SRI LANKAN PHYSICS OLYMPIAD COMPETITION – 2009

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

Date of Examination : 18 – 07 – 2009 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 semi – structured type 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 or the final numerical answers 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 motorist travels 320 km at 80 km hr^{-1} and then 320 km at 100 km hr^{-1}. What is the average speed of the motorist for the entire trip to the nearest integer?

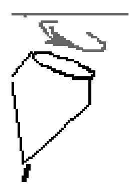
(1) 84 km hr^{-1} (2) 89 km hr^{-1} (3) 90 km hr^{-1}

(4) 91 km hr^{-1} (5) 95 km hr^{-1}

(2) A car is stopped at a traffic light. At t = 0 the light turns green and the car accelerates at a rate of 2.0 m s^{-2}. At t = (10/3) s a bus traveling at a constant speed of 15 m s^{-1} in the same direction passes the stop light. When does the bus overtake the car?

(1) $t = 5.0\,\text{s}$ (2) $t = 6.0\,\text{s}$ (3) $t = 7.5\,\text{s}$ (4) $t = 12.0\,\text{s}$ (5) $t = 21.0\,\text{s}$

(3) A top is spinning in the direction shown in the following figure.



Its axis of rotation makes an angle of 15º with the vertical. If frictional forces can be neglected, which of the following is correct regarding the magnitude of the top's angular momentum and its direction?

. (1) increases, preceses in the counterclockwise direction when seen from above.

(2) increases, not preceses

(3) remains the same, not preceses

(4) remains the same, preceses in the clockwise direction when seen from above

(5) remains the same, preceses in the counterclockwise direction when seen from above.

(4) An astronaut of weight W on Earth lands on a planet with mass 0.1 times the mass of Earth and radius 0.5 times the radius of Earth. The astronaut's weight on the planet is

(1) $0.02W$ (2) $0.04W$ (3) $0.2W$ (4) $0.4W$ (5) W

(5) A child of mass M stands on the edge of a merry-go-round of radius R and moment of inertia I. Both the merry-go-round and child are initially at rest. The child walks around the circumference with speed v with respect to the ground. What is the magnitude of the angular velocity of the merry-go-round with respect to the ground?

(1) 0 (2) $\omega = \frac{MRv}{I}$ (3) $\omega = \frac{v}{R}$ (4) $\omega = \frac{MRv}{I - MR^2}$ (5) $\omega = \frac{MRv}{I + MR^2}$

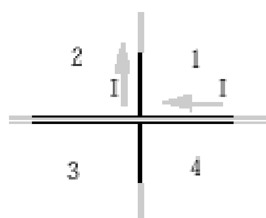
(6) An ideal gas is expanded at constant pressure from initial volume V_i and temperature T_i to final volume V_f and temperature T_f. The gas has molar heat capacity C_P at constant pressure. The amount of work done by n moles of the gas during the process is given by

(1) 0 (2) $nRT_i \ln\left(\frac{V_f}{V_i}\right)$ (3) $C_P n\left(T_f - T_i\right)$ (4) $nR\left(V_f - V_i\right)$ (5) $nR\left(T_f - T_i\right)$

(7) An organ pipe which is open at both ends resonates with fundamental frequency 300 Hz. If one end of the pipe is closed, it will resonate with a fundamental frequency of:

(1) 75 Hz (2) 150 Hz (3) 300 Hz (4) 600 Hz (5) 1200 Hz

(8) Identical currents flow in two perpendicular wires, as shown in the accompanying figure. The wires are very close but do not touch.



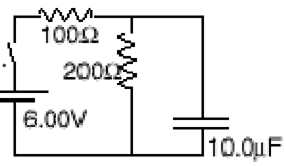
The magnetic flux density can be zero

(1) at a point in region 1 only (2) at a point in region 2 only

(3) at points in both regions 2 and 4 (4) at points in both regions 1 and 4

(5) at points in both regions 1 and 2

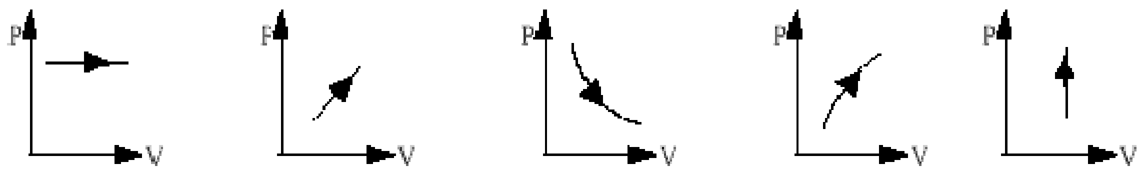
(9) The switch is closed in the circuit shown.
The battery has a negligible internal resistance.



What is the charge on the capacitor when it is fully charged?

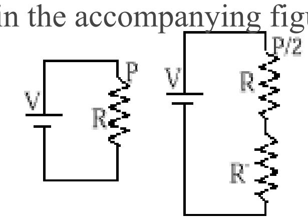
(1) 5.0 μC (2) 10.0 μC (3) 20.0 μC (4) 40.0 μC (5) 60 μC

(10) Which of the accompanying PV diagrams best represents an adiabatic process?



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

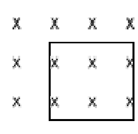
(11) A resistor *R* dissipates power *P* when connected directly to a voltage source *V* with negligible internal resistance, as shown in the accompanying figures.



What resistance *R′* must be connected in series with *R* to decrease the power dissipated in *R* to ½*P*?

(1) $\frac{R}{2}$ (2) $\frac{R}{\sqrt{2}}$ (3) *R* (4) $R\left(\sqrt{2}-1\right)$ (5) $R\sqrt{2}$

(12) A uniform magnetic field of flux density 0.080 T is directed into the plane of the page and perpendicular to it, as shown in the figure. A wire loop in the plane of the page has an area 0.010 m^2. The magnitude of the magnetic field decreases at a constant rate of 3.0×10^{-4} T s^{-1}.



The magnitude and direction of the induced e.m.f. is

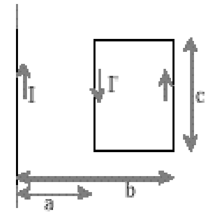
(1) 3.0×10^{-6} V clockwise (2) 3.0×10^{-6} V counterclockwise

(3) 2.4×10^{-5} V counterclockwise (4) 8.0×10^{-4} V counterclockwise

(5) 8.0×10^{-4} V clockwise

(13) The infinitely long straight wire carries a current I as shown in the figure. The rectangular loop carries a current I' in the counterclockwise direction.

The net force on the rectangular loop is



(1) $\frac{\mu_0 II'c}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$ *to the right* (2) $\frac{\mu_0 II'c}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$ *to the left*

(3) $\frac{\mu_0 II'}{2\pi}\left(\frac{c}{a}+\frac{c}{b}+\frac{2(b-a)}{c}\right)$ *to the left* (4) $\frac{\mu_0 II'}{2\pi}\frac{2(b-a)}{c}$ *to the right* (5) 0

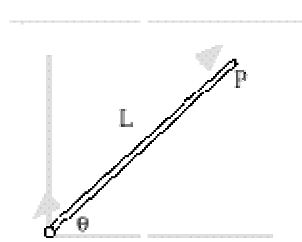
(14) A firecracker exploding on the surface of a lake is heard as two sounds – a time interval t apart – by a person on the ground. Sound travels with speed u in water and speed v in air. The distance from the exploding firecracker to the person is

(1) $\frac{uvt}{u+v}$ (2) $\frac{t(u+v)}{uv}$ (3) $\frac{t(u-v)}{uv}$ (4) vt (5) $\frac{uvt}{u-v}$

(15) The root mean square velocity of a certain gas (relative molecular mass 16) is v at room temperature. The root mean square velocity of helium (relative atomic mass 4) at the same temperature is

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

(16) A uniform rod of length L and mass M is pivoted on the ground with a frictionless hinge. The rod makes an angle θ with the horizontal. The moment of inertia of the rod about one end is $\frac{1}{3}ML^2$.

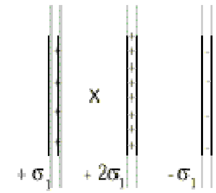


If it starts falling from the position shown in the diagram, the linear acceleration of the free end of the rod – labeled P – would be

(1) $\frac{2}{3}g\cos\theta$ (2) $\frac{2}{3}g$ (3) g (4) $\frac{3}{2}g\cos\theta$ (5) $\frac{3}{2}g$

(17) The figure below depicts three infinite, parallel, non conducting thin plates carrying surface charge densities $+\sigma_1$, $+2\sigma_1$, and $-\sigma_1$ respectively.

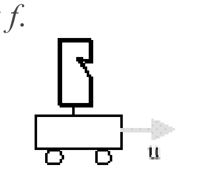
The net electric field intensity at the point labeled X is given by



(1) $\dfrac{2\sigma_1}{\varepsilon_0}$, to the left (2) $\dfrac{\sigma_1}{2\varepsilon_0}$, to the left (3) 0 (4) $\dfrac{\sigma_1}{2\varepsilon_0}$, to the right

(5) $\dfrac{2\sigma_1}{\varepsilon_0}$, to the right

(18) On a day when the velocity of sound in air is *v*, a whistle moves with velocity *u* toward a stationary wall. The whistle emits sound with frequency *f*.



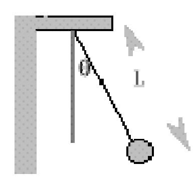
What frequency of reflected sound will be heard by an observer traveling along with the whistle?

(1) $f\left(\dfrac{v-u}{v+u}\right)$ (2) $f\left(\dfrac{v}{v+u}\right)$ (3) f (4) $f\left(\dfrac{v}{v-u}\right)$

(5) $f\left(\dfrac{v+u}{v-u}\right)$

(19) A simple pendulum of length *L* and mass *m* is attached to a moving support.

In order for the pendulum string to make a constant angle θ with the vertical, the support must be moving to the



(1) right with constant acceleration a = g tanθ.

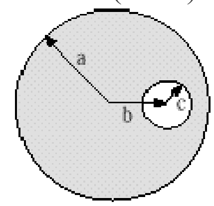
(2) left with constant acceleration a = g tanθ.

(3) right with constant acceleration a = g sinθ.

(4) right with constant velocity $v = \sqrt{Lg \tan\theta}$

(5) left with constant velocity $v = \sqrt{Lg \tan\theta}$

(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 at the center of the cavity is given by

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

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

PART B

(1) A lunar space vehicle of mass (M) is moving with constant speed (v) around the moon of mass (M_M) along a circular orbit of radius (R) from the center of the moon. The radius of the moon is R_M. ($R > R_M$) Neglect any resistive forces acting on the vehicle.

(i) (a) Derive an expression for v in terms of G, M_M and R. Here G is the universal gravitational constant.

(b) Obtain the numerical value of v given that

$$G = 7.0 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}; M_M = 7.0 \times 10^{22}\,\mathrm{kg}; R = 16.0 \times 10^5\,\mathrm{m}$$

(ii) The astronauts in the space vehicle want to change the orbit of the vehicle from R to R_M in order to prepare for landing. One way to achieve this is to reduce the speed, (v), of the vehicle by an amount Δv, by firing a rocket along the direction of v for a short time. Then the kinetic energy of the vehicle would be reduced and it falls into a lower orbit.

(a) Using energy conservation and angular momentum conservation, derive an expression for the speed (v'), of the vehicle just after firing the rocket in order to change the orbit of the vehicle from R to R_M in terms of G, M_M, R and R_M.

(b) Hence obtain an expression for Δv in terms of v, R and R_M. Here $v' = v - \Delta v$

(c) Determine the numerical value for Δv. $\left(R_M = 15.0 \times 10^5\,\mathrm{m}; \text{Take} \sqrt{\dfrac{30}{31}} = 0.98 \right)$

(iii) In the process of igniting the rocket, some amount of fuel will be burned.

(a) If the speed of the ejected gases relative to the vehicle is u, obtain an expression for the mass (Δm), of spent fuel in terms of M, Δv, and u.

(b) Determine Δm if $M = 10^4$ kg; $u = 10^4$ m s^{-1}.

(2) The mass (m), of a sample made from aluminum is to be measured using a chemical balance and brass weights. Usually when the same mass (m) from weights is placed on the other pan one should obtain the balance condition. But if the buoyancy forces acting on the sample and the weights by outside air are considered, the balance condition will be altered.

(i) (a) If the measurement is done on a dry day (density of dry air is ρ_d), write down an expression for the unbalanced force (ΔF_1) acting on the masses in terms of the difference in volumes (ΔV) between the sample and weights, ρ_d and g.

(b) Similarly If the measurement is done on a humid day (density of humid air is ρ_h), write down an expression for the unbalanced force (ΔF_2) acting on the masses in terms of the difference in volumes (ΔV) between the sample and weights, ρ_h and g.

(c) Which has the larger value out of ΔF_1 and ΔF_2?

(d) Write down an expression for ΔF. $\left(\Delta F = \left|\Delta F_1 - \Delta F_2\right|\right)$

(ii) If the densities of aluminum and brass are ρ_a and ρ_b respectively, write down an expression for ΔV in terms of m, ρ_a and ρ_b.

(iii) Assuming dry air and humid air behave as ideal gases write down expressions for ρ_d and ρ_h in terms of atmospheric pressure P_0, effective molar mass of dry air M_d, effective molar mass of humid air M_h, gas constant R, and temperature T.

(iv) Obtain an expression for the minimum value (m_{min}) that m should have in order to be able to practically measure the difference in the balance reading ΔF, provided the sensitivity of the balance is 0.1 mg. (expression should be in terms of P_0, M_d, M_h, ρ_a, ρ_b, R and T.)

ANSWER SHEET FOR PART B

QUESTION NUMBER	ANSWERS	MARKS (examiner's use)
1 (i) (a)	$\boldsymbol{v} =$	
(i) (b)	$\boldsymbol{v} =$	
(ii) (a)	$v' =$	
(ii) (b)	$\Delta v =$	
(ii) (c)	$\Delta v =$	
(iii) (a)	$\Delta m =$	
(iii) (b)	$\Delta m =$	

2. **(i) (a)**	$\Delta F_1 =$	
(i) (b)	$\Delta F_2 =$	
(i) (c)		
(i) (d)	$\Delta F =$	
(ii)	$\Delta V =$	
(iii)	$\rho_d =$	
	$\rho_h =$	
(iv)	$m_{\min} =$	