The Open University of Sri Lanka
B.Sc. Degree Programme – Level 03
Final Examination – 2009/2010
Waves in Physics
PYU 1162 / PYE 3162

Duration: Two Hours (2 Hrs.)

Date: 07.07.2010 **Time: 09.30 am *to* 11.30 am**

Useful physical constants

Speed of sound in air = 340 m s^{-1}

Speed of electromagnetic waves is = 3×10^8 m s^{-1}

Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}

ANSWER FOUR QUESTIONS ONLY

1. (a) Write down an expression for the displacement of a particle, executing simple harmonic motion, as a function of time *t*. Define the physical quantities used in your equation.

   (b) One end of a light spring with force constant *k* is attached to a rigid ceiling and hangs vertically. A mass *m* is fixed to the lower end of the spring. Prove that when displaced vertically and released, the mass executes simple harmonic motion of period,

   $$T = 2\pi\sqrt{\frac{m}{k}}$$

   (c) A spring of length 30 cm is hung vertically with its upper end attached to a rigid ceiling. When a mass of 150 g is attached to the lower end of the spring, length increases to 35.5 cm. The mass is further pulled down by 3 cm and released from rest, so that it oscillates about equilibrium. Find,
   (i) the spring constant of the spring.
   (ii) the time period of oscillations of the mass.
   (iii) the maximum speed of the mass.

2. An object of mass 0.2 kg is hung from a spring whose spring constant is 80 N m^{-1}. The object is subject to a resistive force given by $-bv$, where v is its velocity.

   (a) Establish the differential equation of motion for free oscillations of the system.

   (b) If the damped frequency is 0.995 of the undamped frequency, what is the value of the constant b?

   (c) What is the Q value of the system, and by what factor is the amplitude of the oscillation reduced after 4 complete cycles?

   (d) Which fraction of the original energy is left after 4 oscillations?

3. (a) Explain briefly what is meant by the Doppler Effect in sound. State at least three applications of it.

   (b) Derive an expression for the observed frequency, f_o, when a source emitting a sound at frequency, f_s, is moving with a velocity v_s towards a stationary observer hearing that sound.

   (c) (i) Write down a general expression for the observed frequency, f_o, when the source and the observer are moving with the velocities v_s and v_o respectively.

   (ii) Two trains on separate tracks approach each other, with train A has a speed of 90 km h^{-1} and train B has a speed of 126 km h^{-1}. Train A blows its horn at a frequency of 500 Hz. What is the frequency heard by the driver of the train B?

4. (a) Show that the intensity, I, of sound can be expressed as,

$$I = \frac{1}{2}\rho v_s \omega^2 x_m^2$$

   where, ρ is density of the medium and v_s, ω, and x_m are velocity, angular frequency and amplitude of sound waves respectively.

   (b) Describe the intensity level of sound in terms of decibel scale.

   (c) Derive an expression for the difference in sound levels of two sound waves with intensities I_1 and I_2 and use this expression to find the intensity of sound whose intensity of sound level is 140 dB higher than the threshold of hearing of 1×10^{-12} W m^{-2}.

5. (a) Would an inductor and a capacitor used together in an AC circuit dissipate any energy? Explain briefly.

   (b) The electric field and magnetic field components of a plane electromagnetic wave can be expressed as, $\boldsymbol{E}(\boldsymbol{x},\boldsymbol{t}) = \boldsymbol{E_m}\sin(kx - \omega t)$ and $\boldsymbol{B}(\boldsymbol{x},\boldsymbol{t}) = \boldsymbol{B_m}\sin(kx - \omega t)$ respectively. Show that *E (x, t)* and *B (x, t)* satisfy the wave equations,

   $$\frac{\partial^2 E}{\partial t^2} = c^2\,\frac{\partial^2 E}{\partial x^2}$$

   and

   $$\frac{\partial^2 B}{\partial t^2} = c^2\,\frac{\partial^2 B}{\partial x^2}$$ respectively.

   (Symbols have their usual meanings).

6. (a) The intensity, *I*, of plane electromagnetic waves is defined as the average power transmitted by it per unit area. Derive an expression for *I* in terms of amplitude of the electric field component.

   (b) Establish expressions for the force *F* exerted by electromagnetic waves of intensity *I* on a flat surface area *A,* when (i) the waves are completely absorbed by the surface and (ii) the waves are completely reflected back, along its original path, by the surface.

   (c) Earth receives 1300 watts per square meter of solar energy. Assuming the energy to be in the form of plane electromagnetic waves, compute the magnitude of the electric field strength in the sunlight.

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