FACULTY	:	AGRICULTURE, ENGINEERING & NATURAL SCIENCES			
SCHOOL	:	SCIENCE			
DEPARTMENT	:	PHYSICS, CHEMISTRY & MATERIAL SCIENCE			
MODULE	:	Waves & Optics			
MODULE CODE	:	S3611PW			
DATE	:	··· June 2026	**TIME**	:	···
DURATION	:	3 hours	**FULL MARKS**	:	100

FIRST OPPORTUNITY EXAMINATION

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This question paper consists of **3** pages of **10** questions (excluding this front page).

INSTRUCTIONS:

- Answer **all** the questions.
- *Vector notation* is crucial: *typed vectors* are shown in bold here. Please indicate all handwritten vectors with arrows (or hats for unit vectors) above the symbol.
- Demonstrate your understanding by *showing all your work*, including diagrams where applicable.
- Take care to use coherent mathematical notation. You shall be penalized if you fail to do this.
- Calculators (preferably *scientific*) may be used.

UNIVERSITY OF NAMIBIA EXAMINATIONS

Section A — Waves

Question 1 ..... Total: 5

Assuming that we have a *three-dimensional* wave function $\psi(x, y, z, t)$, write down the corresponding *wave equation* using $\Box^2$ (the *d'Alembertian operator*).

Question 2 ..... Total: 5

How fast will waves travel in a one-meter taut string that "weighs" 100 grams if the tension in the string is 5.0 N?

Question 3 ..... Total: 10

In a mathematical sense, a *wave* is a function that moves over time t, position x and may in a special *monochromatic* case, be of the form (in 1D)

$$\tfrac{1}{10}\sin\left(2\pi t - \tfrac{4\pi}{10}x\right)$$

where all physical quantities therein takes the usual SI-units.

Hint: Think of the simple wave with trigonometric arguments $kx - \omega t + \delta$.

(a) What are the numerical values of the *wave number*, the *angular frequency*, and the amplitude of the given wave? (3)

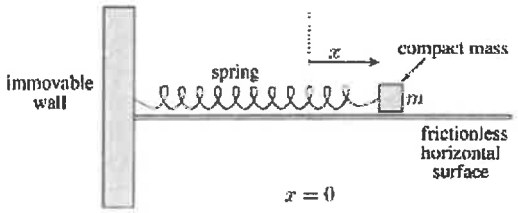
(b) Calculate the *speed* at which this wave propagates. (7)

Question 4 ..... Total: 10

A classic example of a Simple Harmonic Oscillator (SHO) is a oscillating mass m attached to a spring on a frictionless surface. Using Newton's Second Law we derived the Ordinary Differential Equation (ODE)

$$\ddot{x} + 4x = 0$$

that the system obeys, where all quantities herein are in SI-units.



It is further noticed that, initially, i.e. at $t = 0$, the particle is at position $x = \sqrt{3}$ units when it is projected towards the origin with speed $\dot{x} = -2$ units. Show that the *general solution* for the *displacement* of m from the equilibrium at time t is given by

$$x(t) = \sqrt{3}\cos 2t - \sin 2t$$

and show also that the *velocity* of m at time t is

$$\dot{x}(t) = -\left[2\sqrt{3}\cos 2t + \sin 2t\right]$$

Question 5 ..... Total: 10

Given the *Equation of Motion* (EoM) of a system that undergoes a linear oscillation is the second-order inhomogeneous linear differential equation

$$\ddot{x} + 2K\dot{x} + \Omega^2 x = F$$

where K is the *damping constant* and Ω is associated with the *natural frequency*. Reduce this problem to the *ideal / classical* case (undamped and undriven) such that the *solution* of the resulting reduced homogeneous problem is of the form

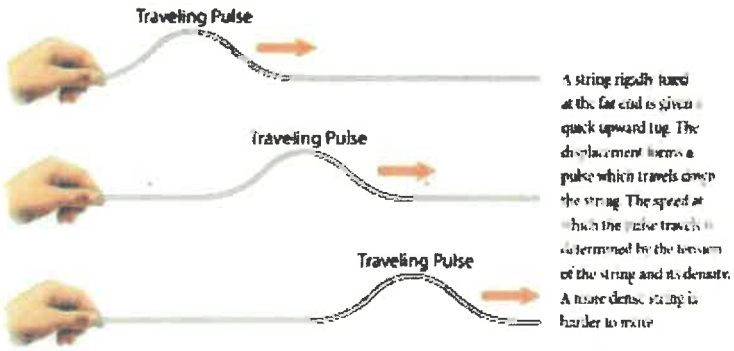
$$x = e^{\lambda t}$$

Now find the two possible values of λ.

Question 6 ..... Total: 10

We know that one-dimensional waves travelling in a string (of linear mass density μ) and tension T obey the celebrated *wave equation*

$$v^2 \frac{\partial^2 \psi}{\partial x^2} = \frac{\partial^2 \psi}{\partial t^2}$$



It is further known that this wave equation is satisfied by the *solution* (wave function) given by

$$\psi(x,t) = A\cos(kx - \omega t)$$

Now using the above two equations show that the *speed* of the wave pulses is

$$v = \frac{\omega}{k}$$

Section B

Question 7 ..... Total: 10

Define the following concepts and principles briefly by proving a *short* but *concise* formal statement. If a mathematical equation is associated with the definition you are providing, then provide such an equation.

(a) The refractive index of a medium, (2)

(b) The Law of Reflection, (2)

(c) The Lens Formula, (2)

(d) Interference, and (2)

(e) The Laser, (2)

Question 8 ..... Total: 20

An object with a height of 4 cm is positioned at a distance of $u = 3f$ from a *convex mirror* with a radius of curvature R.

(a) What is the mathematical expression relating the focal length f of a spherical mirror to its radius of curvature R? (2)

(b) Using the *mirror formula* find symbolically the image distance v in terms of f in this scenario. (5)

(c) If after careful measurements, it is established that the *focal length* f of this convex mirror is 100 cm and the *image* is formed at a distance $v = 150$ cm, determine the *object distance* u using the *mirror equation.* (4)

(d) Calculate the magnification m and explain what the value you obtain implies. (3)

(e) Discuss the *nature* of the image formed with this *convex mirror.* (3)

(f) On the otherhand, list at least three *real-life applications* of *concave* mirrors and explain the principle behind each. (3)

Question 9 ..... Total: 10

Determine the *focal lengths* of *two lenses* that satisfy the *achromatic condition* when in contact, given that the *combined (equivalent) focal length* of the system is $F = 50$ cm. The *dispersive powers* of the materials of the two lenses are $\omega_1 = 0.0154$ and $\omega_2 = 0.0306$, respectively.

Question 10 ..... Total: 10

Describe the phenomenon of *dispersion of light* and explain how it leads to the *formation* of a rainbow.

Total marks: 100