SINGAPORE JUNIOR PHYSICS OLYMPIAD 2010
GENERAL ROUND

4 August, 2010

2:30 pm – 4:00 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.
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 gravitational constant G	=	$6.67 \times 10^{-11}\ \mathrm{m^3/(kg \cdot s^2)}$
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 for water, L_f	=	$3.34 \times 10^{5}\ \mathrm{J/kg}$

1. Two identical balls are at rest and side by side at the top of a hill. You let one ball, A, start rolling down the hill. A little later, you start the second ball, B down the hill by giving it a shove. The second ball rolls down the hill along a line parallel to the path of the first ball and passes it. At the instant ball B passes ball A,

   (A) only the displacement and velocity are the same for both balls.

   (B) only the displacement and acceleration are the same for both balls.

   (C) only the velocity and acceleration are the same for both balls.

   (D) the displacement, velocity and acceleration are the same for both balls.

   (E) the displacement, velocity and acceleration are all different for both balls.

2. Consider a train that can speed up with an acceleration of 20 cm/s^2 and slow down with a deceleration of 100 cm/s^2. Find the minimum time for the train to travel between two stations 2 km apart. You may assume that the train has to stop at every station.

   (A) 33.3 s

   (B) 57.7 s

   (C) 81.6 s

   (D) 141 s

   (E) 155 s

3. A man pushes against a rigid, immovable wall. Which of the following statement is the most accurate statement concerning this situation?

   (A) The man can never exert a force on the wall that exceeds his weight.

   (B) If the man pushes on the wall with a force of 200 N, we can be sure that the wall is pushing back with a force of exactly 200 N on him.

   (C) Since the wall cannot move, it cannot exert any force on the man.

   (D) The man cannot be in equilibrium since he is exerting a net force on the wall.

   (E) The friction force on the man's feet is directed away from the wall.

4. The same constant force is used to accelerate two carts of the same mass on frictionless tracks. The force applied to cart A is twice as long in time as it is applied to cart B. The work the force does on A is W_A; that on B is W_B. Which statement is correct?

   (A) $W_A = W_B$.
   (B) $W_A = \sqrt{2}W_B$.
   (C) $W_A = 2W_B$.
   (D) $W_A = 4W_B$.
   (E) $W_B = 2W_A$.

5. A block of mass m is hung from a light vertical spring of spring constant k, which is hung in turn from another identical spring. The amount by which each spring stretches is x. The total elastic potential energy of the system when at rest is:

   (A) $\frac{1}{2}mgx$
   (B) mgx
   (C) $2mgx$
   (D) $\frac{1}{2}\frac{m^2g^2}{k}$
   (E) $\frac{2m^2g^2}{k}$

6. Two boys in a canoe toss a baseball back and forth. What effect will this have on the canoe?

   (A) None, because the ball remains in the canoe.
   (B) The canoe will drift in the direction of the boy who throws the ball harder each time.
   (C) The canoe will drift in the direction of the boy who throws the ball with less force each time.
   (D) The canoe will oscillate back and forth always moving opposite to the ball.
   (E) The canoe will oscillate in the direction of the ball because the canoe and ball exert forces in opposite directions upon the person throwing the ball.

7. A sample of water at 100°C undergoes the following sequential process (ignore the container):

   Process 1: An amount of thermal energy Q is removed from the water.

   Process 2: An additional amount of thermal energy Q is removed from the water.

   In the final equilibrium state after the process 2, half of all the water has become ice at 0°C, while the rest remains as water at 0°C. What is the approximate temperature of the sample after process 1? Evaporation can be ignored and you may use the information given in page 2.

   (A) 50°C
   (B) 30°C
   (C) 10°C
   (D) 0°C
   (E) There is not enough information to answer this question.

8. The ideal gas law, $pV = nRT$, describes the condition of gases best when

   (A) density of the gas is low.
   (B) pressure is high.
   (C) gas is colourless.
   (D) gas is monatomic.
   (E) temperature is close to absolute zero.

9. A room is heated by a radiator that has a constant but unknown temperature T. When the outside temperature is 260 K, the room temperature is 300 K. However, when the outside temperature drops to 240 K, the room temperature is only 290 K. Estimate the radiator temperature T. (Hint: The rate of heat transfer is approximately proportional to the temperature difference.)

   (A) 320 K
   (B) 340 K
   (C) 360 K
   (D) 380 K
   (E) 400 K

10. The image of an erect candle, formed using a convex mirror, is always

    (A) virtual, inverted, and smaller than the candle.
    (B) virtual, inverted, and larger than the candle.
    (C) virtual, erect, and larger than the candle.
    (D) virtual, erect, and smaller than the candle.
    (E) none of the above.

11. Which of the following choices best explains why a certain colour of light will allow the observer to see the greatest detail when using a microscope?

    (A) Blue light because it has the shortest wavelength.
    (B) Blue light because it travels fastest through the microscopic lens.
    (C) Red light because our eyes are most sensitive to this colour.
    (D) Red light because it is less likely to be scattered.
    (E) Red light because it has the longest wavelength.

12. Which of the following properties could NOT be demonstrated by sound travelling in the air?

    (A) reflection
    (B) refraction
    (C) polarization
    (D) diffraction
    (E) all the above properties can be demonstrated by sound

13. A beam of light from the air is incident on a transparent block of material. The angle of incidence is 49° while the angle of refraction is 30°. What is the velocity of light in the transparent material?

(A) 1.8×10^8 m/s

(B) 2.0×10^8 m/s

(C) 2.3×10^8 m/s

(D) 3.0×10^8 m/s

(E) It is not possible to get these angles.

14. The S-waves (transverse) and P-waves (longitudinal) produced by earthquakes travel at different speeds through the earth. If the S-waves travel about 4000 m/s while the P-waves travel at nearly 7000 m/s, how far away must an earthquake be for the P-waves to arrive 2 minutes before the S-waves?

(A) 360 km

(B) 480 km

(C) 840 km

(D) 1120 km

(E) 1320 km

15. Three wave pulses travel along the same string held at the same tension as shown in the diagram below. Which of the following is true?

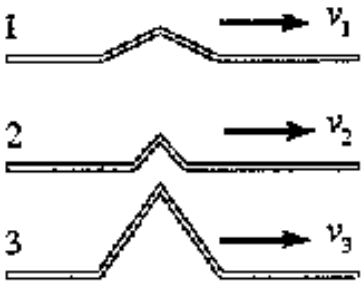
(A) $v_1 > v_2 = v_3$

(B) $v_2 < v_1 < v_3$

(C) $v_3 < v_1 < v_2$

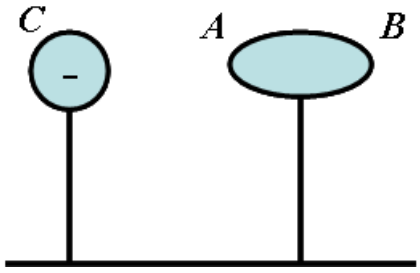
(D) $v_1 = v_2 = v_3$

(E) The comparison of speed cannot be made from the information given.



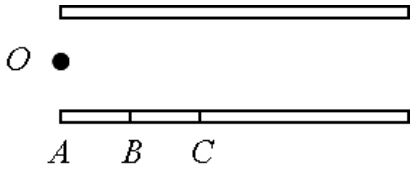
16. As shown in the figure, a neutral conductor is mounted on an insulator and brought close to a negatively charged conductor C. When electrostatic equilibrium has been achieved, which of the following mathematical statements regarding the potential of the A and B ends of the conductor is true? (Assume ground to be of zero potential.)

(A) $V_A > V_B$
(B) $V_A = V_B = 0$
(C) $V_A = V_B > 0$
(D) $V_B > V_A$
(E) $V_A = V_B < 0$



17. 2 charged particles P_1 and P_2 are launched in quick succession from O into a uniform electric field with the same velocity and in a direction perpendicular to the electric field. Under the influence of the electric field, P_1 and P_2 are noticed to impact on B and C respectively where $AB = BC$. The ratio of the magnitude of the charges on P_1 and P_2 is $3 : 1$. In this case, the ratio of the masses of P_1 and P_2 is

(A) $3 : 2$
(B) $2 : 3$
(C) $4 : 3$
(D) $3 : 4$
(E) $1 : 1$



18. Which of the following statements is correct regarding equipotential lines?

(A) No work is done by external force when a charge moves along equipotential lines.
(B) No force is required to move a charge from one equipotential line to another equipotential line.
(C) No work is done to move a charge from one equipotential line to another equipotential line.
(D) Electric field lines are the same as the equipotential lines.
(E) Electric field lines can be parallel to the equipotential lines.

19. Wire A and wire B carry currents I_A and I_B respectively in the same direction. If $I_B = 2I_A$, the magnitudes of the forces acting on wire A (F_A) and wire B (F_B) are related by

(A) $F_A = F_B$

(B) $F_A = 2F_B$

(C) $F_A = 4F_B$

(D) $F_A = F_B/2$

(E) $F_A = F_B/4$

20. Two identical bar magnets are dropped from equal heights but with different polarity pointing downward. The ground below magnet A is bare, i.e., not covered with any special material while the ground below magnet B is covered with an aluminium plate. Which magnet strikes first?

(A) Magnet A

(B) Magnet B

(C) Both strikes at the same time.

(D) The magnet that has the N pole toward the ground.

(E) The magnet that has the S pole toward the ground.

21. A 50 g lead bullet, specific heat, 129 J/(kg $\cdot^\circ$ C) is initially at 300°C. It is fired vertically upwards with a speed of 840 m/s and on returning to the starting level strikes a cake of ice at 0°C. How much ice is melted? Assume that all the energy is spent in melting only.

(A) 19 g

(B) 39 g

(C) 59 g

(D) 79 g

(E) 99 g

22. A man of mass m on an initially stationary boat gets off the boat by leaping to the left in an exactly horizontal direction. Immediately after the leap, the boat, of mass M, is observed (by an earth observer) to be moving to the right at speed v. How much work did the man do during the leap (both to his own body and on the boat)?

(A) $\frac{1}{2}Mv^2$.

(B) $\frac{1}{2}mv^2$.

(C) $\frac{1}{2}(M+m)v^2$.

(D) $\frac{1}{2}\left(M+\frac{M^2}{m}\right)v^2$

(E) $\frac{1}{2}\frac{Mm}{M+m}v^2$

23. Given that the radius of the Earth is 6.4×10^6 m, the total mass of the Earth's atmosphere is approximately

(A) 5×10^{16} kg.

(B) 1×10^{18} kg.

(C) 5×10^{18} kg.

(D) 1×10^{20} kg.

(E) 5×10^{9} kg.

24. A baseball is thrown vertically upward and feels no air resistance. As it is rising,

(A) both its momentum and its mechanical energy are conserved.

(B) both its momentum and kinetic energy are conserved.

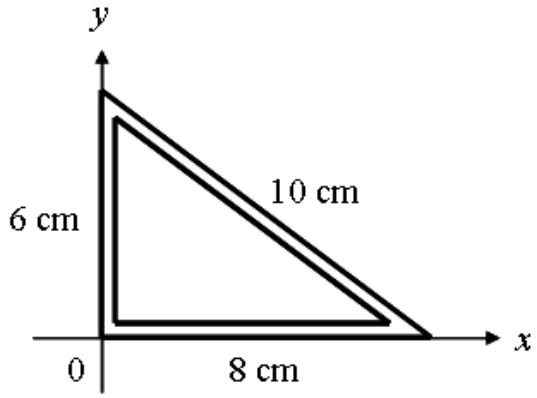
(C) its kinetic energy is conserved but its momentum is not conserved.

(D) the gravitational potential energy is not conserved but its momentum is conserved.

(E) its momentum is not conserved but its mechanical energy is conserved.

25. In the figure below, a 24-cm length of uniform wire, is bent into a right triangle. The two shorter sides lies on the x and y axes as shown below. You may neglect the thickness of the wire. The x- and y-coordinates of the centre of mass, in cm, are closest to

(A) (4.0, 3.0)
(B) (3.0, 3.0)
(C) (3.0, 2.5)
(D) (3.0, 2.0)
(E) (2.7, 2.0)



26. A student drifting down Singapore River, assumed to be straight with a current of 0.75 m/s, falls off from his raft. He grabs a piling of Coleman Bridge besides him and holds on for 40 s. He then swims after the raft with a speed relative to the water of 0.95 m/s. The distance of the raft downstream from the bridge when the student catches it is

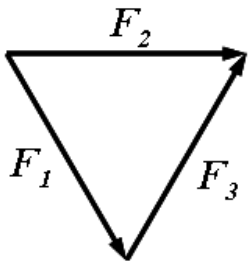
(A) 54 m
(B) 67 m
(C) 78 m
(D) 90 m
(E) 120 m

27. The soccer ball approaches a player at $v = 12$ m/s. At what velocity u should the player's foot move in order to stop the ball upon contact? Assume that the mass of the foot is much greater than that of the ball and that the collision is elastic.

(A) $u = 12$ m/s in the direction opposite to the original velocity of the ball
(B) $u = 6$ m/s in the direction opposite to the original velocity of the ball
(C) $u = 6$ m/s in the same direction as the original velocity of the ball
(D) $u = 0$ m/s, i.e., he should hold his foot very still.
(E) This feat cannot be done.

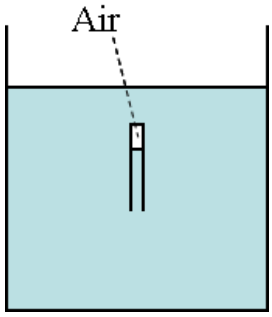
28. 3 forces that are the same in magnitude but different in direction acts on a mass m. These forces magnitudes and directions form a triangle as shown. The net force experience by this mass is

(A) $2F_2$
(B) F_2
(C) F_3
(D) $2F_3$
(E) 0



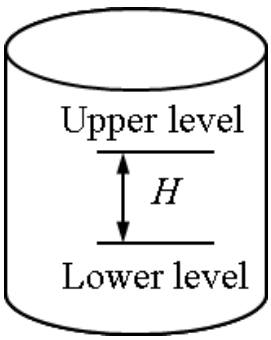
29. The diagram below shows an immersed test-tube with its open end facing downwards and an air bubble trapped in the test-tube. At a certain height, the test-tube is not moving. If we pour more water into the beaker, the test-tube will

(A) remains where it is.
(B) accelerate upwards.
(C) accelerate downwards.
(D) oscillate about a point.
(E) do any of the above depending on the amount of water poured in.



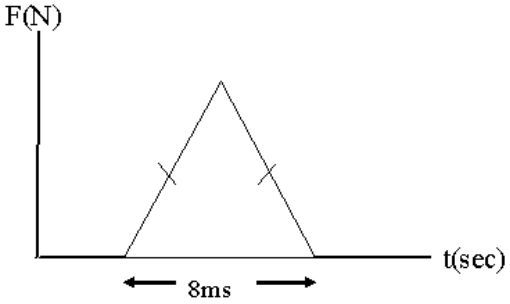
30. In an experiment for measuring g, a particle is thrown vertically up in an evacuated tube and allowed to fall down. ΔT_L is the time interval when the particle crosses a lower level in the tube while going up and while falling down. Similarly ΔT_H is the time interval when it crosses an upper level while going up and while falling down. H is the distance between two levels as shown in the figure. The correct value of g is :

(A) $g = \dfrac{8H}{\Delta T_L^2 - \Delta T_H^2}$
(B) $g = \dfrac{2H}{\Delta T_L^2 - \Delta T_H^2}$
(C) $g = \dfrac{2H}{\Delta T_L^2 + \Delta T_H^2}$
(D) $g = \dfrac{8H}{\Delta T_L^2 + \Delta T_H^2}$
(E) $g = \dfrac{2H}{\Delta T_L \Delta T_H}$



31. A ball of mass 0.25 kg is thrown with a speed of 30 m/s. The ball strikes a bat and it is hit straight back along the same line at a speed 50 m/s. Variation of the interaction force as long as the ball remains in contact with the bat is shown as an isosceles triangle in Fig.2, The maximum force exerted by the bat on the ball is:

(A) 2500 N
(B) 5000 N
(C) 7500 N
(D) 1250 N
(E) 1000 N



32. A juggler throws balls into air. He throws one whenever the previous one is at the highest point. How high do the balls rise if he throws n balls each second? Acceleration due to gravity is g.

(A) $g/(4n^2)$
(B) $2n^2g$
(C) $g/(2n^2)$
(D) g/n
(E) n/g

33. A fireworks rocket explodes at height h, the peak of its vertical trajectory. It throws out burning fragments in all directions, but all at the same speed v. Pellets of solidified metal fall to the ground without air resistance. Find the smallest angle that the final velocity of an impacting fragment makes with the horizontal.

(A) 0 degrees
(B) $\tan^{-1}\dfrac{\sqrt{2gh}}{v}$
(C) $\tan^{-1}\dfrac{\sqrt{2gh+v^2}}{v}$
(D) $\tan^{-1}\dfrac{v}{\sqrt{2gh+v^2}}$
(E) $\tan^{-1}\dfrac{v}{\sqrt{2gh}}$

34. A rock is thrown vertically upward with initial speed v_0. Assume a frictional force proportional to the speed of the rock, and neglect the upthrust exerted by air. Which of the following is correct?

(A) The acceleration of the rock is always g.

(B) The acceleration of the rock is equal to g only at the top of the flight.

(C) The acceleration of the rock is always less than g.

(D) The speed of the rock upon return to its starting point is v_0.

(E) The rock can attain a terminal speed greater than v_0 before it returns to its starting point.

35. An object is moving to the right in a straight line with a constant speed. Which of the following statements **must be** correct.

(A) There are no forces acting on the object.

(B) There is a larger number of forces acting on the object to the right than to the left.

(C) There is only one force acting on the object and it is acting to the right.

(D) The kinetic energy of the object is pointing to the right.

(E) The momentum of the object is pointing to the right.

36. The magnitude of the resistive force on a cruising plane is directly proportional to v^2 where v is the planes velocity. If the power expended by the plane is P when the plane is cruising at velocity v, what will be the power expended by the plane when the plane is cruising at velocity $2v$?

(A) $8P$

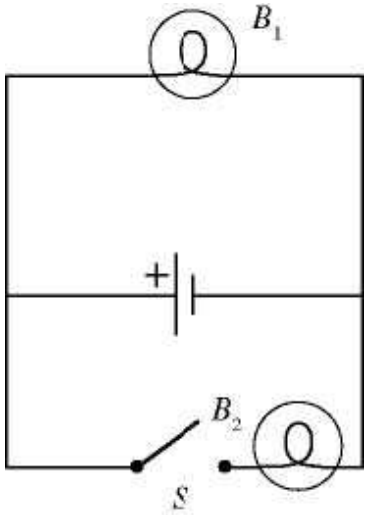
(B) $4P$

(C) $2P$

(D) P

(E) It cannot possibly be determined.

37. The battery has appreciable internal resistance. What happens to the brightness of bulb B_1 after we close the switch S?



(A) The brightness does not change.

(B) The brightness decreases temporary but gradually increases back to its original brightness.

(C) The brightness increases temporary but gradually decreases back to its original brightness.

(D) The brightness increases permanently.

(E) The brightness decreases permanently.

38. Two very large parallel sheets carry equal but opposite uniform surface charge densities. A point charge that is placed near the middle of the sheets equidistant from both of them feels an electrical force F due to the sheets. If this charge is now moved to half its original distance from the positive plate, the force it will feel is closest to:

(A) $F/4$

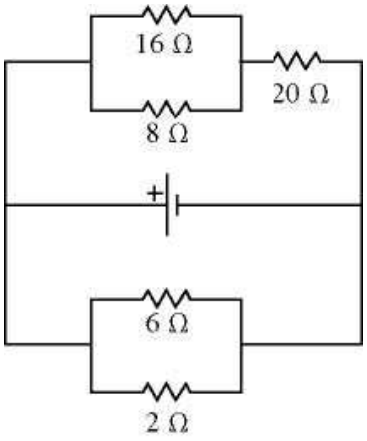
(B) $2F$

(C) F

(D) $4F$

(E) $F/2$

39. The current of the circuit in the 8-Ω resistor is 0.5 A. What is the current in the 2-Ω resistor?



(A) 9.5 A

(B) 0.75 A

(C) 2.25 A

(D) 4.5 A

(E) 6.4 A

40. If you rub a balloon on your sweater and then press it to a wall, it will often stick there. Why does this happen?

(A) Rubbing removes a surface layer of grease, allowing the rubber to come in sufficiently close contact with the wall so that air pressure hold it there.

(B) Rubbing the balloon charges it electrostatically, and this charge on the balloon induces an opposite charge on the wall. The attraction between induced charge and the charge on the balloon holds the balloon to the wall.

(C) A wall typically has a net electric charge on it, and rubbing the balloon charges it electrostatically. If the wall happens to have opposite charge to that on the balloon, the balloon will stick.

(D) Rubbing the balloon causes moisture to condense on it, and surface tension causes the balloon to stick to the wall.

(E) Rubbing the balloon surface causes it to become slightly conducting. When the balloon is touched to the wall, electrons flow from the balloon to the wall. This sets up an electric field which bonds weakly to the wall.

41. If the magnetic field vector is directed toward the north and an electron is moving toward the east, what is the direction of the magnetic force on the electron?

(A) East

(B) West

(C) South

(D) Up

(E) Down

42. If a charged pion that decays in 10^{-8} second in its own rest frame is to travel 30 m in the laboratory before decaying, the pion's speed must be most nearly

(A) 0.43×10^8 m/s

(B) 2.84×10^8 m/s

(C) 2.90×10^8 m/s

(D) 2.98×10^8 m/s

(E) 3.00×10^8 m/s

43. In the Einstein's photoelectric equation $eV_0 = hf - \phi$, the quantity ϕ is the

(A) minimum energy required to free an electron from its binding to the cathode material.

(B) energy difference between the two lowest electron orbits in the atoms of the photocathode.

(C) total light energy absorbed by the photocathode during the measurement.

(D) minimum energy a photon must have in order to be absorbed by the photocathode.

(E) average energy of all electrons in the photocathode.

44. The minimum sensitivity of the human eye is about 2×10^{-11} W/m^2. If the diameter of the pupil of the eye is 5 mm, how many photons/s of wavelength 500 nm must enter the eye for a distant star to be visible?

(A) 3 photons/s

(B) 10 photons/s

(C) 50 photons/s

(D) 200 photons/s

(E) 1000 photons/s

45. A very slow moving electron has its kinetic energy increased to four times its original value. What happens to the electron's corresponding de Broglie wavelength?

(A) The wavelength is decreased by a factor of 4.

(B) The wavelength is decreased by a factor of 2.

(C) There is no change in the wavelength.

(D) The wavelength is increased by a factor of 2.

(E) The wavelength is increased by a factor of 4.

46. Light is emitted due to transition from the $n = 3$ to the $n = 2$ level of a hydrogen atom in the Bohr model. If the transition were from the $n = 3$ to $n = 1$ level instead, the light emitted would have

(A) lower frequency

(B) less energy

(C) longer wavelength

(D) greater speed

(E) greater momentum

47. When a radioactive nucleus emits an alpha particle and a gamma ray, the number of

(A) protons increases by one while the number of neutrons decreases by one.

(B) protons decreases by one while the number of neutrons increases by one.

(C) protons and neutrons each decrease by two.

(D) protons decreases by one while the number of neutrons decreases by three.

(E) protons and neutrons remain unchanged.

48. The following fusion reaction occurs in the sun:

$$^{3}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{7}_{4}\mathrm{Be}$$

The masses of the nuclei are:

$$^{3}_{2}\mathrm{He} \;:\; 3.016049 \text{ u}$$

$$^{4}_{2}\mathrm{He} \;:\; 4.002604 \text{ u}$$

$$^{7}_{4}\mathrm{Be} \;:\; 7.016930 \text{ u}$$

Was energy absorbed or released? What is the value of this energy?

(A) zero

(B) Absorbed, 2.6×10^{-13} J

(C) Released, 2.6×10^{-13} J

(D) Absorbed, 1.5×10^{-10} J

(E) Released, 1.5×10^{-10} J

49. According to the special theory of relativity, which one of the following quantities has the same value for all observers?

(A) the length of an object.

(B) the speed of an object.

(C) the duration of a time interval.

(D) the speed of light in a vacuum.

(E) the mass of an object.

50. A physicist observes a stationary bare nucleus undergoes radioactive decay in a uniform magnetic field. Two traces were made by the products' paths as in the diagram shown. The diameter of the bigger circle to that of the smaller circle is 16:1. He ponders over the 4 statements made by his colleagues.

I. The nucleus underwent α decay.

II. The recoil nucleus path follows the smaller circle in the anti-clockwise direction.

III. The atomic number of the nucleus was originally 15.

IV. The period of the recoil nucleus and the radioactive entity has the same period.

Which of the above statements is/are true?

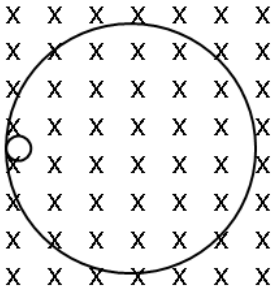
(A) I only

(B) I and II only

(C) I and IV only

(D) II and IV only

(E) II and III only



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