35th Singapore Physics Olympiad Theory Paper 1 With Answers

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 twelve (12) pages.
   The second page is a General Information Sheet.
3. Attempt all questions. Write your index number on the top of all pages submitted.
4. Write your answers in the space provided in the question booklet. Full working must be shown. Correct answer without proper working will **NOT** be awarded marks.
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: _____

For Examiner's Use

Question No.	Marks Awarded
1	**/ 10**
2	**/ 10**
3	**/ 11**
4	**/ 9**
5	**/ 10**
Total	**/ 50**

GENERAL INFORMATION SHEET

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 particle is projected with speed u up a smooth inclined plane with inclination of $30°$ to the horizontal. It travels for 50 m along a line of greatest slope before reaching the top of the inclined plane. After leaving the inclined plane, it travels in a curved path before hitting a target which is at the same horizontal level as the base of the inclined plane and at a distance 153.3 m from the vertical face of the inclined plane. Calculate the value of u.

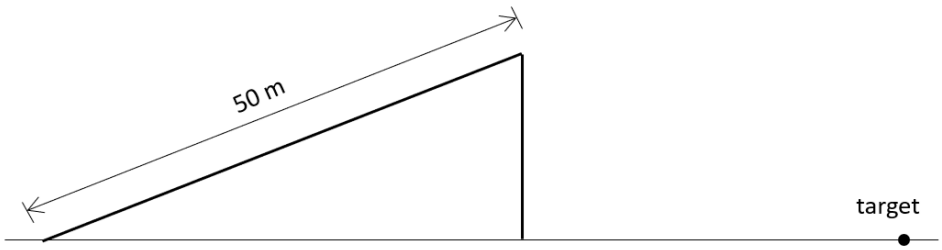
[5 marks]

[$u = 43$ ms^{-1}]

1. (b) Consider the case where the surface of the inclined plane is not smooth. The coefficient of kinetic friction between the particle and the inclined plane is 0.25. What **percentage change** in the value of u will make the particle strike the target again after leaving the top of the inclined plane?

[5 marks]

[5.46%]



2. (a) Due to tidal motion, the depth of sea water around a particular harbour varies from 20 m at 12 noon to 30 m at 6.00 pm and then back to 20 m again at 12 midnight. To stay in the harbour, a ship requires a sea water depth of 22.5 m. The ship sails near the harbor around noon. From what time to what time can the ship stay in the harbor?

State any assumption in your calculation.

[6 marks]

[2 pm to 10 pm]

2. (b) (i) A stationary sound source emits sound waves of frequency 256 Hz. The sound waves hit an object moving directly away from the sound source and are reflected back to the source. A beat of frequency 7 Hz is detected between the emitted waves and the reflected waves. Given that the speed of the sound waves emitted is 340 ms^{-1}, what is the speed of the moving object?

[9.6 ms^{-1}]

(ii) Suppose the sound source now starts to move with a constant speed of 5.0 ms^{-1} towards the moving object [still moving with the same speed as in part(i)]. What will be the beat frequency between the emitted waves and the reflected waves?

[3.4 Hz]

[4 marks]

3. A ring of radius 50 cm has a uniform linear charge density of $+10\ \text{nC m}^{-1}$. A small charged object having mass 1 mg and carrying charge of $-5.0\ \text{nC}$ is initially at a point on the axis of the ring and at a distance of 5.0 mm from the centre of the ring.

(a) How long does the object take to reach the centre of the ring for the first time?

[8 marks]

[0.467 s]

(b) What is the kinetic energy of the charged object when it is at the centre of the ring?

[3 marks]

[1.412×10^{-10} J]

[For a uniformly charged ring with radius R, and carrying a total charge of $+Q$, the electric field on the axial point, at a distance x from the centre of the ring is $\vec{E} = \frac{Q}{4\pi\varepsilon_0} \frac{x}{\left(R^2 + x^2\right)^{\frac{3}{2}}} \hat{i}$ where $\hat{i}$ is a unit vector along the axis of the ring and pointing away from the centre of the ring].

4. (a) A well-lagged uniform cylindrical rod is 20.0 cm long and has a diameter of 2.00 cm. One end of it is in thermal contact with a hot reservoir maintained at a temperature of $150°C$ while the other end is in thermal contact with a very large block of ice at temperature $0°C$.

(i) It is found that the ice block is melting at a rate of $0.1683 \text{ kg min}^{-1}$. What is the thermal conductivity of the material of the rod?

[400 W m^{-1} K^{-1}]

(ii) Calculate the rate of change of the entropy of the system comprising the hot and cold reservoirs and the rod.

[0.1224 J K^{-1}]

[5 marks]

[Latent heat of fusion of ice $= 3.36 \times 10^4 \text{ J kg}^{-1}$]

4. (b) A spherical blackbody has a diameter of 10.0 m and is placed in an environment with constant temperature of $27.0\,°C$. A **parallel beam** of thermal radiation having intensity 2400 Wm^{-2} is incident onto the blackbody continuously. What is the final equilibrium temperature of the blackbody?

[4 marks]

[369.7 K]

5. In a photoelectric experiment, monochromatic ultraviolet light of wavelength 60 nm and intensity 0.7 ~~m~~W m^{-2} is incident onto a cathode which has a surface area of 10 cm^2. It is found that the photoelectric current decreases to zero when the anode has a **negative** potential of 4.25 V with respect to the cathode. When the anode is at a positive potential with respect to the cathode, the saturation photoelectric current is 21.7 ~~m~~μA.

(a) Calculate the linear momentum of the photoelectrons which are emitted with the maximum kinetic energy.

[3 marks]

[1.114×10^{-24} Ns]

(b) What is the ratio of $\frac{N_e}{N_p}$ where N_e & N_p are the rate of emission of photoelectrons and number of photon incident onto the cathode per second?

[3 marks]

[0.6415]

(c) One of the electrons with maximum kinetic energy makes a collision with a hydrogen atom which is in the ground state. What are the possible wavelengths of the photon emitted when the hydrogen atom de-excite?

[4 marks]

[Show that the energy of the electron is not sufficient to excite the hydrogen atom from ground sate to the first excited state. Hence, no emission of spectral lines is possible.]

[The energy of hydrogen atom in the stationary states with principal quantum number n is $-\frac{13.6}{n^2}$ eV.]

Note: Responses were graded based on erroneous values given in the original question. Corrections are in RED.