.** *Given four charges at the corners of a square. All are equal in magnitude. Point P is located at the center of the square. Point R is located in the middle of the line joining the upper two charges. Point T is located directly above points P and R, a distance S/2 above point R. S is the length of the side of the square.*

48. If the electric potential at point P is zero, the electric field strength, **E** , at point P __.

A) must be zero only
B) could be zero or non-zero
C) must point upward (toward top of the page)
D) must point downward (toward bottom of page
E) cannot be zero

49. If the electric potential at point P were zero, then the electric potential at points R and T ____ .

A) could both be zero or non-zero B) must both be zero
C) cannot both be zero D) must be positive E) must be negative

The following description applies to items 50 through 52. *A 1000 Hz tuning fork produces resonance conditions in a resonance tube with adjustable water level. Resonance occurs for water levels at the 7.5, 24.5, 41.5, 58.5 and 75.5 cm marks.*

50. The wavelength of the 1000 Hz note produced by the tuning fork is ____ cm.

A) 7.5 B) 15.0 C) 17.0 D) 30.0 E) 34.0

51. The next resonance will occur at the ___ cm mark.

A) 83 B) 92.5 C) 100 D) 109.5 E) 111

52. If the temperature of the air in the tube increases, the resonance points will occur ___ the top of the tube.

A) closer to B) farther from C) at the same distance from

The following description applies for items 53 and 54. *Given a double slit illuminated by monochromatic light. The center to center separation between the slits is d . The size of the slit opening is b. At a distance L from the slits there is screen. On the screen is a typical interference pattern with maximums separated by a distance Y.*

53. If the wavelength were doubled, the separation between light maximums on the screen will ___

A) be 1.41 times the original value B) double
C) remain the same D) be 0.707 times the original value E) be halved

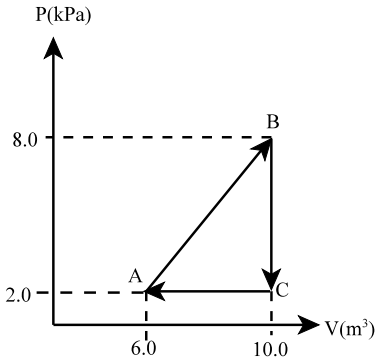
54. Using the original monochromatic light and keeping d the same while increasing b by 50% (reducing the section between slits), the separation between light maximums on the screen will ___ .

A) be 1.41 times the original value B) double
C) remain the same D) be 0.707 times the original value E) be halved

55. An optical system consists of a single converging (positive) lens, an object, and a screen for viewing images. For a real object the lens can <u>never</u> produce an image which is ____.

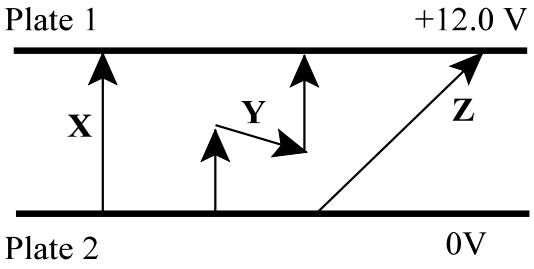
A) virtual and enlarged B) virtual and reduced
C)real and enlarged D) real and reduced
E) none of these (it could produce all of these choices)

56. A gas is taken through a cyclic process A⇒B⇒C⇒A as indicated in the PV diagram. The work done BY the gas during one complete cycle is...



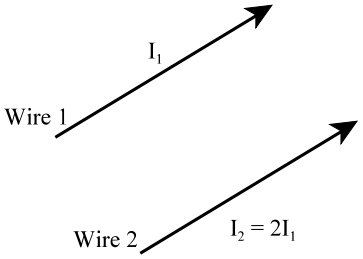
A) 24 kJ
B) 20 kJ
C) 12 kJ
D) 6 kJ
E) 4 kJ

57. A pair of charged, parallel metal plates in a vacuum have EMF as indicated in the sketch. The work required to move a small POSITIVE test charge from Plate 2 to Plate 1 is ...



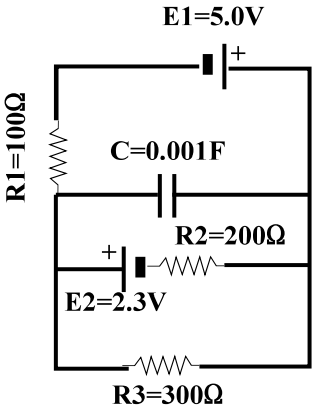
A) greatest for path X
B) greatest for path Y
C) greatest for path Z
D) the same for all paths
E) dependent on the slope of the middle portion of Y

58. Two parallel wires carry currents I_1 and I_2 in the same direction as shown in the sketch. The magnitude of the force on Wire 1 due to the current in Wire 2 is F_1. The magnitude of the force on Wire 2 due to the current in Wire 1 is ...



A) 4 F_1 B) 2 F_1 C) $\sqrt{F_1}$ D) F_1 E) $F_1/2$

The circuit diagram shown here is for use in items 59 and 60.



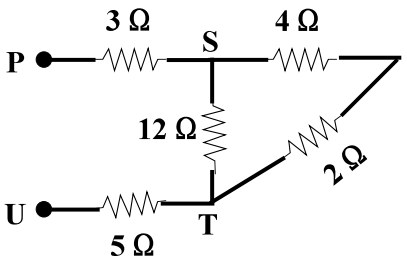
59. A steady-state condition has been achieved in the circuit shown (t=100s) with the two ideal EMF's as labeled (E1=5.0V and E2=2.3V). With the other components valued as indicated, the current through R2 is 22mA. With these conditions the current in R3 is approximately _____ mA.

A) 0 B) 0.14 C) 3.5 D) 7.0
E) 9.5

60. In the same circuit shown above if the maximum power consumption of any of the three resistors is to be 0.1W, ...

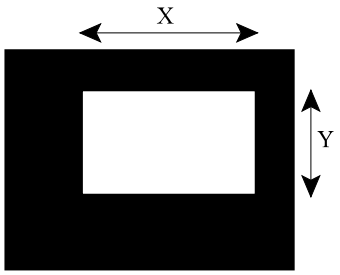
A) no power consumption would exceed the limit.
B) both of the two EMF's would need to be reduced.
C) only E1 would need to be reduced.
D) only E2 would need to be reduced.
E) either R1 or R2 would need to be reduced.

61. If the potential difference between P and U is 12 Volts, the potential difference between P and T would be ____ V.



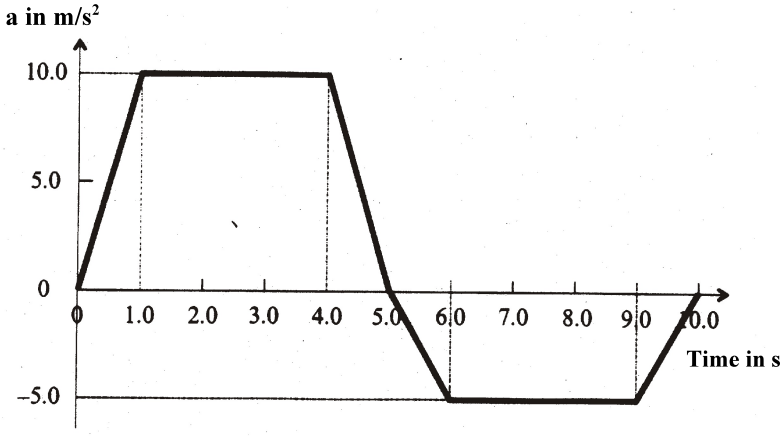
A) 12 B) 10 C) 9 D) 7
E) 5

62. The dark color in the figure indicates a rectangular brass plate in which there has been cut a rectangular hole of dimensions x and y. If the plate were heated uniformly...



A) x will increase and y will decrease.
B) both x and y will decrease.
C) x will decrease and y will increase.
D) both x and y will increase.
E) both x and y will remain the same.

The graph and description apply to items 63 and 64. *The graph shows acceleration in m/s^2 as a function of time in seconds for a 4.0 kg mass starting from rest and undergoing rectilinear motion in the positive direction.*



63. The kinetic energy of the 4.0 kg mass when t was 5 seconds was ___ J.

A) 3200
B) 400
C) 320
D) 80
E) 0

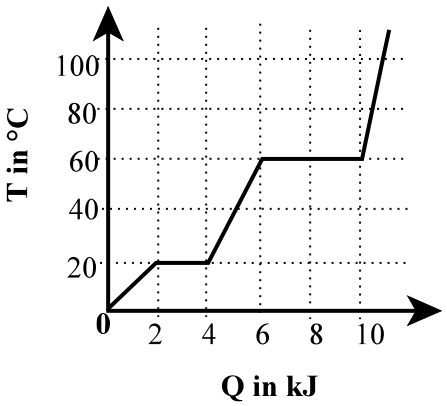
64. The net force on the 4.0 kg object when t was 4.5 seconds was approximately ___ N.

A) 20 in the negative direction
B) 20 in the positive direction
C) zero
D) 40 in the negative direction
E) 40 in the positive direction

65. A communications satellite in circular orbit is 400 km above the Earth. The mass of the Earth is 6.0 x 10^{24} kg and its radius is 6.4 x 10^6 m. The period of its orbit is approximately ____ seconds. (G=6.67x10^{-11} Nm^2/kg^2)

A) 86,000 B) 5,600 C) 5,100 D) 510 E) 79

The following graph and description apply to items 66 and 67.
A sample of mass 0.100 kg of a solid composed entirely of a pure unknown substance is heated. The plot of its temperature, T, as a function of the heat added, Q, is shown. It was observed to go from a solid to a gas during the heating.



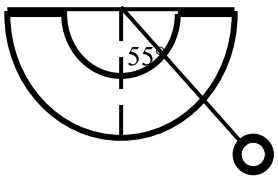
66. The temperature at which the substance began to boil as given by the graph is ____ °C.

A) 20 B) 40 C) 60 D) 115
E) Cannot tell because the graph doesn't go far enough.

67. As indicated by the graph the latent head of fusion of this substance is approximately ____ kJ/kg.

A) 2 B) 4 C) 10 D) 20 E) 40

68. During the annual trip to Physics Day at a nearby amusement park a student sought to "check" the acceleration of the circular portion of the path of the newest roller coaster. The path was a level circle. The student "made" an accelerometer from a metal washer, string, and a protractor. The sketch indicates the position of the washer when the protractor was held level as the coaster followed the level circular path. The angle of the string was 55 degrees from the vertical (rest) position. The centripetal acceleration of the roller coaster was measured to be approximately ___ m/s^2.



A) 7 B) 10 C) 14 D) 17 E) Cannot be solved without the mass of the washer.

This is the end of the test.

Merck Physics 2005 Answers

1	E	26	A	51	B
2	C	27	C	52	B
3	A	28	B	53	B
4	C	29	D	54	C
5	D	30	C	55	B
6	A	31	E	56	B
7	B	32	B	57	D
8	B	33	D	58	D
9	B	34	E	59	D
~~10~~	~~A~~	35	D	60	A
11	C	36	D	61	D
12	E	37	E	62	D
13	D	38	B	63	A
14	E	39	A	64	B
15	D	40	B	65	B
16	B	41	A	66	C
17	D	42	E	67	D
18	E	43	D	68	C
19	B	44	B		
20	B	45	B		
21	C	46	C		
22	E	47	A		
23	C	48	B		
24	E	49	A		
25	C	50	E		