MACHAKOS UNIVERSITY

University Examinations 2020/2021

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FIRST YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SPH 102: WAVES AND OPTICS

DATE: 21/6/2021 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

Useful Equation:

$$\sin\alpha + \sin\beta = 2\sin\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$$

Answer QUESTION ONE (Compulsory) and any other TWO QUESTIONS

QUESTION ONE (30 MARKS)

a) Define the following terms as used in the superposition of waves

i. Resonance (2 marks)

ii. Beat (2 marks)

b) State three characteristics of sound or a note. (3 marks)

c) State two defects of the eye and explain with an aid of a diagram how each can be corrected. (6 marks)

d) Distinguish between;

(i) Traveling and standing waves (2 marks)

(ii) Diffraction and interference (2 marks)

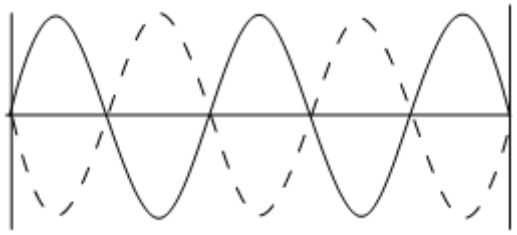
e) Show that the equation $y = A(x + vt)^2$ represents a traveling wave (5 marks)

f) Light from a distant galaxy shows the characteristic lines of oxygen spectrum, except that the wavelengths are shifted from their values as measured using laboratory sources. In particular, the line expected at 513 nm shows up at 525 nm. What is the speed of the galaxy relative to the earth? (Assuming v << c) (4 marks)

g) A concave mirror forms an image on a screen twice as large as the object. Both object and screen are then moved to produce an image on the screen that is three times the size of the object. If the screen is moved 75 cm in the process, how far is the object moved? What is the focal length of the mirror? (4 marks)

QUESTION TWO (20 MARKS)

a) The figure below shows a stationary wave on a tight string of length 30 cm.



The string oscillates at a frequency of 1500 Hz

i. Calculate the speed of the wave in the string (3 marks)

ii. Explain what happens to the speed of the wave if the length of the string is tripled (2 marks)

b) A string under tension produces sound waves when plucked. State three factors that determine the frequency of the emitted note. (3 marks)

c) A tuning fork of frequency 440 Hz is sounded at the top of a tube initially filled with water, which is allowed to run out slowly, and the position of resonance noted. Calculate the length of the air column corresponding to the first overtone assuming negligible errors. (Take speed of sound in air as 330 m/s) (4 marks)

d) Given that the speed of sound in air is 330 m/s, calculate the frequency of the fundamental and first three overtones of an organ pipe 3 m long when the tube operates as a closed pipe. (8 marks)

QUESTION THREE (20 MARKS)

a) Define lateral magnification (2 marks)

b) By applying the Fermat's principle to refraction, derive the Snell's Law (6 marks)

c) An object 3 cm high is placed 20 cm from (a) a convex and (b) a concave spherical mirror, each of 10 cm focal length. Determine the position and nature of the image in each case. (6 marks)

d) A double convex lens has a diameter of 5 cm and zero thickness at its edges. A point object on an axis through the center of the lens produces a real image on the opposite side. Both object and image distances are 30 cm, measured from a plane bisecting the lens. The lens has a refractive index of 1.52. Using the equivalence of optical paths through the center and edge of the lens, determine the thickness of the lens at its center. (6 marks)

QUESTION FOUR (20 MARKS)

a) State the Huygens' Principle (2 marks)

b) Write the equation of a harmonic wave traveling along the *x*-direction at $t = 0$ if it has amplitude of 5 m and a wavelength of 50 m. (2 marks)

c) Write an expression for the disturbance of the wave in (a) above at $t = 4\,s$ if it is moving in the negative *x*-direction at 2 m/s. (2 marks)

d) To test for resonance effects one student stands at each end of a flexible bridge and jumps up and down sending pulses along the bridge. These pulses form two identical transverse waves travelling along the bridge towards each other. Each wave has amplitude of 1.5 mm and a wavelength of 6.0 cm. The speed of the waves is 1.5 ms^{-1}.

i) Write the equation for each of the travelling waves. (4 marks)

ii) Describe the waveform that results from the superposition of the two travelling waves. (2 marks)

iii) Write the equation for the superposed resultant wave. (4 marks)

iv) Plot the shape of the bridge at times t = 0 (arbitrary), t = 5, t = 10, t = 15, and t = 20 ms. (4 marks)

QUESTION FIVE (20 MARKS)

a) State the **two** factors which determines the intensity of a wave (2 marks)

b) Describe the Doppler's Effect (2 marks)

c) Distinguish between

i. Classical and Relativistic Doppler effect (2 marks)

ii. Ultrasonic and infrasonic frequencies as used in waves (2 marks)

d) Show that $\frac{\lambda}{\lambda_o} = 1 - \frac{u}{c}$ for the Doppler Effect follows from $\lambda = \lambda_o \left[\frac{1-\frac{u}{c}}{1+\frac{u}{c}}\right]^{\frac{1}{2}}$ when $u << c$ (3 marks)

e) Calculate the speed at which one would approach a red traffic light to see a green signal? (Take the wavelength of red as 640 nm and a green as 540 nm.) (3 marks)

f) Laser light passes through two identical parallel slits, 0.2 mm apart. Interference fringes are seen on a screen 1 m away with the Interference maxima separated by 3.29 mm.

i. Calculate the wavelength of the light? (3 marks)

ii. Describe how the intensity at the screen vary, if the contribution of each slit alone is I_0? (3 marks)