SRI LANKAN PHYSICS OLYMPIAD COMPETITION – 2014

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

Date of Examination : 21 – 06 – 2014 **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 15 multiple choice questions. Underline the response corresponding to your choice in each question. If you change the choice of an answer, the previous underline mark must be completely erased/removed.**
- **Part B contains two questions.**
- **Use the papers provided to do all the derivations.**
- **At the end of each question an answer sheet is provided for you to write down the corresponding final expressions or numerical answers.**
- **At the end of the exam, handover the full question paper together with the final answer sheets.**
- **Handover the papers used to work out the problems separately with your index number written on each paper.**
- **Do not detach any sheet from the question paper.**

PART A

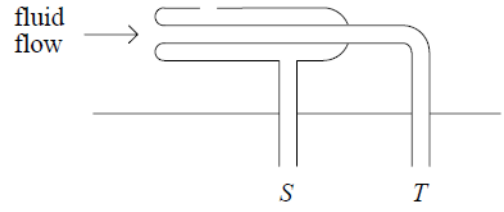
1. The e.m.f. E_b of a battery is given by $E_b = P/I$ where P is the power dissipated when a current I flows. The e.m.f. E_c induced in a coil by a changing magnetic flux is equal to the rate of change of the magnetic flux (Φ), $E_c = d\Phi/dt$. Which of the following is a unit for magnetic flux?

(1). m s^{-1} A (2). m s^{-2} A^{-1} (3). kg m^2 s^{-2} A (4). kg m s^2 A^{-1} (5). kg m^2 s^{-2} A^{-1}

2. The diagram shows a Pitot-static tube situated in a moving fluid. A manometer connected to S and T shows a difference h in the liquid levels. If v = the velocity of the moving fluid, d = the density of the moving fluid, ρ = the density of the liquid in the manometer, then v^2 is equal to

(1) $2\rho gh/d$ (2) $2dgh$ (3) $\rho gh/d$

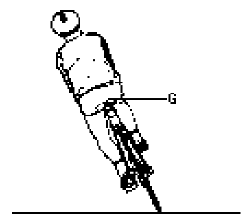
(4) dgh/ρ (5) ρdgh

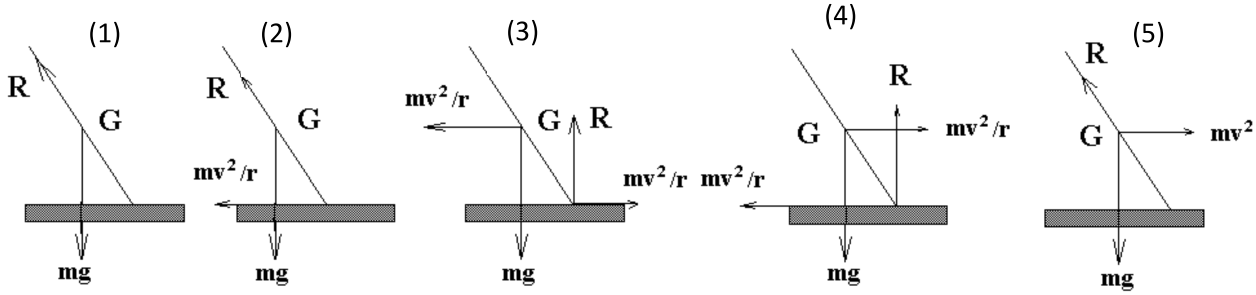


3. A projectile of mass m is projected with a speed u making an angle θ with the horizontal and falls at a distance R from the point of projection on the same horizontal level. The magnitude of change in momentum during flight will be

(1) zero (2) $2mu$ (3) $2mu\cos\theta$ (4) $2mu\sin\theta$ (5) $2mu\tan\theta$

4. The diagram represents a cyclist making a left turn of radius r on a rough road surface at constant speed v, as viewed from behind. The total mass of the bicycle and rider is m and their combined centre of gravity is at G. If R is the resultant force of the normal reaction and the frictional force, which vector diagram represents the directions of the forces acting on the bicycle and its rider with respect to an inertial observer?

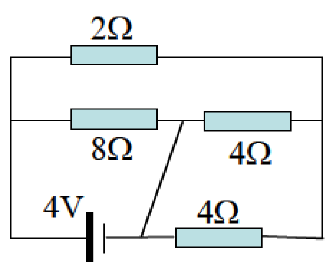




5. In the circuit shown, the current through the battery with negligible internal resistance is

(1) 1 A (2) 2 A (3) 2.5 A (4) 4 A

(5) 1.5 A



6. A beam of electrons enters a region in which there are magnetic and electric fields. How should an electric field E be applied such that the beam passes straight through the region without deviation? (The direction of the magnetic field is shown with the arrows in the diagram)

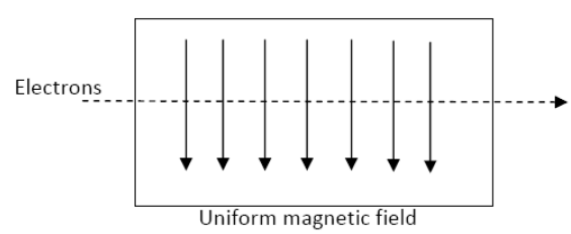
(1) Downwards along the plane of the paper

(2) Upwards along the plane of the paper

(3) Into the plane of the paper

(4) Out of the plane of the paper

(5) Electrons are not affected by magnetic fields so no application of any field is necessary.



7. The edge of a concave lens is uniformly blackened so that the aperture of the lens is a circle with diameter 4.0 cm. When a beam of light passes though the whole aperture of the lens parallel to the principal axis, a circular bright spot with diameter 20.0 cm is formed on the screen situated 60.0 cm from the lens. What is the focal length of the lens?

(1) 10.7 cm (2) 15.0 cm (3) 18.0 cm (4) 20.0 cm (5) 60.0 cm

8. The total energy of a blackbody radiation source is collected for one minute and the collected energy is used to heat water. The temperature of the water increases from 20.0°C to 20.5°C. If the absolute temperature of the blackbody is doubled and the experiment is repeated, which of the following statements would be most nearly correct?

(1) The temperature of the water would increase from 20°C to a final temperature of 21°C.

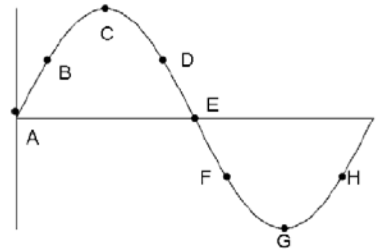
(2) The temperature of the water would increase from 20°C to a final temperature of 24°C.

(3) The temperature of the water would increase from 20°C to a final temperature of 28°C.

(4) The temperature of the water would increase from 20°C to a final temperature of 36°C.

(5) The water would boil within the one-minute time period.

9. The figure shows a transverse wave at a particular instant in time. If the point F is moving downwards at that time, we can deduce that



(1) the wave is travelling towards the right.

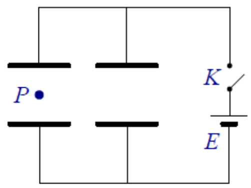
(2) C will reach the equilibrium position earlier than B.

(3) the point H is moving in the same direction as point F.

(4) the acceleration at D at this point is the maximum.

(5) A is not moving at all.

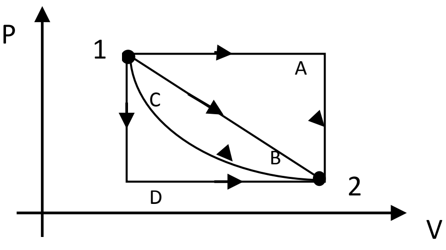
10. As shown, two parallel plate capacitors are placed horizontally and connected to a battery *E*. After charging the capacitors, the switch *K* is open. A charged particle is placed in the left capacitor and is at rest. If the distance between the plates of the right capacitor is reduced, the particle will then



(1) move horizontally (2) move downwards (3) move upwards

(4) move in circle (5) remain at rest

11. In the PV diagram of an ideal gas shown, which paths from 1-2 depicts most work done by the gas?



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

(5) All paths do the same work

12. A whistle of frequency 540 Hz rotates in a circle of radius 2 m at an angular speed of 15 rad s^{-1}. What are the respective highest and lowest frequencies heard by a listener, a long distance away at rest with respect to the centre of the circle. (Velocity of sound in air = 330 m s^{-1})

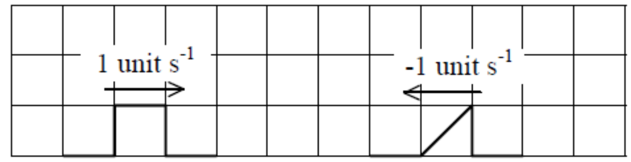
(1) 540 Hz, 495 Hz (2) 594 Hz, 540 Hz (3) 594 Hz, 495 Hz (4) 540 Hz, 540Hz

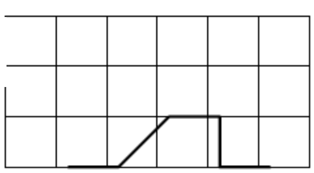
(5) 540 Hz, 0

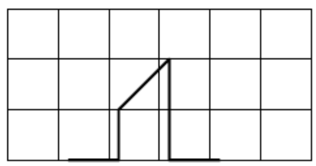
13. A communications satellite of mass m moves at a constant angular speed ω in a circular orbit of radius r about the Earth's centre of mass. What is the work done on the satellite in one revolution due to gravitational forces?

(1) zero (2) $2\pi mr^2\omega^2$ (3) $\pi mr^3\omega^2$ (4) $mr^2\omega^2$ (5) $\frac{1}{2}mr^2\omega^2$

14. Figure below shows two pulses moving in opposite directions along a string. What will the pulse look like after 3.25 s? (1 unit = width of a small square)



(1)


(2)


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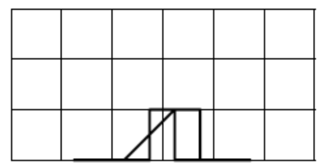

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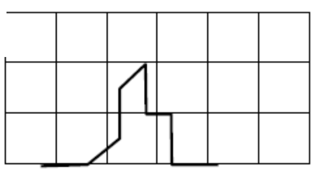
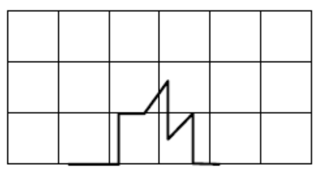
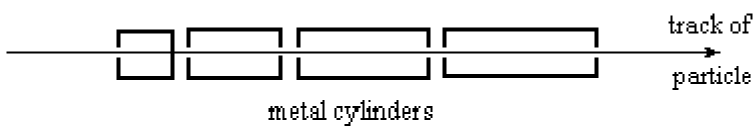
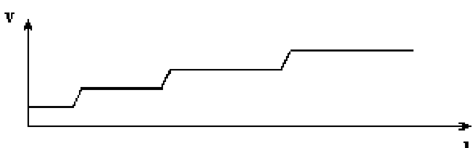


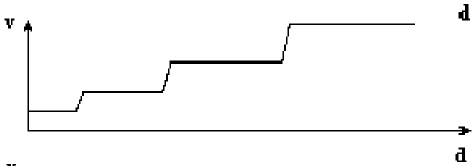
(5)


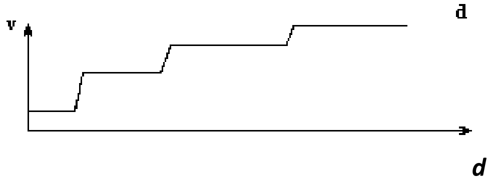
15. A linear accelerator sends a charged particle along the axis of a set of coaxial hollow metal cylinders as shown in the diagram.



The particle travels at constant speed inside each cylinder. The particle crosses the gaps between the cylinders at equal time intervals, and at each gap its kinetic energy increases by a fixed amount. Which of the graphs best represents the way in which v, the velocity of the particle varies with d, the distance along its track?

(1)


(2)


(3)


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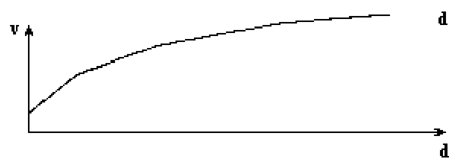
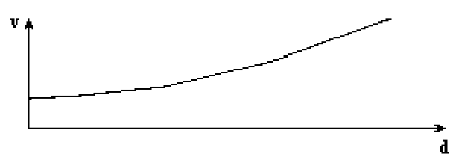


(5)


PART B

(1) Consequences of an asteroid impact on Earth

65 million years ago Earth was hit by an asteroid of mass 1.0×10^{15} kg, and with a speed of 2.0×10^{4} m s^{-1}. This impact resulted in the extermination of most of the life on Earth, including dinosaurs and the formation of the enormous Chicxulub Crater in Mexico. Assume that an identical asteroid would hit the Earth today in a completely inelastic collision. (i.e. the asteroid embeds to the earth at the point of contact and comes to rest) Use the data given below to answer the following questions.

Mass of the Earth $= 6.0 \times 10^{24}$ kg; Radius of the Earth $= 5.0 \times 10^{6}$ m; Take $\pi = 3$; Assume that the moment of inertia of the Earth is equal to that for a homogeneous sphere of the same mass and radius. The moment of inertia of a homogeneous sphere with mass *M* and radius *R* is given by $\frac{2}{5}MR^2$. Further assume that the radius of the asteroid is very small compared to the radius of the Earth, so once the asteroid is embedded to the Earth surface it could be considered as a point particle. Neglect any changes to the orbit of the Earth due to the impact. Use the principle of angular momentum conservation to answer the parts (d)(iii), and (e) .

(a) Calculate the angular velocity, ω_E, of the Earth around its rotational axis. $\left(\frac{1}{144} = 7.0 \times 10^{-3}\right)$

(b) Calculate the moment of inertia, I_E, of the Earth around its rotational axis.

(c) Calculate the angular momentum, L_E, of the Earth around its rotational axis.

(d) Let the asteroid hit the North Pole as shown in Fig.(1).

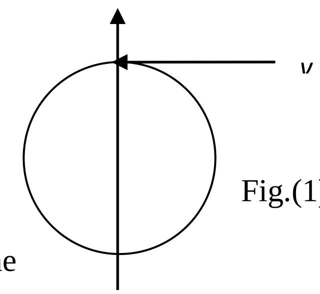


Fig.(1)

(i) Calculate the angular momentum, L_{ast}, of the asteroid relative to the center of the Earth.

(ii) What is the direction of L_{ast} relative to L_E?

(iii) Find the maximum change, $\Delta\theta$, (in radians) in angular orientation of the axis of Earth after the impact. $\left[\tan(\Delta\theta) = \Delta\theta;\ \left(\frac{1}{4.2} = 0.24\right)\right]$

(iv) How far, Δl, does the North Pole moves due to the impact?

(e) Let the asteroid hit the Equator along a radial direction as shown in Fig. (2). Find the change, $\Delta\tau_{rad}$, in the duration of one revolution of Earth after the impact. $\left(\frac{75}{21} = 3.60\right)$

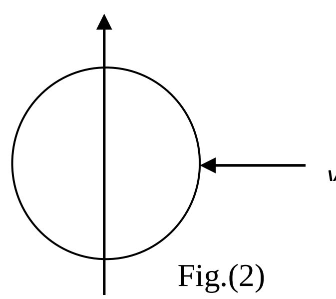


Fig.(2)

ANSWER SHEET

Question 1	Results	Marks
(a)	$\omega_E =$	

(b)	$I_E =$	
(c)	$L_E =$	
(d)(i)	$L_{ast} =$	
(d)(ii)	Underline the correct statement. L_{ast} **is parallel to** L_E L_{ast} **is perpendicular to** L_E	
(d)(iii)	$\Delta\theta =$	
(d)(iv)	$\Delta l =$	
(e)	$\Delta\tau_{rad} =$	

2. **A Floating Soap Bubble**

A spherical soap bubble with internal air density ρ_i, pressure P_i, temperature T_i and radius R_0 is surrounded by air with density ρ_a, atmospheric pressure P_a and temperature T_a. The soap film has surface tension γ, density ρ_s, and thickness t. The mass and the surface tension of the soap flim do not change with the temperature. Assume that $R_0 \gg t$.

(a) Write down an expression for P_i in terms of P_a, γ and R_0.

(b) (i) Assuming that internal and external air behave like ideal gases, derive an expression for the ratio $\frac{\rho_i T_i}{\rho_a T_a}$ in terms of P_a, γ and R_0.

(ii) Find the numerical value of $\frac{\rho_i T_i}{\rho_a T_a} - 1$ [$P_a = 1.0 \times 10^5$ Pa; $\gamma = 2.5 \times 10^{-2}$ N m^{-1}; $R_0 = 1.0$ cm]

(c) The bubble is initially formed with warmer air inside. Derive an expression for T_i in terms of R_0, ρ_a, P_a, T_a, γ, ρ_s, and t, such that the bubble can float in still air.

(d) After the bubble is formed for a while, it will be in thermal equilibrium with the surroundings. Then the radius of the bubble decreases by a small amount and let it be R_1. This bubble in still air will naturally fall towards the ground. Find an expression for the minimum velocity u of an up draught (air flowing upwards) that will keep the bubble from falling at thermal equilibrium. Give your answer in terms of R_1, ρ_a, P_a, γ, ρ_s, g, t and viscosity of air η. You may assume that the velocity u is small such that Stokes's law applies.

ANSWER SHEET

Question 2	**Results**	**Marks**
(a)	$P_i =$	
(b)(i)	$\frac{\rho_i T_i}{\rho_a T_a} =$	
(b)(ii)	$\frac{\rho_i T_i}{\rho_a T_a} - 1 =$	
(c)	$T_i =$	
(d)	$u =$	