SINGAPORE JUNIOR PHYSICS OLYMPIAD 2012
GENERAL ROUND

1 August, 2012

3:00 pm – 4:30 pm

Time Allowed: ONE hour THIRTY minutes

INSTRUCTIONS

1. This paper contains **50** multiple choice questions and **19** printed pages.
2. Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one that is best in each case and then shade the corresponding bubble on the answer sheet.
3. Only the answer sheet will be collected at the end of the test. Answers written anywhere else will not be marked.
4. Use 2B pencil only. Using any other type of pencil or pen may result in answers unrecognizable by the machine.
5. Answer all questions. Marks will **NOT** be deducted for wrong answers.
6. Scientific calculators are allowed in this test. Graphic calculators are not allowed.
7. A table of information is given in page 2.

TABLE OF INFORMATION

Acceleration due to gravity at Earth surface, g	=	$9.80\ \mathrm{m/s^2}$
Universal gas constant, R	=	$8.31\ \mathrm{J/(mol \cdot K)}$
Vacuum permittivity, ϵ_0	=	$8.85 \times 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$
Vacuum permeability, μ_0	=	$4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$
Atomic mass unit, u	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
Speed of light in vacuum, c	=	$3.00 \times 10^{8}\ \mathrm{m/s}$
Charge of electron, e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
Planck's constant, h	=	$6.63 \times 10^{-34}\ \mathrm{J \cdot s}$
Mass of electron, m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Mass of proton, m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
Boltzmann constant, k	=	$1.38 \times 10^{-23}\ \mathrm{J/K}$
Avogadro's number, N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Standard atmosphere pressure, P_0	=	$1.01 \times 10^{5}\ \mathrm{Pa}$
Density of water, ρ_w	=	$1000\ \mathrm{kg/m^3}$
Specific heat (capacity) of water, c_w	=	$4.19 \times 10^{3}\ \mathrm{J/(kg \cdot {}^\circ C)}$
Latent heat of fusion of water, L_f	=	$3.33 \times 10^{5}\ \mathrm{J/kg}$
Latent heat of vaporization of water, L_v	=	$2.26 \times 10^{6}\ \mathrm{J/kg}$

1. A constant force is applied to a body that is already moving. The force is directed at an angle of 70° to the direction of the body's velocity. What is most likely to happen is that

   (A) the body will stop moving.

   (B) the body will move in the direction of the force.

   (C) the body's velocity will increase in magnitude but not change direction.

   (D) the body will gradually change direction more and more toward that of the force.

   (E) the body will first stop moving and then move in the direction of the force.

2. A sphere of mass m is suspended from two strings of unequal length as shown. The tensions T_1 and T_2 in the strings must satisfy which of the following relations?

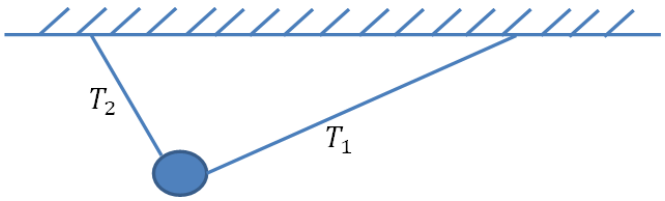
   (A) $T_1 = T_2$

   (B) $T_1 > T_2$

   (C) $T_1 < T_2$

   (D) $T_1 + T_2 = mg$

   (E) $T_1 - T_2 = mg$



3. A car with mass 10^5 kg starts from rest, driven by an engine with uniform power output of 5×10^6 W. Forty seconds later, it is 400 m from the starting point and has a velocity v. If the resistance experienced by the car is always 0.1 times of car weight, what is is the value of v? Take g to be 10 m/s^2.

   (A) 20 m/s

   (B) 23 m/s

   (C) 57 m/s

   (D) 60 m/s

   (E) 68 m/s

4. Raindrops fall vertically down to the ground with a speed of 10 m/s. If we place a hollow cylinder of cross-sectional area 80 cm^2, height 10 cm on the ground, the height of water in the cylinder after 30 min is 1 cm. Suppose there is a gust under which the raindrops fall at 30° to the vertical. How long would it take to fill the same cylinder up to the same level?

   (A) more than 30 min
   (B) 30 min
   (C) less than 15 min
   (D) 15 min
   (E) 26 min

5. A balloon is filled with 200 m^3 of helium. How much mass can the balloon lift? The density of helium is 1/7 that of air, and the density of air is 1/800 that of water.

   (A) 36 kg
   (B) 145 kg
   (C) 215 kg
   (D) 250 kg
   (E) 415 kg

6. A block of mass M is sliding on horizontal surface with a mass-less spring attaching it to a wall on the right. When it moves to the equilibrium position another mass m falls and sticks onto it. Oscillation of the combined mass will have

   i) smaller amplitude
   ii) same amplitude
   iii) larger period
   iv) same period

   (A) i) and iii)
   (B) i) and iv)
   (C) ii) and iii)
   (D) ii) and iv)
   (E) none of the above

7. It is known that a photon of frequency f and wavelength λ has energy $E = hf$ and momentum $p = h/\lambda$, with h as Planck's constant. The speed of light, c can be expressed as

   (A) p/E
   (B) E/p
   (C) Ep
   (D) E^2/p^2
   (E) $\sqrt{Ep}$

8. A nucleus X turns into nucleus Y after an α decay, then turns into nucleus Z after a β^- decay, i.e .

$$ {}^{a}_{b}X \xrightarrow{\alpha} {}^{c}_{d}Y \xrightarrow{\beta} {}^{e}_{f}Z $$

   Which of the following relations is not true?

   (A) $a = e + 4$
   (B) $c = e$
   (C) $d = f - 1$
   (D) $b = f + 3$
   (E) All the above are true.

9. A battery of emf 1.50 V has an internal resistance of 1.20 Ω. When a wire with circular cross-section of 2 mm in diameter and 250 m long is connected across the terminals of this battery, the current in the circuit is 0.4 A. What is the resistivity of the material from which the wire is made?

   (A) 2.40×10^{-8} Ωm
   (B) 2.80×10^{-8} Ωm
   (C) 3.20×10^{-8} Ωm
   (D) 3.60×10^{-8} Ωm
   (E) 4.00×10^{-8} Ωm

10. Equal but opposite charges Q are placed on the plates of an air-filled parallel-plate capacitor. The plates are then pulled apart to twice their original separation. Which of the following statements about this capacitor are true?

I) The energy stored in the capacitor is doubled.

II) The electric field between the plates has increased.

III) The potential difference across the plates has doubled.

IV) The capacitance has doubled.

(A) II and IV only

(B) I and III only

(C) III and IV only

(D) I and IV only

(E) II and III only

11. For the system consisting of the 2 blocks shown in the figure below, a horizontal force F is applied so that block B does not fall due to its weight. The masses of A and B are 12.0 kg and 2.0 kg respectively. The horizontal surface is frictionless and the coefficient of static friction between the 2 blocks is 0.45. The minimum magnitude of F is

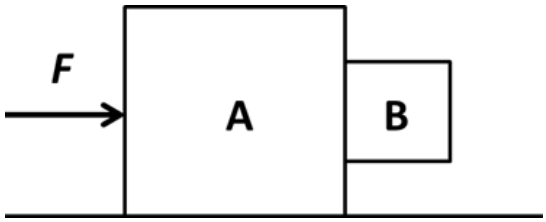
(A) $\frac{63}{10}g$

(B) $\frac{100}{3}g$

(C) $\frac{280}{9}g$

(D) $\frac{560}{9}g$

(E) $70g$



12. The pressure of a fixed mass of gas at constant volume is greater at higher temperature because the

(A) molecules collide with the container walls more frequently.

(B) number of intermolecular collisions increases.

(C) molecules travel greater distances between collisions with one another.

(D) size of each individual molecule increases.

(E) number of molecules increases.

13. A fixed mass of ideal gas of volume V at temperature T and pressure P is heated and allowed to expand to a final volume $2V$ and pressure $2P$. By how much does the translational kinetic energy of the gas molecules change?

(A) increased by 4 times

(B) increased by 2 times

(C) no change

(D) reduced by half

(E) increased by $\sqrt{2}$ times

14. With the following assumptions,

I) world's population is about 6 billions,

II) 10% of the world's population use handphones

III) a person spends an average of 30 mins on the cellphone each day,

estimate the number of people talking on their cell phones at this instant.

(A) 10^3

(B) 10^4

(C) 10^5

(D) 10^6

(E) 10^7

15. A typical classroom van de Graff generator has a metal sphere of diameter 15 cm that can be charged. Which of the following is the best approximate of the van de Graff's electric potential just before the air around the ball suffers a dielectric breakdown? The breakdown occurs in air at an electric field strength of $E_{\max} = 3 \times 10^6$ N/C.

(A) 2.3×10^5 V

(B) 6.0×10^5 V

(C) 3.0×10^6 V

(D) 5.2×10^6 V

(E) 6.0×10^6 V

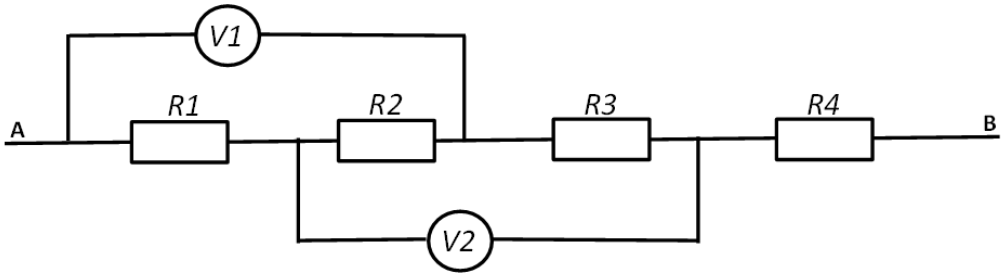
16. A tractor moving forward at uniform speed on a horizontal ground has a front wheel diameter of 0.8 m and back wheel diameter of 1.25 m. The horizontal distance between the axles of the two wheels is 2 m. During a trip a pebble stuck to the front wheel flew off the wheel at the highest point. 0.2 s later, another pebble flew off the back wheel at its highest point too. The two pebbles landed on the same spot on the ground. Find the speed of the tractor.

(A) 3 m/s
(B) 5 m/s
(C) 8 m/s
(D) 10 m/s
(E) 12 m/s

17. A mole of ideal gas is heated in an insulated constant volume container until the root-mean-square velocity of its molecules is doubled. Its pressure would therefore increase by

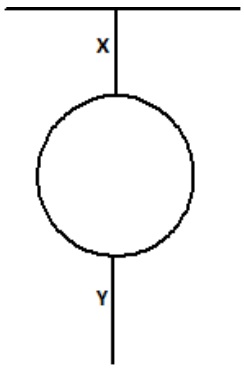
(A) 0.5
(B) 1
(C) 2
(D) 4
(E) 8

18. In the circuit as shown below, the voltmeter V1 measures a potential difference of 10 V and the voltmeter V2 measures a potential difference of 15 V. Resistor R2 has the same resistance as resistor R4. What is the potential difference across AB?



(A) 25 V
(B) 30 V
(C) 35 V
(D) 32.5 V
(E) There is not enough information.

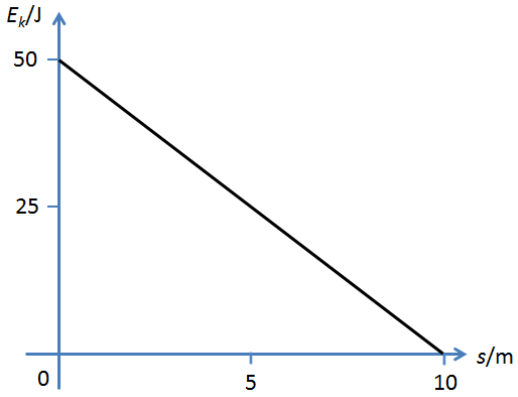
19. As shown in the diagram below, a heavy metal ball hangs freely from a string X which is in turn attached to the ceiling. Another string Y hangs freely from the other end of the ball. Consider the situations where a pulling force applied to string Y is (i) increased slowly and (ii) large and sudden. Which of the following strings will break in these 2 situations?



	Situation (i)	Situation (ii)
(A)	X	Y
(B)	Y	X
(C)	X	X
(D)	Y	Y

(E) This cannot be determined.

20. A 2-kg mass slides across a rough surface and its kinetic energy is plotted as a function of distance. What is the time that it took to slide across the surface?



(A) 5 s

(B) 4 s

(C) $2\sqrt{2}$ s

(D) 2 s

(E) 10 s

21. An object falls freely through air. What is the ratio of

distance fallen in 1st sec : distance fallen in 2nd sec : distance fallen in 3rd sec?

You may neglect air resistance.

(A) 1 : 2 : 3

(B) 1 : 4 : 9

(C) 1 : 3 : 5

(D) 1 : $\sqrt{2}$: $\sqrt{3}$

(E) 1 : $\sqrt{2} - 1$: $\sqrt{3} - 1$

22. Two identical rectangular bricks of length S are piled with one on top of the other on a table. What is the maximum distance L (see the figure below) that the top brick can be extended beyond the edge of the table for the system to remain balanced? (Note that the figure is not drawn to scale.)

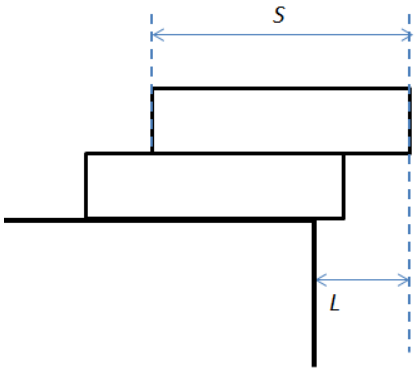
(A) $\frac{1}{2}S$

(B) $\frac{2}{3}S$

(C) $\frac{3}{4}S$

(D) $\frac{7}{8}S$

(E) S



23. A beam of light strikes one mirror of a pair of right angle mirrors at an angle of incidence of 45° as shown in the diagram. If the right angle mirror assembly is rotated such that the angle of incidence is now 55°, what will happen to the angle of the beam that emerges from the right angle mirror assembly?

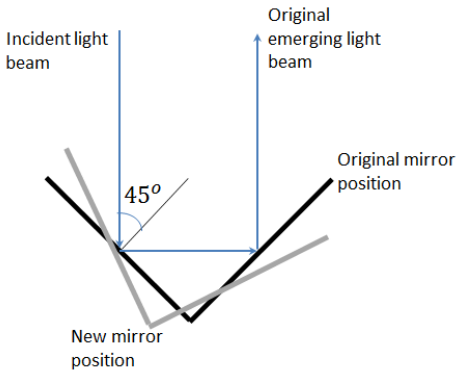
(A) It will move through an angle of 15° with respect to the original emerging beam.

(B) It will move through an angle of 35° with respect to the original emerging beam.

(C) It will move through an angle of 45° with respect to the original emerging beam.

(D) It will move through an angle of 55° with respect to the original emerging beam.

(E) It will emerge parallel to the original emerging beam.



24. A circus clown weighing 1000 N walks across a tightrope that is 20 m in length. When the clown is at the center, the center sags by 1.0 m. What is the tension in the rope?

(A) 1.0×10^3 N

(B) 2.0×10^3 N

(C) 1.0×10^4 N

(D) 5.0×10^3 N

(E) 2.0×10^4 N

25. 100 g of ice at 0°C and 100 g of steam at 100°C interact thermally in a well-insulated container. The final state of the system is

(A) an ice-water mixture at 0°C.

(B) water at a temperature between 0°C and 50°C.

(C) water at 50°C.

(D) water at a temperature between 50°C and 100°C.

(E) a water steam mixture at 100°C.

26. In a particular photoelectric experiment, it was found that when light of wavelength 187 nm is incident on the metal surface, the stopping potential is 2.70 V. What will be the stopping potential if light of wavelength 87 nm is used instead?

(A) 0 V

(B) 1.70 V

(C) 4.94 V

(D) 10.3 V

(E) No electrons will be emitted

27. A truck of mass 20000 kg travelling at 50 km/h collided head-on with a car of mass 2500 kg travelling at 25 km/h. What is the ratio of the force exerted on the truck to the force exerted on the car during the collision?

(A) 1 : 8

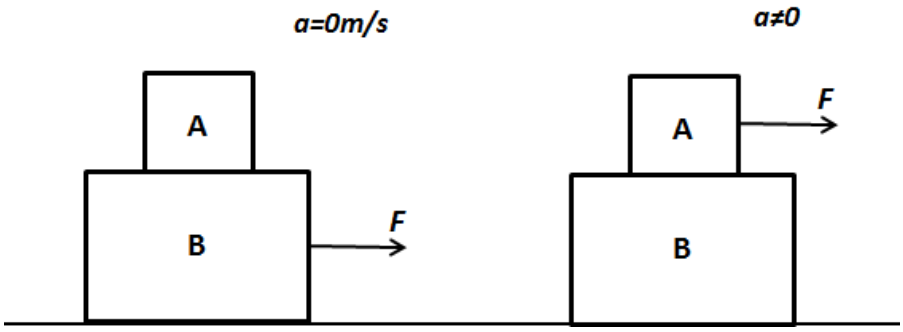
(B) 8 : 1

(C) 16 : 1

(D) 1 : 16

(E) 1 : 1

28. In the figure depicting 2 situations below, solid objects A and B are moving towards the right and are stationary with respect to each other. There is significant friction between box B and the ground and the accelerations and applied forces are as shown.



Which of the following shows the correct sign of the work done on box A by friction between box A and B respectively?

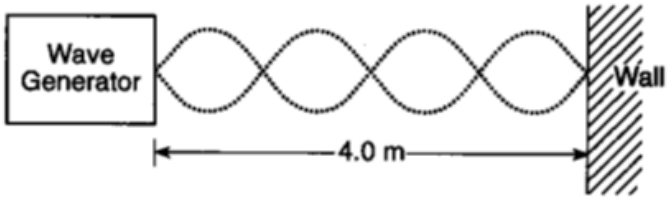
	Situation 1	Situation 2
(A)	Positive	Negative
(B)	Positive	Positive
(C)	Negative	Positive
(D)	Zero	Negative
(E)	Zero	Positive

29. A source of 2-kilohertz sound is moving straight toward you at a speed 0.9 times the speed of sound. The frequency you receive is

(A) 0.2 kHz
(B) 1.0 kHz
(C) 2.2 kHz
(D) 3.8 kHz
(E) 20 kHz

30. A wave generator located 4.0 m from a reflecting wall produces a standing wave in the string, as shown in the diagram below. If the speed of the wave is 30 m/s, what is its frequency?

(A) 1.2 Hz
(B) 15 Hz
(C) 30 Hz
(D) 40 Hz
(E) 36 Hz



31. The following shows a wire coiled around an insulating, non-magnetic pipe with a current running in it. A conducting ring is placed near the centre of the coil with their axes aligned (see figure below). As the electrical current is decreased, which of the following happens?

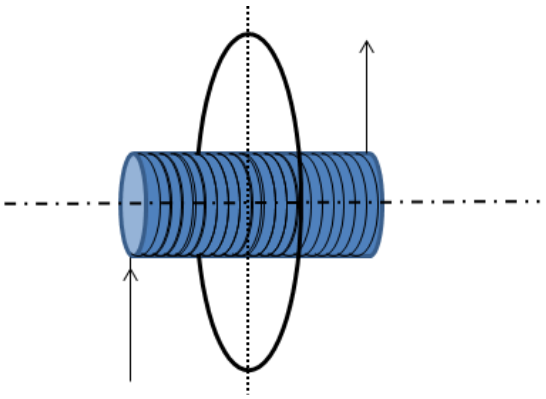
(A) The conducting ring experiences a force that tends to shrink the area of the circle.

(B) The conducting ring experiences a force that tends to expand the area of the circle.

(C) The conducting ring experiences a force that tends to move it to the right.

(D) The conducting ring experiences a force that tends to move it to the left.

(E) The conducting ring does not experience any force at all.



32. The diagram below which shows a ray of monochromatic light ($f = 5.09 \times 10^{14}$ Hz) passing through a glass prism. What is the speed of the light ray in the prism?

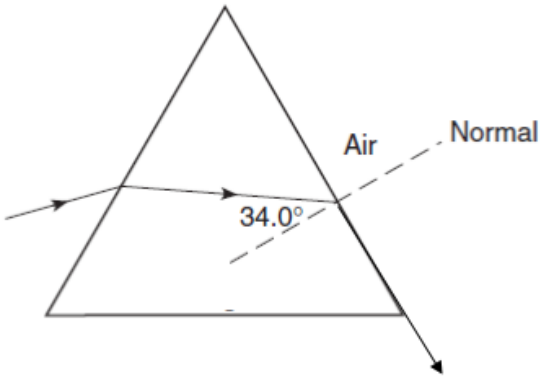
(A) 1.68×10^8 m/s

(B) 1.81×10^8 m/s

(C) 3.00×10^8 m/s

(D) 1.03×10^8 m/s

(E) 2.60×10^8 m/s



33. A space traveler is moving relative to the Earth at 2.4×10^8 m/s ($\approx 0.8c$), as measured in the Earths frame of reference. Measured in the Earth's frame of reference, in one year, what will happen to the space traveler?

(A) travel 0.6 light year and age 0.6 year

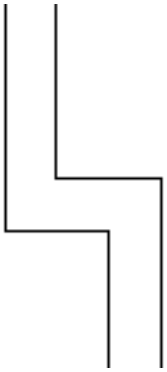
(B) travel 0.8 light year and age 0.6 year

(C) travel 0.8 light year and age 1 year

(D) travel 0.8 light year and age 1.67 year

(E) travel 1 light year and age 1 year

34. Can the lines in the figure below be equipotential lines (lines of same electric potential)?



(A) No, because they are sharp corners

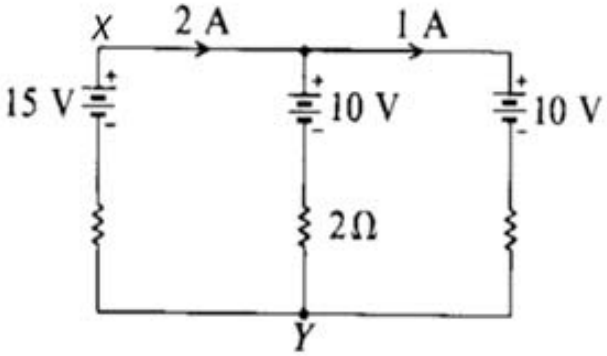
(B) No, because they are isolated charges

(C) Yes, because any lines within a charge distribution are equipotential lines.

(D) Yes, because they can be lines on two surfaces of a conductor.

(E) It is not possible to say without further information.

35. In the circuit shown below, the emfs of the batteries are given, as well as the currents in the outside branches and the resistance in the middle branch. What is the magnitude of the potential difference between X and Y?



(A) 16 V

(B) 12 V.

(C) 15 V.

(D) 8 V

(E) 4 V

36. A projectile of mass M_1 is fired horizontally from a spring gun that is initially at rest on a frictionless surface. The combined mass of the gun and projectile is M_2. If the kinetic energy of the projectile after firing is K, the gun will recoil with a kinetic energy equal to

(A) K

(B) $\frac{M_2}{M_1}K$

(C) $\frac{{M_1}^2}{{M_2}^2}K$

(D) $\frac{M_1}{M_2 - M_1}K$

(E) $\sqrt{\frac{M_1}{M_2 - M_1}}K$

37. A ball is dropped from a height of 10 m onto a hard surface so that collision at the surface may be assumed to be elastic. Under such conditions, the motion of the ball is

(A) Simple harmonic with a period of 1.4 s

(B) Simple harmonic with a period of 2.8 s

(C) Simple harmonic with an amplitude of 5.0 m

(D) Periodic with a period of about 2.8 s but not simple harmonic

(E) Motion with constant momentum

38. An isolated capacitor with oil between its plates has a potential V_0 and charge Q_0. After the space between the plate is completely cleared of oil, the difference in potential is V and the charge is Q. Which of the following pairs of relationships is correct?

(A) $Q = Q_0$ and $V > V_0$

(B) $Q = Q_0$ and $V < V_0$

(C) $Q > Q_0$ and $V = V_0$

(D) $Q < Q_0$ and $V < V_0$

(E) $Q > Q_0$ and $V > V_0$

39. As shown in the diagram, 2 columns of air a and b of equal lengths $L_a = L_b$ are locked in a U-tube manometer by liquid mercury. If more liquid mercury is poured in through the opening, which of the following is true of the new lengths L'_a and L'_b?

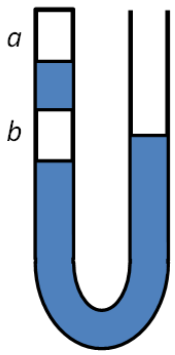
(A) $L'_a > L'_b$

(B) $L'_a < L'_b$

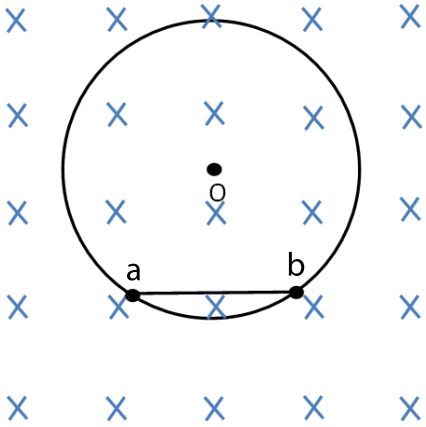
(C) $L'_a = L'_b \neq 0$

(D) $L'_a = L'_b = 0$

(E) Unable to determine



40. A charged particle moves in a circular path in a magnetic field of $B = 0.8$ T. As shown in the diagram below, the particle takes 2.0×10^{-4} s to travel from a to b and then continues to take another 1.0×10^{-3} s to go from b to a. The distance between a and b is 0.30 m and the charge on the particles is 3.0×10^{-8} C. The momentum of the particle is



(A) 7.2×10^{-9} kg m/s
(B) 3.6×10^{-9} kg m/s
(C) 1.44×10^{-8} kg m/s
(D) 2.88×10^{-8} kg m/s
(E) 5.76×10^{-8} kg m/s

41. A diatomic molecule consists of two point masses, m_1 and m_2, separated by a distance r. If x is the distance from m_1 to the center of mass, what is the moment of inertia about an axis parallel to the molecular axis and passes through the center of mass. Note that the molecular axis is the line joining the two atoms in the diatomic molecule.

(A) 0
(B) $\dfrac{m_1 m_2 r^2}{(m_1 + m_2)}$
(C) $m_1(r - x)^2 + m_2 x^2$
(D) $m_1 x^2 + m_2(r - x)^2$
(E) $m_2 x^2 + m_1 r^2$

42. Rutherford's experiment shows that when a gold sheet is bombarded with alpha particle, most of the particles pass through, with only a few being reflected back. Which of the following is a correct interpretation of the results?

(A) Atoms have equal numbers of positive and negative charges.
(B) Electrons in atoms are arranged in shells.
(C) Neutrons are at the center of an atom.
(D) Neutrons and protrons in atoms have nearly equal mass.
(E) The positive charge of an atom is concentrated in a small region.

43. For an ideal gas, the specific heat at constant pressure C_p is greater than the specific heat at constant volume C_v because the

(A) gas does work on its environment when its pressure remains constant while its temperature is increased.

(B) heat input per degree increase in temperature is the same in processes for which either the pressure or the volume is kept constant.

(C) pressure of the gas remains constant when its temperature remains constant.

(D) increase in the gas's internal energy is greater when the pressure remains constant than when the volume remains constant.

(E) heat needed is greater when the volume remains constant than when the pressure remains constant

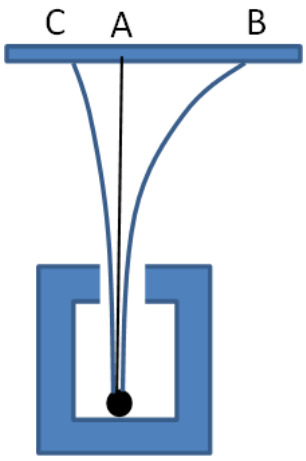
44. The figure shows a radioactive substance being held in a small lead box with a hole where α, β and γ rays emit from the hole. The rays trace out the paths indicated in the diagram. The rays finally impact on a screen at points A, B and C. It can be seen that $AB > AC$. Which of the following electric/magnetic fields can possibly have been applied in the space just above the hole and between the lead box and the screen?

I. Uniform Magnetic field pointing into the paper

II. Uniform Magnetic field pointing out of the paper

III. Uniform Electric field pointing to the right

IV. Uniform Electric field pointing to the left



(A) I or III

(B) I or IV

(C) II only

(D) II or III

(E) II or IV

45. The water level in a reservoir is maintained at a constant level. What is the exit velocity in an outlet pipe 3.0 m below the water surface?

(A) 2.4 m/s

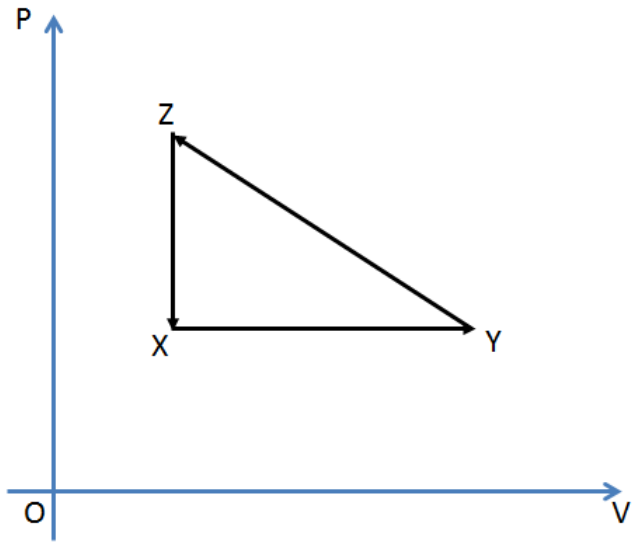
(B) 3.0 m/s

(C) 5.4 m/s

(D) 7.7 m/s

(E) 49 m/s

This diagram is meant for Questions 46 and 47.



46. A thermodynamic system is taken from an initial state X along the path $XYZX$ as shown in the PV-diagram above. For the process X to Y, $W > 0$ and

(A) $\Delta U_{XY} < 0$ and $Q > 0$
(B) $\Delta U_{XY} > 0$ and $Q > 0$
(C) $\Delta U_{XY} < 0$ and $Q = 0$
(D) $\Delta U_{XY} > 0$ and $Q < 0$
(E) $\Delta U_{XY} = 0$ and $Q = 0$

47. If $\Delta U_{XY} = -\Delta U_{ZX}$, then for the process Y to Z,

(A) $\Delta U_{YZ} < 0$ and $Q > 0$
(B) $\Delta U_{YZ} > 0$ and $Q > 0$
(C) $\Delta U_{YZ} = 0$ and $Q < 0$
(D) $\Delta U_{YZ} < 0$ and $Q < 0$
(E) $\Delta U_{YZ} = 0$ and $Q = 0$

48. The total energy of a blackbody radiation source is collected for one minute and used to heat water. The temperature increases from 27.0°C to 28.0°C. If the absolute temperature of the blackbody source is doubled, what is the final temperature of the water?

(A) 29.0°C
(B) 32.0°C
(C) 35.0°C
(D) 43.0°C
(E) 54.0°C

49. Two waves are described by

$$y_1 = 5\sin(6x - 900t) \text{ m} \quad \text{and} \quad y_2 = 5\sin(6x - 900t - 2) \text{ m}$$

What is the wavelength of the resultant wave?

(A) 1 m
(B) 2 m
(C) 3 m
(D) 4 m
(E) 6 m

50. Approximately how much uranium (in kg) must undergo fission per day to provide 1000 MW of power? (Assume an efficiency of 30%). The nuclear reaction is

$$\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3\text{n}$$

where $m(\text{n}) = 1.008665$ u, $m(\text{U}) = 235.043915$ u, $m(\text{Ba}) = 140.9139$ u, $m(\text{Kr}) = 91.8973$ u and u $= 1.66 \times 10^{-27}$ kg.

(A) 1.0
(B) 3.5
(C) 2.3
(D) 4.6
(E) 0.1

END OF PAPER.