SRI LANKAN PHYSICS OLYMPIAD COMPETITION – 2011

Time Allocated : 02 Hours
Calculators are not allowed to use.

Date of Examination : 24 – 09 – 2011 Index No. : ………………

Time : 9.00 a.m. - 11.00 a.m.

INSTRUCTIONS

- Answer all questions
- There are two parts (A and B) in this paper.
- Part A contains 20 multiple choice questions. Your answer to each question must be marked on the body of the question paper itself.
- Select the single answer that provides the best response to each question. Please be sure to use a pencil and underline the response corresponding to your choice. If you change the choice of an answer, the previous underline mark must be completely erased.
- Your score on this multiple choice section will be your number of correct answers. There is no penalty for guessing. It is to your advantage to answer every question.

- Part B contains two questions.
- Use the paper provided to do all the calculations in part A as well as in part B.
- Write down the corresponding final expressions for part B questions on the last page attached in the question paper.
- At the end of the exam, handover the question paper with your marked responses together with the final answer sheet.
- Handover the papers used to workout the problems in Part B separately with your index number written on each paper.
- Do not detach any sheet from the question paper.

$g = 10 \text{ m s}^{-2}$

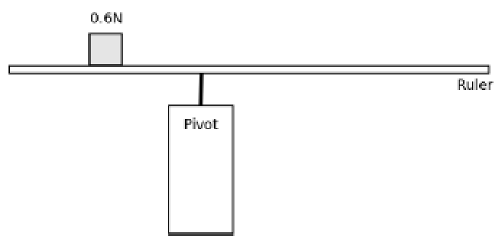
PART A

1. A frictionless trolley accelerates down a smooth straight sloping runway. When the mass of the trolley is doubled, the acceleration

(1) Doubles (2) Increases a bit but does not double (3) Stays the same

(4) Decreases a bit but does not halve (5) Halves

2. A uniform ruler is 100 cm long. A 0.6 N weight is placed at the 80 cm mark. The ruler is balanced in equilibrium on a pivot placed at the 60 cm mark. The weight of the ruler is



(1) 1.2 N (2) 1.0 N (3) 0.6 N (4) 0.5 N (5) 0.3 N

3. A radioisotope with a half life of 6 hours and an initial activity of 800 Bq is added to 500 litres of paint. If the paint is mixed evenly then after one day the activity of 1 litre of paint should be

(1) 133 Bq (2) 50 Bq (3) 1.6 Bq (4) 0.2 Bq (5) 0.1 Bq

4. When 1000 J of thermal energy is transferred to 200 g of material *X* the temperature increases by 4 °C. When 2000 J of thermal energy is transferred to 100 g of material *Y* the temperature increases by 8 °C.

The ratio $\dfrac{\text{specific heat capacity of } X}{\text{specific heat capacity of } Y}$ is

(1) 4 (2) 2 (3) 1 (4) 1/2 (5) 1/4

5. Microwaves and radio waves can both used to transfer data from one place to another. The advantage of using microwaves is that they

(1) are not diffracted (2) travel faster

(3) can transfer more information per second (4) have a longer wavelength

(5) are not absorbed by the atmosphere

6. A current carrying conductor in a magnetic field experiences a force. Which of the following factors does NOT affect the magnitude of the force?

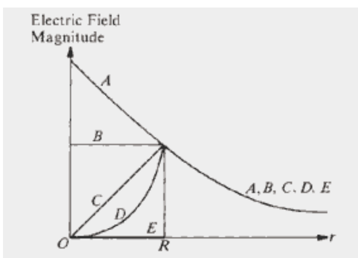
(1) The size of the current (2) The strength of the magnetic field

(3) The angle between the conductor and the direction of the magnetic field

(4) The length of the conductor in the magnetic field

(5) The direction of the current

7. An isolated sphere of radius R contains a uniform volume distribution of positive charge. Which of the curves on the graph below correctly illustrates the dependence of the magnitude of the electric field of the sphere with the distance r from the center?

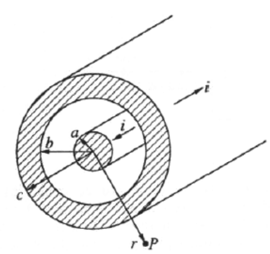


(1) A (2) B (3) C (4) D (5) E

8. A wire of diameter 0.02 m contains 10^{28} free electrons in a m^{-3}. For a current of 100 A, the drift velocity for free electrons in the wire is most nearly equal to (in m s^{-1})

(1) 6×10^{-30} (2) 1×10^{-19} (3) 5×10^{-10} (4) 2×10^{-4} (5) 8×10^{3}

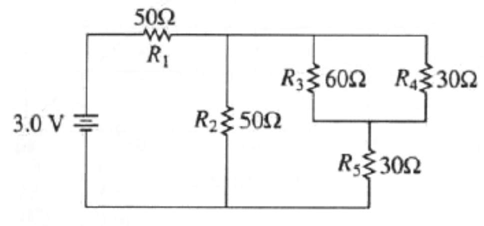
9. A coaxial cable having radii a, b, and c carries equal and opposite currents of magnitude i on the inner and outer conductors. What is the magnitude of the magnetic flux density at point P outside of the cable at a distance r from the axis?



(1) 0 (2) $\dfrac{\mu_0 ir}{2\pi a^2}$ (3) $\dfrac{\mu_0 i}{2\pi r}$ (4) $\dfrac{\mu_0 ir}{2\pi a^2}\dfrac{(c^2-r^2)}{(c^2-b^2)}$ (5) $\dfrac{\mu_0 ir}{2\pi a^2}\dfrac{(r^2-b^2)}{(c^2-b^2)}$

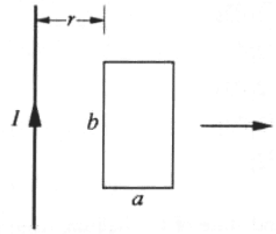
10. A beam of electrons is accelerated through a potential difference of 25 kV in an X-ray tube. The continuous X-ray spectrum emitted by the target of the tube will have a short wavelength limit of most nearly ($hc = 12.4\times10^3$ eV $\mathring{A}$)

(1) 0.1 $\mathring{A}$ (2) 0.5 $\mathring{A}$ (3) 2 $\mathring{A}$ (4) 25 $\mathring{A}$ (5) 50 $\mathring{A}$

11. 

In the circuit shown, the battery has negligible internal resistance. The resistor that dissipates the most power is

(1) R_1 (2) R_2 (3) R_3 (4) R_4 (5) R_5

12. 

A rectangular loop of wire with dimensions shown is coplanar with a long wire carrying current *I*. The distance between the wire and the left side of the loop is *r*. The loop is pulled to the right as indicated. What are the directions of the induced current in the loop and the magnetic forces on the left and the right sides of the loop as the loop is pulled?

Induced Current Force on Left Side ... Force on Right Side

(1) Counterclockwise ... To the left .... To the right

(2) Counterclockwise ... To the left .... To the left

(3) Counterclockwise ... To the right .... To the left

(4) Clockwise .... To the right .... To the left

(5) Clockwise .... To the left .... To the right

13. A cavity radiator has its maximum spectral radiancy at a wavelength of 30.0 μm. The absolute temperature of the body is increased so that the radiant intensity of the radiator is doubled. The new temperature of the radiator is (Wien's constant = 3000 $\mu m\,K$)

(1) $\sqrt[4]{100}$ K (2) $\sqrt[4]{200}$ K (3) $\sqrt[4]{2}\times 100$ K (3) $\sqrt[4]{4}\times 100$ K (5) $\sqrt{1000}$ K

14. When radiations of wave length λ are incident on a photosensitive surface, the maximum kinetic energy of the photoelectrons emitted from the surface is 2 eV. When the wave length of the incident radiation is changed to 2λ, the maximum kinetic energy of the photoelectrons emitted from the surface is 0.5 eV. The photoelectric work function of the surface and the threshold wavelength for photoelectric emission from the surface are respectively

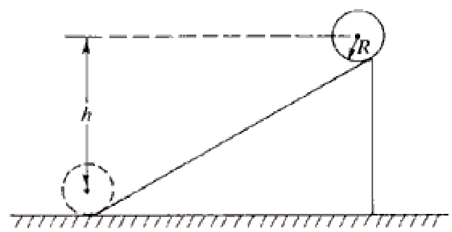
(1) 0.15 eV, $\lambda/2$ (2) 0.25 eV, λ (3) 0.5 eV, $3\lambda/2$ (4) 0.75 eV, 2λ (5) 1.0 eV, 3λ

15. A beta particle, gamma ray, and alpha particle all have the same momentum. Which has the longest de Broglie wavelength?

(1) beta particle. (2) gamma ray. (3) alpha particle. (4) all the same.

(5) depends on gamma ray energy.

16. A hoop of mass M and radius R is at rest at the top of an inclined plane as shown. The hoop rolls down the plane without slipping. When the hoop reaches the bottom, its angular momentum around its center of mass is



(1) $MR\sqrt{gh}$ (2) $\frac{1}{2}MR\sqrt{gh}$ (3) $MR\sqrt{2gh}$ (4) $2MR\sqrt{gh}$ (5) $MRgh$

17. A uranium nucleus decays at rest into a thorium nucleus and a helium nucleus. Which of the following is true?

(1) Each decay product has the same kinetic energy.

(2) Each decay product has the same speed.

(3) The decay products tend to go in the same direction.

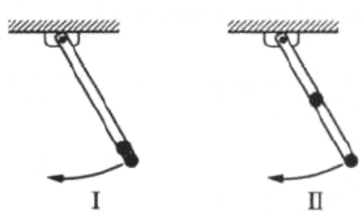
(4) The thorium nucleus has more momentum than the helium nucleus.

(5) The helium nucleus has more kinetic energy than the thorium nucleus.

18. A hollow cube has a constant electric potential V on its surface. If there are no charges inside the cube, the potential at the center of the cube is

(1) 0 (2) $V/8$ (3) $V/6$ (4) $V/4$ (5) V

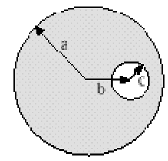
19.



A long, straight, and massless rod pivots about one end in a vertical plane. In configuration I, two small identical masses are attached to the free end; in configuration II, one mass is moved to the center of the rod. What is the ratio of the frequency of small oscillations of configuration II to that of configuration I?

(1) $\sqrt{6/5}$ (2) $\sqrt{3/2}$ (3) 6/5 (4) 3/2 (5) 5/3

20. A non conducting sphere of radius a has uniform charge density ρ. A spherical cavity of radius c is formed in the sphere. The cavity is centered a distance b ($b > c$) from the center of the sphere.



The magnitude of the electric field intensity anywhere inside the cavity is given by

(1) $\frac{\rho b}{3\varepsilon_o}$ (2) $\frac{\rho a^3}{3\varepsilon_o b^2}$ (3) $\frac{\rho(a^3 - c^3)}{3\varepsilon_o b^2}$ (4) $\frac{\rho\left(b - \frac{c^3}{2b^2}\right)}{3\varepsilon_o}$

(5) $\frac{\rho\left(b - \frac{c^3}{b^2}\right)}{3\varepsilon_o}$

PART B

(1) A star more massive than the sun can collapse under its own gravity to form a neutron star. Here the electrons and protons combine to form neutrons. A star having an initial radius R_1 spinning with an initial angular frequency ω_1 collapses to form a neutron star with final radius R_2 spinning with final angular frequency ω_2

(i) If the volume of the star decreases by a factor of 10^{15}, and the shape of the star remains the same, then what is the ratio of the final to initial radii $\frac{R_2}{R_1}$?

(ii) (a) Write down an expression for ω_2 in terms of ω_1.

(b) Write down an expression for the final period (T_2) of the star in terms of ω_1. (Take $\pi = 3$)

(iii) As the core of the star collapses its magnetic field lines becomes frozen into the material of the star and thereby increase its magnetic flux density. If the magnetic flux (ϕ) is given by $\phi = BR^2$, where B being the magnetic flux density whose initial value is 10^{-2} T, then determine the final magnetic flux density after the collapse.

(iv) If a neutron star spins too fast, it will start losing material from its equatorial region. Derive an expression for the minimum period (T_{min}) that the star should have in order not to lose material from its equatorial region in terms of G, R, and M. (Here G = universal gravitational constant; R = radius of the neutron star; M = mass of the neutron star)

(2) In order to probe the structure of a nucleus, whose radius is about 10^{-15} m, a beam of electrons from a particle accelerator is fired at a solid target. If the wavelength of the electrons is similar to the size of the nucleus, then a diffraction effects will occur and the size of the nucleus can be determined.

(i) (a) Calculate the momentum (p) of the electron beam which is needed to make the wavelength equal to the nuclear diameter.

(b) Calculate the energy (E) of the electron beam. Assume that the electrons are moving at almost the speed of light, and $E = pc$, where p is the momentum, and c is the speed of light.

(ii) If the beam current is 10^{-8} A, calculate the number (n) of the electrons hitting the target per second.

(iii) A copper target of thickness 0.1 cm intercepts the electron beam in part (i) above. The beam has a cross sectional area of 9 mm^2 when it hits the copper target.

(a) What is the volume (V) of copper through which the beam passes?

(b) Determine the number (n_{target}) of target nuclei lying in the beam.

(iv) If the target nuclei do not lie behind each other, calculate the ratio (r) of the total area of the nuclei lying in the path of the beam to the cross sectional area of the beam. (Take $\pi = 3$)

(v) The ratio calculated in part (iv) above can be taken as the probability that an electron will collide with a target nucleus. From your answer obtained in part (ii) above, calculate the number ($n_{collisions}$) of collisions that the beam makes per second in the target.

[Electronic charge = 1.6×10^{-19} C; Density of copper = 8.0×10^{3} kg m^{-3};
Relative atomic mass of copper = 64;
Avogadro's number = 6.0×10^{23} atoms mole^{-1};
Planck constant = 6.6×10^{-34} J s ; Speed of light = 3.0×10^{8} m s^{-1}]