32nd Singapore Physics Olympiad Theory Paper 1

Organised by

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Instructions to Candidates

1. This is a 2-hour paper.

2. This paper consists of five (5) questions printed on eleven (11) pages.

3. Attempt all questions.

4. Write your answers in the space provided in the question booklet.

5. You may request working paper from the invigilators.

6. You may not refer to any books or documents relevant to the competition.

NAME:_____ INDEX NO: _____

SCHOOL: _____

GENERAL INFORMATION

Acceleration due to gravity at Earth surface,	$g = 9.81 \text{ m s}^{-2}$
Stefan-Boltzmann constant,	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Speed of light in vacuum,	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
Charge of electron,	$e = 1.60 \times 10^{-19} \text{ C}$
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
Mass of electron,	$m_e = 9.11 \times 10^{-31} \, kg$
Mass of proton,	$m_p = 1.67 \times 10^{-27} \, kg$

1.	(a)	A projectile is fired with initial velocity v_0 and at an angle θ with the horizontal. It passes through two points, both a distance h above the horizontal. Derive an expression for the horizontal separation, D of the two points.	[7 marks]

1.   (b)   If the projectile is fired with initial velocity 200 ms^{-1}, and the angle of the barrel of the gun with the horizontal is adjusted for maximum range, calculate the value of D.

[3 marks]

2.   (a)   A mass of 0.25 kg is attached to an unstretched spring that has a force constant of 20 Nm^{-1}. The mass is released and oscillates with ever decreasing amplitude and eventually comes to rest. The process is irreversible. Assume that the temperature of the surrounding remains constant at 27°C, calculate the entropy change of the surroundings.   [4 marks]

2.   (b)   (i)   The intensity of sunlight reaching the surface of the Earth facing the Sun is 1.37×10^3 Wm^{-2}. The radius of the Sun is 6.957×10^5 km. The radius of the orbit of the Earth round the Sun is 1.496×10^8 km. Estimate the surface temperature of the Sun.

       (ii)   The radius of the orbit of Mars round the sun is 2.280×10^8 km. Estimate the equilibrium temperature   [6 marks]

3.   (a)   A particle of mass 0.1 kg is oscillating in simple harmonic motion about a point O. The force acting on the particle during the motion is given by $F = -10x$ (N) where x is the displacement of the particle from O. The motion begins with the particle at a displacement of 0.05 m from O and moves with a velocity of $\sqrt{3}/2$ ms^{-1} away from O. Calculate

(i)   the amplitude of the motion.

(ii)   the initial phase angle.

(iii)   the maximum speed and maximum acceleration of the particle.   [4 marks]

3. (b) A rod with a uniform cross-section and length L floats vertically in a liquid with a length h projecting above the surface of the liquid. Show that it executes simple harmonic motion when given a small displacement and find an expression for the period of the motion. [6 marks]

4. (a) The electric potential at the surface of a spherical oil drop is 1000V. If two such drops of equal charge and radius unite to form a single spherical drop, what is the electric potential at the surface of the resulting drop? (Assume no charge is lost when the two drops unite). [5 marks]

4.   (b)   In a helium dilution refrigerator, ^3He and ^4He are mixed in a special chamber to obtain extremely low temperatures. A Bainbridge mass spectrometer is used to measure the ratio of the two isotopes.

(i)   If the spectrometer were used with $100\ \text{Vcm}^{-1}$ between the plates and a magnetic field of 0.2 T, what would be the speed of an ion that can pass through the velocity filter?

(ii)   If the velocity filter exit slit were 1 mm wide, can this machine resolve the two isotopes?   [5 marks]

5.   (a)   A beam of monochromatic light of intensity 50 Wm^{-2} is incident normally onto a perfectly reflecting surface. Determine the pressure exerted on that surface by the incident radiation.   [5 marks]

5. (b) Positronium is a hydrogen-like system with the proton replaced by a positron. The positron has the same mass as an electron but carries a positive charge of the same magnitude as electron. Calculate the shortest wavelength of the Lyman series in the positronium.   [5 marks]