SRI LANKAN PHYSICS OLYMPIAD COMPETITION – 2008

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

Date of Examination : 12 – 07 – 2008 Index No. : ....

Time : 9.30 a.m. - 11.30 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. An object has a mass of 10 kg on Earth. The gravitational acceleration on the moon is 1/6 to that on the Earth. What is the object's mass on the moon?

(1) 60 kg (2) 10kg (3)1.67 kg (4) $10\sqrt{6}$ kg (5) $10/\sqrt{6}$ kg

2. A body of mass m has kinetic energy E. The magnitude of its momentum is

(1) $\sqrt{Em}$ (2) $\frac{2E}{\sqrt{m}}$ (3) $\frac{4E^2}{m}$ (4) $2Em$ (5) $\sqrt{2Em}$

3. A box is held at rest by pressing it against a vertical wall. Which of the following is generally true?

(1) It will be easier to hold the box if the surfaces in contact are smooth.

(2) Force required to hold the box is smaller than the weight of the box.

(3) Force required to hold the box is greater than the weight of the box.

(4) Force required to hold the box is equal to the weight of the box.

(5) Force required to hold the box is independent of friction between surfaces in contact.

4. One mole of hydrogen gas and one mole of oxygen gas are at the same temperature. The ratio $\frac{\text{r.m.s velocity of hydrogen molecules}}{\text{r.m.s velocity of oxygen molecules}}$ is equal to

(1) 1:1 (2) 1:4 (3) 4:1 (4) 16:1 (5) 32:1

5. A uniform electric and uniform magnetic fields are setup along the same direction in a certain region. An electron is projected in this region along the same direction as the fields. Which of the following statements is true?

(1) The velocity of the electron will decrease in magnitude.

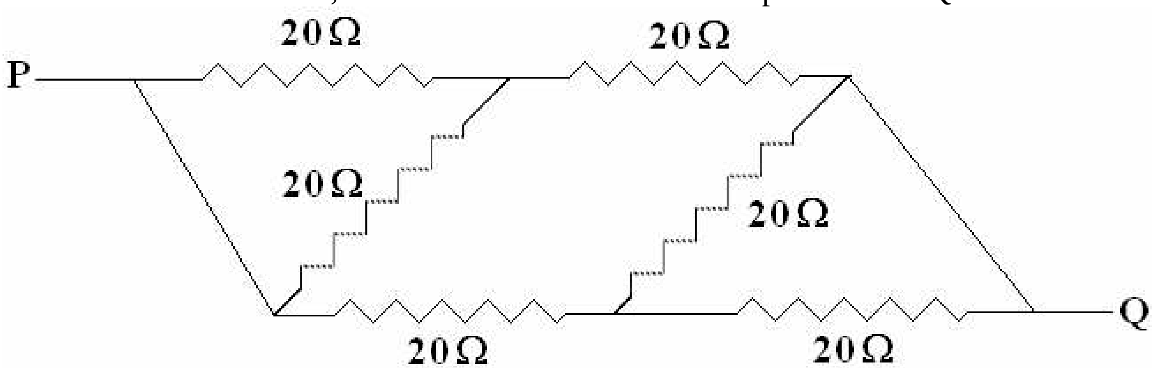
(2) The velocity of the electron will increase in magnitude.

(3) The electron will turn to its right.

(4) The electron will turn to its left.

(5) The electron will travel with the same velocity.

6. For the network shown, the effective resistance between points P and Q is



(1) 15 Ω (2) 40 Ω (3) 60 Ω (4) 80 Ω (5) 100 Ω

7. The speed of sound in a perfect gas is v. The r.m.s. speed of molecules of this gas is c. If $\gamma = \frac{c_p}{c_v}$, then the ratio $\frac{v}{c}$ is equal to

(1) $\frac{3}{\gamma}$ (2) 0.33γ (3) $\sqrt{\frac{3}{\gamma}}$ (4) $\sqrt{\frac{\gamma}{3}}$ (5) $\sqrt{\frac{2\gamma}{3}}$

8. Two factories are sounding their sirens at 800 Hz each. A man walks from one factory towards the other at a speed of 2 m s^{-1}. The velocity of sound is 320 m s^{-1}. The number of beats heard by the person in one second will be

(1) 10 (2) 8 (3) 6 (4) 4 (5) 2

9. Figure shows positions of the image "I" of an object "O" formed by a lens. This is possible if

(1) a convex lens is placed to left of O.

(2) a concave lens is placed to left of O.

(3) a convex lens is placed between O and I.

(4) A concave lens is placed to right of I.

(5) A concave lens is placed in between O and I.

10. A, B, C, and D are points on a vertical straight line such that AB = BC = CD. If a body is released from position A at rest, the time of descent through AB, BC and CD respectively are in the ratio

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

(3) $1 : \sqrt{2}-1 : \sqrt{3}$ (4) $1 : \sqrt{2} : \sqrt{3}-1$

(5) 1: 2: 3

11. When pure distilled water is taken in a clean capillary tube of silver, the surface of water is found to be exactly horizontal. This is because

(1) in a silver container, the surface tension of water becomes zero.

(2) in a silver container, the surface tension of water becomes infinity.

(3) adhesive force between silver and water molecules is zero.

(4) for a molecule of water in contact with silver, the resultant cohesive force due to water molecules is $\sqrt{2}$ times the resultant adhesive force due to atoms of silver.

(5) the angle of contact is zero for water in a silver container.

12. Twelve identical resistances are placed at edges of a cube and are connected in the way as the following figure indicates. If a current *I* is introduced as shown in the figure, what is the current that flows from point A to point B? (negative sign indicates opposite flow direction)

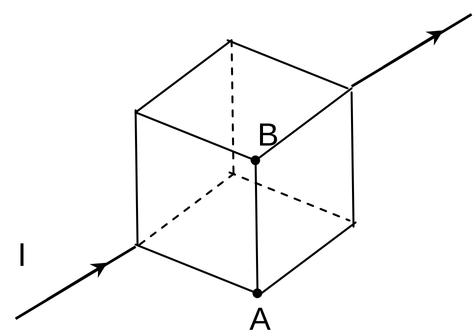
(1) $-I/6$

(2) $-I/3$

(3) $I/6$

(4) $I/3$

(5) $I/12$



13. A 10 g bullet moving on a horizontal straight line at 500 m s^{-1} penetrates a 1.0 kg block moving along the same line at -1 m s^{-1} on a frictionless surface. Right after being penetrated by the bullet, the block moves with a velocity of 2 m s^{-1}. What is the velocity of the bullet right after it emerges from the block?

(1) 100 m s^{-1} (2) 200 m s^{-1} (3) 300 m s^{-1} (4) 400 m s^{-1} (5) 500 m s^{-1}

14. When 0.1 kg of metal A at $52\,°C$ is dropped in 0.3 kg of some liquid B at $10\,°C$, the maximum final temperature is found out to be $16\,°C$. What is the final maximum temperature when 0.2 kg of metal A at $60\,°C$ is dropped in 0.5 kg of liquid B at $12\,°C$? (Assume that there is no heat loss and neglect the heat capacity of the container)

(1) $42\,°C$ (2) $36\,°C$ (3) $28\,°C$ (4) $24\,°C$ (5) $20\,°C$

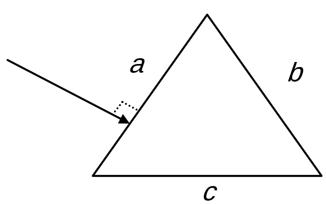
15. The following table shows how the saturated vapour density varies with temperature.

Temperature (°C)	0	4	8	12	16	20	24	28
saturated vapour density (g m^{-3})	3.66	6.33	8.21	10.57	13.70	17.12	21.54	26.93

Suppose that the initial temperature inside a closed room is $28\,°C$ and the relative humidity is 80%. When the temperature inside the room decreases, at what temperature does the dew start to form?

(1) $4\,°C$ (2) $8\,°C$ (3) $12\,°C$ (4) $16\,°C$ (5) $24\,°C$

16. As shown in the following figure, a monochromatic ray of light traveling in the air is incident perpendicular to the side a of an equilateral prism with index of refraction 1.5. Which side will the light ray emerge and what is the angle θ between the incident ray and the emerging ray?



	Emergent side	θ
(1)	b	$\theta = 60^\circ$
(2)	b	$\theta = 30^\circ$
(3)	c	$\theta = 60^\circ$
(4)	c	$\theta = 30^\circ$
(5)	b	$\theta = 120^\circ$

17. A rubber string of length 0.75 m is fixed at one end to the ceiling. It is found that the string extends by 10.0 cm after a small ball of mass 0.10 kg is attached to the other end of the string and reaches equilibrium. Now if the ball is raised to the ceiling and released from rest, what will be the maximum length of the string?

(1) 1.25 m (2) 1.55 m (3) 1.65 m (4) 1.75 m (5) 1.85 m

18. When a single battery is used to power a light bulb, the battery can last for a time t. If two such identical batteries are used to power two such identical light bulbs, which one of the following statements is correct?

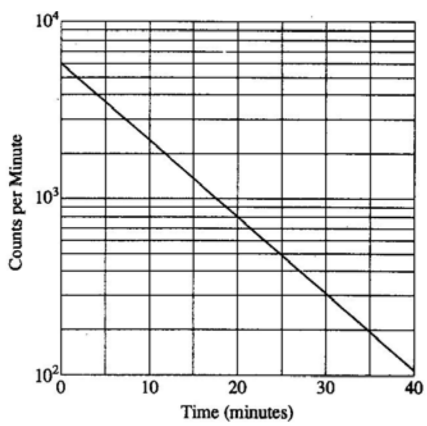
(1) If the batteries are in parallel and the light bulbs are in series, the batteries can power for a time of $t/2$.

(2) If the batteries are in series and the light bulbs are in series, the batteries can power for a time of $2t$.

(3) If the batteries are in parallel and the light bulbs are in parallel, the batteries can power for a time of t.

(4) If the batteries are in series and the light bulbs are in parallel, the batteries can power for a time of $4t$.

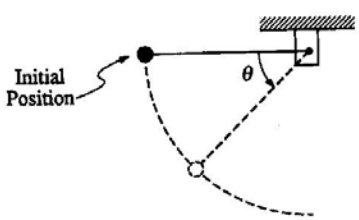
(5) If the batteries are in parallel and the light bulbs are in parallel, the batteries can power for a time of $2t$.

19. 

The graph shows the variation of activity of a decaying radioactive nucleus with time. The vertical axis shows the activity in a log scale. The half life of the nucleus is

(1) 2 min (2) 7 min (3) 11 min

(4) 18 min (5) 20 min

20. 

The figure shows a small mass connected to a inextensible string which is attached freely to a vertical hinge. If the mass is released at rest when the string is horizontal as shown, the magnitude of the total acceleration of the mass varies with θ as

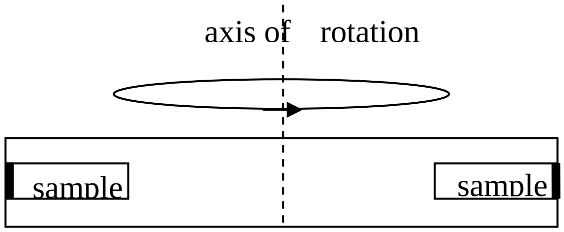
(1) $g\sin\theta$ (2) $2g\cos\theta$ (3) $2g\sin\theta$ (4) $g\sqrt{3\cos^2\theta+1}$

(5) $g\sqrt{3\sin^2\theta+1}$

$$\{\sin^2\theta+\cos^2\theta=1\}$$

PART B

1. As shown schematically in the figure, centrifuges are apparatus in which samples are being rotated rapidly to perform many tasks in biological and medical laboratories. Samples often consist of biological molecules in water.



(i) First consider a test tube filled with water. It is held vertically and stationary and protein molecules are released at rest at the surface of water. Assuming that a protein molecule can be regarded as a sphere with radius R, derive an expression for the terminal speed (v_1), attained by a protein molecule in terms of R, density ρ of proteins, density of water 1.0×10^3 kg m^{-3}, the viscosity η of proteins in water and acceleration g due to gravity.

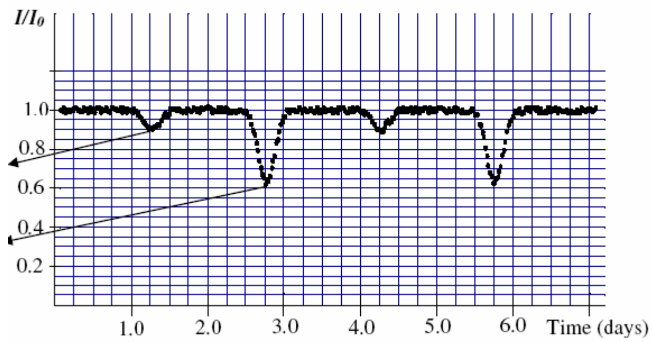
(ii) (a)Now consider the same test tube with protein molecules at the surface of water is placed in the centrifuge. Then the centrifuge is rotated on a horizontal plane with a high angular frequency. Assuming that the centripetal acceleration experienced by protein molecules can be considered as a constant and is 10^5 times g, **draw and label all the horizontal forces** acting on a protein molecule in water relative to the non – inertial (accelerating) frame of reference. (*Hint*: The centrifugal force is acting on a molecule can be considered as a strong gravitational force.)

(b) Hence derive an expression for the terminal speed (v_2), attained by a protein molecule in terms of the relevant parameters mentioned above.

(c) If there are two types of protein molecules A ($\rho_A = 1.3\times10^3$ kg m^{-3}) and B ($\rho_B = 1.6\times10^3$ kg m^{-3}) with the same radius ($R = 3.0\times10^{-6}$ m) present in water, calculate the corresponding terminal speeds v_A and v_B. ($\eta = 6.0\times10^{-3}$ N m^{-2} s)

(d) Hence deduce which protein (A or B) would settle first at the edge of the test tube.

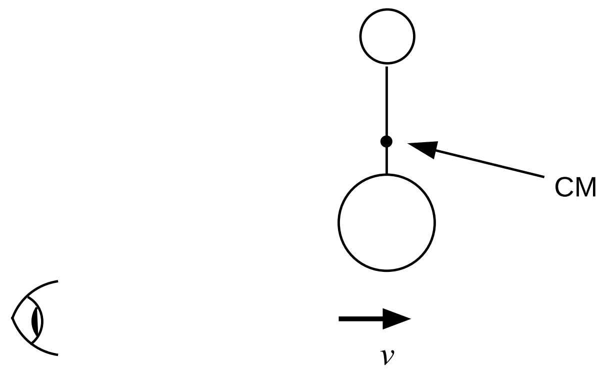
2. Two stars rotating around their center of mass (center of gravity) form a binary star system. Almost half of the stars in our galaxy are binary star systems.
Consider two stars moving on a circular orbit around their common center of mass with a constant angular frequency ω. Assume that we are exactly on the plane of motion of the binary system. If the surface temperatures and the radii of the stars are different, then when one star passes in front of the other, the total intensity of light, measured on earth, show two different minima for each complete rotation. This is plotted in the following figure as a function of time.



(i) By evaluating the time difference between two similar consecutive minima, find the period (T) of the orbital motion of the binary system.
Hence calculate the angular frequency (ω) of the system in **rad s^{-1}**?
(Take $\pi = 3$ and 1 day $= 8.0\times10^4$ s)

(ii) Atoms absorb or emit radiation at certain characteristic wavelengths. Consequently, the observed spectrum of a star contains ***absorption lines*** due to the atoms in the star's atmosphere. Sodium has a characteristic yellow line spectrum (D1 line) with a wavelength $\lambda_0 = 5896$ Å (10 Å = 1 nm). The absorption spectrum of atomic sodium at this wavelength for this binary system could be examined. The spectrum of the light that we receive from the binary star is Doppler-shifted, because the stars are rotating with respect to us. Each star has a different speed. Accordingly the absorption wavelength for each star will be shifted by a different amount. The speed of the center of mass of the binary system in this problem is much smaller than the orbital velocities of the stars. Hence all the Doppler shifts can be attributed to the orbital velocity of the stars.

(a) When one of the stars is moving away from us (look at the following figure) with an orbital velocity v, write down an expression for the measured wavelength λ' of the sodium D1 line observed by a stationary observer on the earth, in terms of λ_0, v, and the velocity of light c. (Since the orbital speeds of the starts are much smaller than the velocity of light, normal Doppler-shift formulae can be used. Use speed of light instead of speed of sound.)



(b) If the measured maximum Doppler-shifted wavelengths for the two stars are $\lambda_1' = 5898\,\overset{0}{\mathrm{A}}$ and $\lambda_2' = 5899\,\overset{0}{\mathrm{A}}$ respectively, calculate the orbital speeds v_1 and v_2 for the two stars. ($c = 3.0\times10^8$ m s^{-1})

(iii) If the masses of the two stars are m_1 and m_2 respectively, find the mass ratio $\frac{m_1}{m_2}$

(iv) If r_1 and r_2 are the distances of each star from their center of mass respectively calculate r_1 and r_2.

(v) Let r be the distance between the starts. Find r.

(vi) Derive expressions for m_1 and m_2 in terms of r, r_1, r_2, v_1, v_2, and G (universal gravitational constant).

ANSWER SHEET FOR PART B

QUESTION NUMBER	**ANSWERS**	**MARKS** (examiner's use)
1 (i)	$v_1 =$	
(ii) (a)	○	
(b)	$v_2 =$	
(c)	$v_A =$	
	$v_B =$	
(d)		

2. (i)	$T =$	
	$\omega =$	
(ii) (a)	$\lambda' =$	
(b)	$v_1 =$	
	$v_2 =$	
(iii)	$\frac{m_1}{m_2} =$	
(iv)	$r_1 =$	
	$r_2 =$	
(v)	$r =$	
(vi)	$m_1 =$	
	$m_2 =$	