31st Singapore Physics Olympiad
Theory Paper 1

Organised by

Institute of Physics Singapore

In conjunction with
National Institute of Education Singapore, Nanyang Technological University Singapore

National University of Singapore

Ministry of Education Singapore

And sponsored by
Micron Technology Foundation, Inc

Instructions to Candidates

1. This is a 2 hour paper.
2. This paper consists of five (5) questions printed on nine (9) 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:_____

SCHOOL: _____

1. A particle X is projected with speed V in a direction which makes an angle of $30°$ from the horizontal. When this particle reaches the highest point of its trajectory, another particle Y is dropped from the roof of a tall building. The two particles collide at the base of the building. The particle Y takes a time of 0.17 s to fall pass a 5.0 m tall window in the building. The base of the window is 50.0 m above the ground. Ignoring the effect of air resistance, find

(a) the height of the building [4 marks]

(b) the value of V [4 marks]

(c) the distance of the point of projection of X from the foot of the building. [2 marks]

2. (a) A horizontal platform vibrates with simple harmonic motion in the horizontal direction with a period of 2.0 s. A small object placed on the platform starts to slide when the amplitude of vibration reaches 0.4m. Calculate the coefficient of static friction between the object and the platform. [5 marks]

(b) The platform now executes vertical simple harmonic motion with a period of 1.5 s. What is the maximum amplitude of the motion if the object were to be in contact with the plate throughout the motion? [5 marks]

3. Consider a gas with molecules of mass m in a constant gravitational field $\vec{g}$.

(a) Write down an equation relating a small change in pressure ΔP over a small change in height Δz . [1 mark]

(b) Show that, if the temperature T is constant, the pressure of a gas, (z) , in a uniform gravitational field decreases with height, z according to the expression $P(z) = P(0)e^{-\frac{mgz}{kT}}$. [9 marks]

4. A copper wire with mass m is stretched between two fixed points, distance l apart and a tension, F_T is applied to it. When the copper wire is vibrating in the fundamental mode together with a 256-Hz tuning fork, a beat of frequency 5 Hz is observed. The copper wire is removed and a brass (which is an alloy made of copper and zinc) wire, with the same length and diameter, is stretched between the same two fixed points. The same tension is again applied to the brass wire. It is found that in this case, the brass wire, vibrating in the fundamental mode, resonates with the 256-Hz tuning fork when the two are vibrated together.

[Densities: copper: 8940 kg m^{-3}; zinc : 7140 kg m^{-3}]

(a) State an equation for the speed of the wave on the string in terms of m, l and F_T only. [1 mark]

(b) Determine the percentage by mass of zinc in the brass wire. State any assumptions you make in your calculation. [9 marks]

5. A 5.00ml solution was injected into the bloodstream of a patient. The solution contains radioactive iodine ^{131}I with a half-life of 8.025 days at a concentration of $1.00 \times 10^{-10}\text{kgm}^{-3}$. The activity of a 5.00 ml blood sample taken 24 hours later is found to be 3171 counts in 30 minutes.

(a) Calculate the decay constant for ^{131}I. [1 mark]

(b) Calculate the total volume of blood in the patient's body given by these results. State any assumptions you make in your calculation. [9 marks]

End of Paper