Eighteenth Singapore Physics Olympiad
Theoretical Paper

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Organized by

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Instructions to Candidates

1. This is a four-hour test.
2. This paper consists of **EIGHT** (8) questions printed on **Three** (3) printed pages.
3. Attempt all questions. Marks allocated for each part of a question are indicated in the brackets [ ].
4. Write your name legibly on the top right hand corner of every answer sheet you submit.
5. Begin each answer on a fresh sheet of paper.
6. Submit all your working sheets. No paper, whether used or unused, may be taken out of this examination hall.
7. No books or documents relevant to the test may be brought into the examination hall.

1. (a) The average temperature of the sun is 5780 K. The radiative energy from the sun striking a surface perpendicular to the sun's rays at the mean earth-sun distance is called the solar constant. Using the given data, estimate the solar constant. [5]

   (b) A 100 m^2 solar panel is coupled to a flywheel so that it converts the incident light into mechanical energy of rotation with an efficiency of 0.5 % efficiency.

      (i) Assuming the flywheel is a solid cylinder of mass 250 kg and radius 50 cm, what is the angular velocity at the end of 8 hours of exposure to the solar panel if it starts from rest? [4]

      (ii) Suppose the flywheel whose axle is horizontal were suddenly released from its stationary bearings and allowed to roll along a horizontal surface with kinetic friction $\mu = 0.1$, how far will it roll before it stops slipping? [4]

      (iii) What is the speed of the center of mass of the flywheel just before it stops slipping? [3]

      (iv) Determine the amount of heat dissipated as heat. [3]

   Data: $\sigma = 5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$; Radius of the Sun $= 7 \times 10^5$ km; Mean distance between the earth and the sun $= 1.5 \times 10^8$ km;

2. A rubgy player must kicked a ball from a point 36 m from the goal. The crossbar of the goal post is 3 m high. Assuming that the ball leaves the ground with a speed of 20 ms^{-1} at an angle of 53° to the horizontal,

   (i) By how much does the ball clear or fall short of the clearing the crossbar?

   (ii) When the ball crosses the crossbar, is it still rising or is it falling?

   [10]

3. A 15.0 m uniform ladder of mass 50 kg rests against a frictionless wall and making an angle of 60° with the horizontal.

   (i) Determine the horizontal and vertical forces that the ground exerts on the base of the ladder when 800-N fire fighter is 4.00 m from the bottom. [6]

   (ii) If the ladder is just on the verge of slipping when the fire fighter is 9.00 m up, what is the coefficient of the static friction between the ladder and the ground. [6]

4. In a cylinder of an automobile engine just after combustion, the gas is confined to volume of 50.0 cm^3 and has an initial pressure of 3.00×10^6 Pa. The piston moves outwards to a final volume of 300 cm^3 and the gas expands without energy loss by heat.

   (i) If the adiabatic constant $\gamma = 1.40$ for the gas, what is the final pressure? [5]

   (ii) Determine the amount of work done by the gas during the expansion. [5]

5. A small thin disk of radius r and mass m is attached rigidly to the face of a second thin disk of radius R and mass M as shown in Fig. 1. The center of the small disk is located at the edge of the large disk. The large disk is mounted at its center on a frictionless horizontal axle. The assembly is rotated through an angle θ from its equilibrium position and released.

   (i) Find the speed of the center of the small disk as it passes through the equilibrium position in terms of R, r, M, m and acceleration due to free fall, g. [7]

   (ii) Determine the period of small oscillation. in terms of R, r, M, m and g. [7]

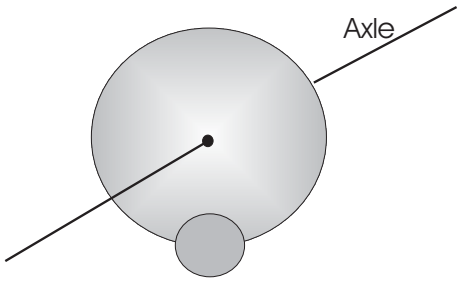

Figure 1: Oscillatory disks

6. An oil film (refractive index $n = 1.45$) floating in water is illuminated by white light at normal incidence. The film is 280 nm thick. Find the

   (i) dominant observed color in the reflected light and

   (ii) dominant color in the transmitted light.

   [10]

7. Two particles with rest masses m_1 and m_2 move collinearly in some inertial frame with uniform velocities u_1 and u_2 respectively. They collide and form a single particle with rest mass m moving at velocity u. Prove that

$$m^2 = m_1^2 + m_2^2 + 2m_1 m_2 \gamma(u_1)\gamma(u_2)\left(1 - \frac{u_1 u_2}{c^2}\right),$$

   where $\gamma(u) = \dfrac{1}{\sqrt{1 - u^2/c^2}}$. Find an expression for u. [14]

8. (a) Two capacitors of capacitances C_1 and C_2 have charges Q_1 and Q_2 respectively Calculate the amount of energy dissipated when they are connected in parallel. How is this energy dissipated? [6]

   (b) The space between the plates of a parallel-plate capacitor with plate separation s and a surface area A is partially filled with a dielectric plate of thickness $t \leq s$ and area A. Show that

$$C = \frac{\epsilon_0 A}{s - t + t/\epsilon_r}$$

   where ϵ_0 and ϵ_r are the permittivity of free space and the relative permittivity respectively. [5]

END OF PAPER

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