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# Semiconductor elastic medium with electromagnetic porosity, photothermal excitation, and the Thomson effect

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The Thomson influence on semiconductors can be studied by investigating the connection between the presence of thermoelectric and magnetic fields and porosity and the photothermal transport mechanism. Elastic waves, voids, magnetic fields, and thermoelectric effects in plasma are investigated. The governing equations were analyzed for a uniformly distributed and isotropic medium under two-dimensional [electronic and elastic (plasmaelastic)] deformations. The charge density is considered solely dependent on the induced electric current over time. The Laplace-Fourier transforms method in two dimensions is employed to obtain solutions for the primary variables. The recombination process results in the application of electro-mechanical loads and thermal effects on the free surface of a porous medium. The Laplace-Fourier transformations inversion operations help obtain comprehensive solutions in this study. The effects of porosity parameters and silicon (Si) on a semiconductor porous material are considered, and the resulting physical field distributions are analyzed and represented graphically.

## KEYWORDS

plasmaelastic, semiconductor, Thomson effect, magnetic field, porosity, fourier transform

## Introduction

The absorption of light by a substance and its subsequent conversion to heat, resulting in thermal expansion or contraction, is known as the photothermal effect. When elastic qualities like stress or strain alter in response to light or heat, we call that material a photothermal elastic media. The principles of photothermal effects and elasticity can be used to explain the behavior of a photothermal elastic media. Photothermal elastic media have been intensively explored in the realm of photonics, particularly in the construction of tunable photonic devices. Applications where the properties of the photothermal elastic media must be regulated include optical switches, filters, sensors, robotics, aerospace, and biomedical engineering. There are a variety of uses for photothermal elastic media. Materials

scientists and engineers, for instance, can use these materials to create structures with malleable mechanical properties. When light is absorbed by a photothermal elastic media, the energy is transformed into heat. The mechanical properties of a material, such as its elasticity parameters Young's modulus, and Poisson's ratio, are affected by thermal expansion as a result of temperature changes. Applications involving altered stress or strain are possible. Photothermal stimulation of semiconductor materials has received a lot of attention in recent years due to the potential impact on those materials' thermo-mechanical properties. Engineering, petroleum, aviation, electronics, and photovoltaics are just a few of the many fields that benefit greatly from semiconductors. Deformations and strains in semiconductors, for example, are thought to be strongly influenced by temperature, according to current physics ideas. This is especially the case when the semiconductor medium is subjected to a wide range of temperatures. Photothermal excitation processes with refined multi-dual phase-lags theory for semiconductor elastic medium are studied by Khamis et al. [1]. Ailawalia et al. [2] produced ramp-type heating in a semiconductor medium under photothermal theory.

The elasticity of a substance is its capacity to stretch and then recover its original form after being stretched or compressed. The vibrations and collisions of particles in the internal medium generate heat, which in turn causes the material to deform. Free electrons and plasma waves are produced when a laser beam is shone on the surface of a semiconductor material. In light of this, investigating how thermal waves, plasma waves, and elastic materials interact is essential. The mechanical, electric, and thermal properties of semiconductor materials change with temperature variations. When a temperature gradient arises in a semiconductor elastic material due to light absorption, it causes an electric potential difference between the endpoints. In such cases, the relationship between heat production and electrical resistance needs to be examined. Hobiny and Abbas [3] described a GL photo-thermal theory on new hyperbolic two-temperature in a semiconductor material. Abbas et al. [4] introduced Photo-thermal interactions in a semi-conductor material with cylindrical cavities and variable thermal conductivity. Alshehri and Lotfy [5] produced memory-dependent derivatives (MDD) for magneto-thermal-plasma semiconductor medium induced by laser pulses with hyperbolic two temperature theory. Lotfy and El-Bary [6] studied magnetic-thermal-elastic waves under the impact of induced laser pulses and hyperbolic two-temperature theory with memory-dependent derivatives (MDD). Magneto-photo-thermo-microstretch semiconductor elastic medium due to the photothermal transport process is discussed by Lotfy and El-Bary [7]. Aldwoah et al. [8] produced a novel magneto-photo-elasto-thermodiffusion electrons-holes model of an excited semiconductor.

Porosity is a material feature that characterizes the presence of internal voids. The ability to absorb or hold liquids or gases is sometimes indicated by this term. Porosity can occur for many reasons depending on the material. Dissolved minerals or the absence of fossils can leave behind voids, which geologists refer to as porosity. In construction materials, porosity can be deliberate, such as in lightweight concrete or aerated blocks, or inadvertent due to poor fabrication procedures or inadequate compaction. Many facets of human existence depend on porosity. The porosity of rock formations is crucial, for instance, in the oil and gas business, for

assessing the viability of energy extraction. Porosity is an important material attribute because it influences the material's physical, chemical, and mechanical properties. Benefits in technology, energy production, building, and healthcare are just some of the areas that could result from a better understanding of and ability to manipulate porosity. Raddadi et al. [9] studied a novel model of a semiconductor porosity medium according to photo-thermoelasticity excitation with initial stress. Bouslimi et al. [10] produced a mathematical model of photothermal and voids in a semiconductor medium in the context of Lord-Shulman theory. Kilany et al. [11] introduced the photothermal and void effect of a semiconductor rotational medium based on Lord-Shulman theory. Bayones et al. [12] discussed a rotational gravitational stress and voids effect on an electromagnetic photothermal semiconductor medium under three models of thermoelasticity. Khalil et al. [13] studied electromagnetic field and initial stress on a photothermal semiconducting void medium under thermoelasticity theories. Jawa et al. [14] produced machine learning and statistical methods for studying voids and photothermal effects of a semiconductor rotational medium with thermal relaxation time.

The creation of heat or cooling at the junction of two different conductive materials caused by an electric current passing through them is referred to as the Thomson effect. Lord Kelvin (then known as William Thomson) made the discovery. The connection can be heated by the Thomson effect or cooled by it. The Thomson effect is strongly linked to the thermalization of semiconducting materials upon their absorption of electromagnetic radiation in the context of electromagnetic photo-thermal media. Electromagnetic radiation (including visible and infrared light) photons can be absorbed by a semiconductor medium to impart energy to the substance. Then, the heat is produced from this source of energy. The Thomson effect in electromagnetic photo-thermal semiconductor mediums involves the formation of heat or cooling at the junction of two conductive materials due to the absorption of electromagnetic radiation in semiconducting materials. Useful in thermoelectric cooling and other related technologies, the phenomena has been observed in nature. Lotfy et al. [15] studied electromagnetic and Thomson effects during the photothermal transport process of a rotator semiconductor medium under hydrostatic initial stress. Mahdy et al. [16] described analytical solutions of time-fractional heat order for a magneto-photothermal semiconductor medium with Thomson effects and initial stress. Alharbi et al. [17] introduced the Thomson effect with hyperbolic two-temperature on magneto-thermo-visco-elasticity. In a photothermal elastic medium, the porosity influences the flow of heat and therefore affects the temperature gradient within the material. As porosity increases, the void spaces act as insulators, hindering the flow of heat through the material. Consequently, this alters the temperature distribution and leads to variations in the Thomson effect. The Thomson effect can cause variations in porosity through electrochemical reactions, thereby modifying the material's properties. Understanding this relationship is crucial for studying the behavior of photothermal elastic media and designing materials with specific thermal and electrical properties. On the other hand, Zenkour [18, 19] studied the properties of thermal activation during photoexcited semiconductor medium using a refined multi-phase-lag technique. Zenkour [20] investigated the gravitational impact on a refined photothermal half-space material. Zenkour and

Abouelregal [21] used a long semiconductor cylinder to study the influence of variable harmonic heat in the context of photoexcited processes.

In the present work, the photothermal theory with the porosity of an electromagnetic semiconductor elastic medium is being utilized to examine the Thomson effect. By employing the photothermal transport process and thermoelasticity equations, the propagation of waves in an external electromagnetic field is described. In this particular model, three effects occur: the first is due to the electromagnetic field, resulting in the appearance of the Thomson effect; the second effect is due to the impact of photo-excitation, leading to the appearance of plasma (carrier density); and finally, the third effect is caused by porosity. To acquire the precise expressions of certain physical quantities distribution in a two-dimensional deformation, the Laplace transform method is employed alongside electro-mechanical, voids, plasma, and thermal loads. The obtained results are then discussed and presented graphically for various scenarios, including the presence or absence of the Peltier coefficient (Thomson parameter), different porosity parameters (with and without porosity), and varying values of the induced magnetic field.

## Mathematical model and basic equations

This problem investigates the impact of porosity on a two-dimensional  $(x, z)$  linear isotropic generalized photo-thermoelastic solid semiconductor medium with the use of Laplace transform method. The semiconductor medium is represented in Cartesian coordinates  $(x, y, z)$ , with the  $-y$ -axis pointing vertically down and the origin at the surface at  $y=0$ . The displacement vector is derived in 2D as  $\vec{u} = (u, o, w)$ , where  $u = (x, t, z), w = (x, t, z)$  are two components representing the displacement distribution and strain  $e = u_x + w_z$ . The photothermal transport mechanism, also known as the photo-excitation phenomenon, occurs when the medium is subjected to a beam of white light. In polymer semiconductors, the absorbed optical energy causes deformation in electron and particle vibrations. Important parameters for semiconductors include carrier density  $N$  (representing plasma dispersion), temperature distribution  $T$  (representing thermal effect), change in volume fraction field  $\phi$ , mechanical displacement  $\vec{u}$ , and induced magnetic field  $h$ . Initially, the medium is subjected to a homogeneous external magnetic field along the  $y$ -axis ( $\vec{H} = (0, H_0, 0)$ ). In addition to the induced electricity, the initial magnetic field  $\vec{H}$  causes the generation of an induced magnetic field  $\vec{h}$  in the medium. The induced electricity effect  $\vec{E} = (E_x, 0, E_z)$  must be considered in the governing equations. Assuming a homogeneous, isotropic medium, the linear equations of the electromagnetic field with porosity and Thomson effect are applied. The focus is on the influence of the electromagnetic field on the heat conductivity equation. The linear equations of electromagnetics and Ohm's law describe the influence of electromagnet-thermal fields on the medium [22].:

$$\vec{J} = \text{curl } \vec{h} - \epsilon_o \frac{\partial \vec{E}}{\partial t} = \sigma_o \left( \vec{E} + \mu_o \left( \dot{\vec{u}} \times \vec{H} \right) \right), \quad (1)$$

$$\text{curl } \vec{E} = -\mu_o \dot{\vec{H}} = \left( -\mu_o \frac{\partial h}{\partial t} \right) \hat{j}, \quad (2)$$

$$\vec{E} = \mu_o \left( \vec{H} \times \dot{\vec{u}} \right), \quad (3)$$

$$\text{div } \vec{h} = 0, \quad (4)$$

$$\text{div } \vec{D} = \rho_q, \quad \vec{D} = \epsilon_o \vec{E} \quad (5)$$

The medium has magnetic permeability and electric permeability that determine its ability to conduct magnetic and electric fields respectively  $\mu_o$  and  $\epsilon_o$ .  $\dot{\vec{u}}$  refers to the speed at which a particle moves through a medium, while the dot represents the rate of change of any variables concerning time  $t$ . In addition, the impact of photo-excitation is also given consideration. Suppose a semiconductor elastic medium is subjected to external beams of light on its surface, the excited free electrons will produce a density of carrier-free charges with energy equal to the gap between them  $E_g$  ( $E > E_g$ ) (carrier density (plasma waves)). The absorption of optical energy leads to changes in the electronic structure and results in the occurrence of elastic vibrations. The heat conductivity equation in this scenario is influenced by thermal-elastic-plasma waves and the presence of an electromagnetic field. The generalized form of the Fourier law for semiconductor materials, considering both the Thomson effect and plasma effect, can be expressed as follows [23].:

$$q_i + \tau_o \dot{q}_i = -kT_{,i} - \int -\frac{E_g}{\tau} N dx_i + \Pi J_i \quad (6)$$

Differentiating the above equation for  $x_i$ , give:

$$q_{i,i} + \tau_o \dot{q}_{i,i} = -kT_{,ii} - \frac{E_g}{\tau} N + \Pi J_{i,i} \quad (7)$$

$$q_{i,i} = \rho C_e \dot{T} + \gamma T_o \dot{e} \quad (8)$$

Substituting from Equation 5 in Equation 1, yields

$$\nabla \cdot \vec{D} = -\nabla \cdot \vec{J} = -J_{i,i} = \dot{\rho}_q \quad (9)$$

Using Eqs 7–9, the general form of paraphrasing the heat conductive equation for a semiconductor elastic medium is as follows:

$$kT_{,ii} = \rho C_e (\dot{T} + \tau_o \ddot{T}) + \gamma T_o (\dot{e} + \tau_o \ddot{e}) - \frac{E_g}{\tau} N + \gamma T_o \frac{\partial \phi}{\partial t} - \Pi \dot{\rho}_q \quad (10)$$

Where, the term  $\frac{E_g}{\tau} N$  expresses the effect of photo-excitation but the term  $\Pi \dot{\rho}_q$  represents the Thomson effect.

The expression of the equation of continuity for charges in the presence of an electromagnetic field can be stated as follows:

$$\frac{\partial \rho_q}{\partial t} + \nabla \cdot (\rho_q v_i) = 0 \quad (11)$$

Where  $v_i$  express the velocity of charges.

Assume that the charge density  $\rho_q$  depends on the time only, i.e.,  $\rho_q = \rho_q(t)$

Therefore, the equation of continuity (11) takes the form:

$$\frac{\partial \rho_q}{\partial t} = -\rho_q \nabla \cdot v_i \quad (12)$$

Consider the velocity  $v_i$  of the charges is proportional to the particle velocity  $\dot{u}_i$ , so the relation between them can be rewritten as:

$$v_i = \zeta \dot{u}_i \Rightarrow \nabla \cdot v_i = \zeta \nabla \cdot \dot{u}_i = \zeta \dot{e} \quad (13)$$

Where  $\zeta$  is a small dimensionless constant. Eq. 12 can be rewritten in the following form

$$\frac{\partial \rho_q}{\partial t} = -\rho_q \zeta \dot{e} \Rightarrow \int \frac{d\rho_q}{\rho_q} = -\zeta \int de \tag{14}$$

Integrating Equation 14 and using series expand, we have

$$\rho_q = \rho_q^0 \exp(-\zeta e) \Rightarrow \rho_q \approx \rho_q^0 (1 - \zeta e) \tag{15}$$

Where  $\rho_q^0$  (is the original charge density) determined when the strain is eliminated. From Equation 15, we obtain (neglected the very small  $\zeta^2$  values)

$$\dot{\rho}_q = -\rho_q^0 \zeta \dot{e} \exp(-\zeta e) \Rightarrow \dot{\rho}_q \approx -\rho_q^0 \zeta \dot{e} (1 - \zeta e) \approx -\rho_q^0 \zeta \dot{e} \tag{16}$$

Then the heat Equation 10 takes the form:

$$kT_{,ii} = \rho C_e (\dot{T} + \tau_0 \ddot{T}) + \gamma T_0 (\dot{e} + \tau_0 \ddot{e}) - \frac{E_g}{\tau} N + \gamma T_0 \frac{\partial \phi}{\partial t} + \Pi \rho_q^0 \zeta \dot{e} \tag{17}$$

The Lorentz force, which arises due to the influence of electromagnetic fields, can be formulated as [24]:

$$\vec{F} = \mu_o (\vec{J} \times \vec{H}) \tag{18}$$

The components of Lorentz force take the form [25]:

$$F_x = -\mu_o \sigma_o H_o (E_z + \mu_o H_o \dot{u}), \tag{19}$$

$$F_z = \mu_o \sigma_o H_o (E_x + \mu_o H_o \dot{v}). \tag{20}$$

By using Eqs. 1–3, we get:

$$\frac{\partial h}{\partial z} = \sigma_o (\mu_o H_o \dot{v} - E_x) - \epsilon_o \frac{\partial E_x}{\partial t}, \tag{21}$$

$$\frac{\partial h}{\partial x} = \sigma_o (E_z + \mu_o H_o \dot{u}) + \epsilon_o \frac{\partial E_z}{\partial t}, \tag{22}$$

$$\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z} = \mu_o \frac{\partial h}{\partial t}, \tag{23}$$

$$\frac{\partial E_z}{\partial z} + \frac{\partial E_x}{\partial x} = -\mu_o H_o \frac{\partial \dot{u}}{\partial z} + \mu_o H_o \frac{\partial \dot{v}}{\partial x}. \tag{24}$$

In addition, the following are presented: equations that describe the electromagnetic field, the impact of porosity on the system, and the influence of the Thomson effect on the photo-induced process in a semiconductor medium.

The coupling between plasma waves and thermal waves [26–30]:

$$\frac{\partial N}{\partial t} = D_E \nabla^2 N - \frac{N}{\tau} + \kappa T. \tag{25}$$

Motion equation (29 and 30):

$$\rho \ddot{\vec{u}} = (k + \mu) \nabla^2 \vec{u} + (\lambda + \mu) \nabla (\nabla \cdot \vec{u}) - \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) \nabla T - \delta_n \nabla N + \lambda_o \nabla \phi + \mu_o (\vec{J} \times \vec{H}). \tag{26}$$

The porous (voids) equation can be given as [31]:

$$\alpha \nabla^2 \phi - \lambda_o e - \varsigma_1 \phi - \omega_o \dot{\phi} + mT = \rho \psi \ddot{\phi} \tag{27}$$

The constitutive relations for the generalized photo-thermoelastic theory in tensor form can be paraphrased as follows [32]:

$$\left. \begin{aligned} \sigma_{ij} &= \lambda u_{r,r} \delta_{ij} + (k + \mu) u_{i,i} + \mu u_{i,i} + \\ &\lambda_o \phi \delta_{ij} - p \delta_{ij} - \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) T \delta_{ij} + (3\lambda + 2\mu) d_n N \delta_{ij} \end{aligned} \right\} \tag{28}$$

In the above equations, the parameter  $\kappa = \frac{\partial N_o}{\partial T} \frac{T}{\tau}$  denotes the thermal activation coupling parameter and  $N_o$  expresses the carrier concentration in the equilibrium case (generally the parameter  $\kappa$  is non-zero at temperature  $T$ ) [33–35].

### Mathematical formulations

The modified linear semiconductor thermoelasticity in the presence of carrier density and an initial external magnetic field, without considering internal heat sources, can be expressed as follows:

$$\left. \begin{aligned} \rho u_{tt} &= (\lambda + \mu) \frac{\partial e}{\partial x} + (k + \mu) (u_{xx} + u_{zz}) - \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) \frac{\partial T}{\partial x} \\ \delta_n \frac{\partial N}{\partial x} + \lambda_o \frac{\partial \phi}{\partial x} - \mu_o \sigma_o H_o (E_z + \mu_o H_o \dot{u}) \end{aligned} \right\} \tag{29}$$

$$\left. \begin{aligned} \rho w_{tt} &= (\lambda + \mu) \frac{\partial e}{\partial z} + (k + \mu) (w_{xx} + w_{zz}) - \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) \frac{\partial T}{\partial z} \\ \delta_n \frac{\partial N}{\partial z} + \lambda_o \frac{\partial \phi}{\partial z} + \mu_o \sigma_o H_o (E_x - \mu_o H_o \dot{v}) \end{aligned} \right\} \tag{30}$$

$$\left. \begin{aligned} K \left[ \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2} \right] &= \rho C_E \left( n_1 + \tau_o \frac{\partial}{\partial t} \right) \frac{\partial T}{\partial t} + \gamma T_o \left( n_1 + n_o \tau_o \frac{\partial}{\partial t} \right) \frac{\partial e}{\partial t} \\ \frac{E_g}{\tau K} N + \gamma T_o \frac{\partial \phi}{\partial t} + \Pi \rho_q^0 \zeta \dot{e} \end{aligned} \right\} \tag{31}$$

$$\left( \alpha \nabla^2 - \rho \psi \frac{\partial^2}{\partial t^2} - \omega_o \frac{\partial}{\partial t} - \varsigma_1 \right) \phi - \lambda_o e + \gamma T = 0 \tag{32}$$

$$\sigma_{xx} = (2\mu + \lambda + k) \frac{\partial u}{\partial x} + \lambda \frac{\partial w}{\partial z} + (3\lambda + 2\mu) d_n N + \lambda_o \phi - \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) T, \tag{33}$$

$$\begin{aligned} \sigma_{zz} &= (2\mu + \lambda + k) \frac{\partial w}{\partial z} + \lambda \frac{\partial u}{\partial x} + (3\lambda + 2\mu) d_n N + \lambda_o \phi \\ &- \gamma \left( 1 + \nu_o \frac{\partial}{\partial t} \right) T, \end{aligned} \tag{34}$$

$$\sigma_{yy} = \lambda \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) - (3\lambda + 2\mu) (\alpha T + d_n N) \tag{35}$$

$$\sigma_{xz} = (k + \mu) \frac{\partial w}{\partial x} + \mu \frac{\partial u}{\partial z}. \tag{36}$$

The dimensionless form can be obtained by using non-dimension variables to represent the main fields.

$$\left. \begin{aligned} (x', z', u', w') &= \frac{(x, z, u, w)}{C_T t^*}, (t', v_0) = \frac{(t, v_0)}{t^*}, T' = \frac{\gamma T}{2\mu + \lambda}, \\ h' &= \frac{\rho C_E h}{\mu_o H_o \sigma_o k}, \sigma'_{ij} = \frac{\sigma_{ij}}{\mu}, N' = \frac{\delta_n N}{2\mu + \lambda}, E'_i = \frac{\rho C_E E_i}{\mu_o^2 H_o \sigma_o k C_T}, \\ t^* &= \frac{k}{\rho C_E c_T^2}, \phi' = \frac{\psi \omega^2}{C_2^2} \phi, c_T^2 = \frac{2\mu + \lambda}{\rho}. \end{aligned} \right\} \tag{37}$$

Eq. 37, when utilized as the key governing equation, paraphrasing leads to the following outcomes:

$$\left(\nabla^2 - q_1 - q_2 \frac{\partial}{\partial t}\right)N + \epsilon_3 T = 0 \tag{38}$$

$$u_{tt} = a_1 \frac{\partial e}{\partial x} + a_2 \nabla^2 u - a_3 \frac{\partial T}{\partial x} - a_4 \frac{\partial N}{\partial x} + b_2 \frac{\partial \varphi}{\partial x} - a_5 (a_6 E_z + a_7 \dot{u}) \tag{39}$$

$$w_{tt} = a_1 \frac{\partial e}{\partial z} + a_2 \nabla^2 w - a_3 \frac{\partial T}{\partial z} - a_4 \frac{\partial N}{\partial z} + b_2 \frac{\partial \varphi}{\partial z} + a_5 (a_6 E_x - a_7 \dot{w}) \tag{40}$$

$$\nabla^2 T - a_8 \frac{\partial T}{\partial t} - a_9 \frac{\partial e}{\partial t} + a_{10} N - b_5 \frac{\partial \phi}{\partial t} = 0 \tag{41}$$

$$(\nabla^2 - b_6)\phi - b_7 e + b_8 T = 0 \tag{42}$$

$$\frac{\partial h}{\partial z} = \sigma_o (a_{15} \dot{w} - a_{16} E_x) - b_1 \frac{\partial E_x}{\partial t}, \tag{43}$$

$$\frac{\partial h}{\partial x} = \sigma_o (a_{16} E_z + a_{15} \dot{u}) + b_1 \frac{\partial E_z}{\partial t}, \tag{44}$$

$$\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z} = \frac{\partial h}{\partial t} \tag{45}$$

$$\sigma_{xx} = a_{11} \frac{\partial u}{\partial x} + \lambda \frac{\partial w}{\partial z} - a_{12} T + a_{13} \phi + a_{14} N, \tag{46}$$

$$\sigma_{zz} = a_{11} \frac{\partial w}{\partial z} + \lambda \frac{\partial u}{\partial x} - a_{12} T + a_{13} \phi + a_{14} N, \tag{47}$$

$$\sigma_{yy} = \lambda e - a_{12} T + a_{13} \phi + a_{14} N. \tag{48}$$

The main coefficients of the equations (38)-(48) can be obtained in the (Appendix A1). Assume that the normal stress is  $\sigma$  which it takes the following dimensionless form:

$$\sigma = \sigma_{xx} + \sigma_{yy} + \sigma_{zz} = a_{11} e - 3(a_{12} T + a_{13} \phi + a_{14} N) \tag{49}$$

Solving the problem.

Laplace transform for function  $\prod(x, z, t)$  with  $s$  (parameter) is expressed as:

$$L[\prod(x, z, t)] = \int_0^\infty \prod(x, z, t) e^{-st} dt = \bar{\prod}(x, z, s) \tag{50}$$

The formula for the exponential Fourier transforms with parameter  $q$  is:

$$\hat{f}(x, q, s) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^\infty f(x, z, s) e^{-iqz} dz \tag{51}$$

Applying Laplace-Fourier double transform into Equations 38-45, yields:

$$\left(D^2 - \alpha_3 \hat{N}\right) + \epsilon_3 \hat{T} = 0 \tag{52}$$

$$(D^2 - a_{26})\hat{e} - (D^2 - q^2)(a_{19}\hat{T} + a_{20}\hat{N} - a_{21}\hat{\phi}) - a_{27}\hat{h} = 0 \tag{53}$$

$$(D^2 - a_{31})\hat{T} - a_{32}\hat{e} + a_{10}\hat{N} - a_{33}\hat{\phi} = 0 \tag{54}$$

$$(D^2 - a_{34})\hat{\phi} - b_7\hat{e} + b_8\hat{T} = 0 \tag{55}$$

$$(D^2 - q^2)\hat{h} + a_{30}\hat{e} = 0 \tag{56}$$

Where,  $\frac{d^2}{dx^2} = D^2, \frac{d}{dx} = D$  Eliminating  $\hat{N}(x, q, s), \hat{T}(x, q, s), \hat{e}(x, q, s), \hat{h}(x, q, s)$  and  $\hat{\phi}(x, q, s)$  between Equations 52-56, the

following tenth-order ordinary differential equations (ODE) are satisfied by  $\hat{N}, \hat{T}, \hat{e}, \hat{h}$  and  $\hat{\phi}$  are obtained as:

$$\begin{aligned} &(D^{10} - A[1]D^8 + A[2]D^6 - A[3]D^4 + A[4]D^2 - A[5]) \\ &\times \left\{ \hat{N}, \hat{T}, \hat{e}, \hat{h}, \hat{\phi} \right\}(x, q, s) = 0 \end{aligned} \tag{57}$$

The main coefficients of the equation (57) can be obtained in the (Appendix A1). The primary 10th ordinary differential Equation 57 were solved using the factorization technique as follows:

$$\begin{aligned} &(D^2 - k_1^2)(D^2 - k_2^2)(D^2 - k_3^2)(D^2 - k_4^2)(D^2 - k_5^2) \\ &\times \left\{ \hat{N}, \hat{T}, \hat{e}, \hat{h}, \hat{\phi} \right\}(x, q, s) = 0 \end{aligned} \tag{58}$$

Where  $k_n^2$  ( $n= 1, 2, 3, 4, 5$ ) are the roots, that they may be taken as real-positive when  $x \rightarrow \infty$ . The solution to Equation 57 is expressed as follows:

$$\hat{T}(x, q, s) = \sum_{n=1}^5 M_n(q, s) e^{-k_n x} \tag{59}$$

$$\hat{N}(x, q, s) = \sum_{n=1}^5 M'_n(q, s) e^{-k_n x} = \sum_{n=1}^5 a_n^* M_n(q, s) e^{-k_n x} \tag{60}$$

$$\hat{e}(x, q, s) = \sum_{n=1}^5 M''_n(q, s) e^{-k_n x} = \sum_{n=1}^5 b_n^* M_n(q, s) e^{-k_n x} \tag{61}$$

$$\hat{\phi}(x, q, s) = \sum_{n=1}^5 M'''_n(q, s) e^{-k_n x} = \sum_{n=1}^5 c_n^* M_n(q, s) e^{-k_n x} \tag{62}$$

$$\hat{h}(x, q, s) = \sum_{n=1}^5 M''''_n(q, s) e^{-k_n x} = \sum_{n=1}^5 d_n^* M_n(q, s) e^{-k_n x} \tag{63}$$

Where,  $M_n$  and  $M'_n, M''_n, M'''_n, M''''_n$  are unknown parameters depending on the parameters  $q, s$  can be determined from boundary conditions. To find the solution of Laplace's main variable transformations in terms of the unknown parameters  $q$  and  $s$ , we need to determine the domain-wide solution. These parameters can be obtained by applying the given boundary conditions.

### Boundary conditions

Consider the elastic semiconductor medium is initially in a state of rest at the vertical plane (free surface)  $x=0$ . The system is thermally isolated. The Laplace and Fourier transform are applied for the following limit conditions.

- (1) The plasma boundary condition when the Laplace transform is used at the free surface to transport and photo-generate the carrier density diffusion during the recombination processes with speed  $\tilde{s}$ , the plasma boundary condition may be reformulated as follows:

$$\hat{N}(0, q, s) = \frac{\lambda \tilde{s}}{D_e} \hat{R}(s) \tag{64}$$

Therefore,

$$a_n^* \sum_{n=1}^5 M_n = \frac{\lambda}{D_e} \hat{R}(s) \tag{65}$$



(II) At the free surface, the isothermal boundary condition sensitive to thermal shock is defined as:

$$\widehat{T}(0, q, s) = T_0 \widehat{g}(s) \tag{66}$$

Therefore,

$$\sum_{n=1}^5 M_n = T_0 \widehat{g}(s) \tag{67}$$

(III) The mechanical boundary condition: the surface has zero strain at the bounding  $x = 0$ , so that

$$\widehat{e}(0, q, s) = 0 \tag{68}$$

So,

$$b_n^* \sum_{n=1}^5 M_n = 0 \tag{69}$$

(IV) The boundary condition of the change in the volume fraction field at the free surface ( $\varphi$  is constant in  $z$ - direction), yields:

$$\frac{\partial \widehat{\phi}}{\partial z} = 0 \tag{70}$$

So

$$e_1 C_n^* \sum_{n=1}^5 M_n = 0 \tag{71}$$

(V) Conditions of induced magnetism at the free surface  $x=0$ , assuming that the initially established magnetic field, which will change over time, is constant

$$\widehat{h}(0, q, s) = h_0 \widehat{g}(s) \tag{72}$$

So,

$$d_n^* \sum_{n=1}^5 M_n = h_0 \widehat{g}(s) \tag{73}$$

The quantities  $g(s) = 1$  and  $R(s) = 1$  are the Heaviside unit step function where  $\lambda$  is a free chosen constant.

### Inversion of the fourier-laplace transforms

To achieve comprehensive solutions of non-dimensional physical field variable distributions in 2D, it is important to reverse the previous main expressions in the physical domain. The numerical inversion technique for Laplace transform, specifically the Riemann-sum approximation method, is utilized to accomplish this [36].

In the Fourier domain, the inverse of any function  $f(x, z, t)$  can be obtained as:

$$\widehat{f}(x, z, s) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \widehat{f}(x, q, s) e^{iqz} dz \tag{74}$$

In the Laplace domain, any function's inverse  $f(x, z, t)$  can be obtained as [37]:

$$f(x, z, t) = \frac{1}{2\pi i} \int_{n-i\infty}^{n+i\infty} \widehat{f}(x, z, s) e^{st} dt \tag{75}$$

Using the Fourier series expand for the function  $f(x, z, t')$  in the closed interval  $[0, 2t']$ , to get the next relationship [34]:

$$f(x, z, t') = \frac{e^{nt'}}{t'} \left[ \frac{1}{2} \widehat{f}(x, z, n) + \text{Re} \sum_{k=1}^N \widehat{f}\left(x, z, n + \frac{ik\pi}{t'}\right) (-1)^k \right] \tag{76}$$

Where the imaginary unit is  $i = \sqrt{-1}$  and  $Re$  is the real part. The sufficient  $N$  can be chosen free as a large integer but can be selected in the notation  $nt' \approx 4.7$  [38].

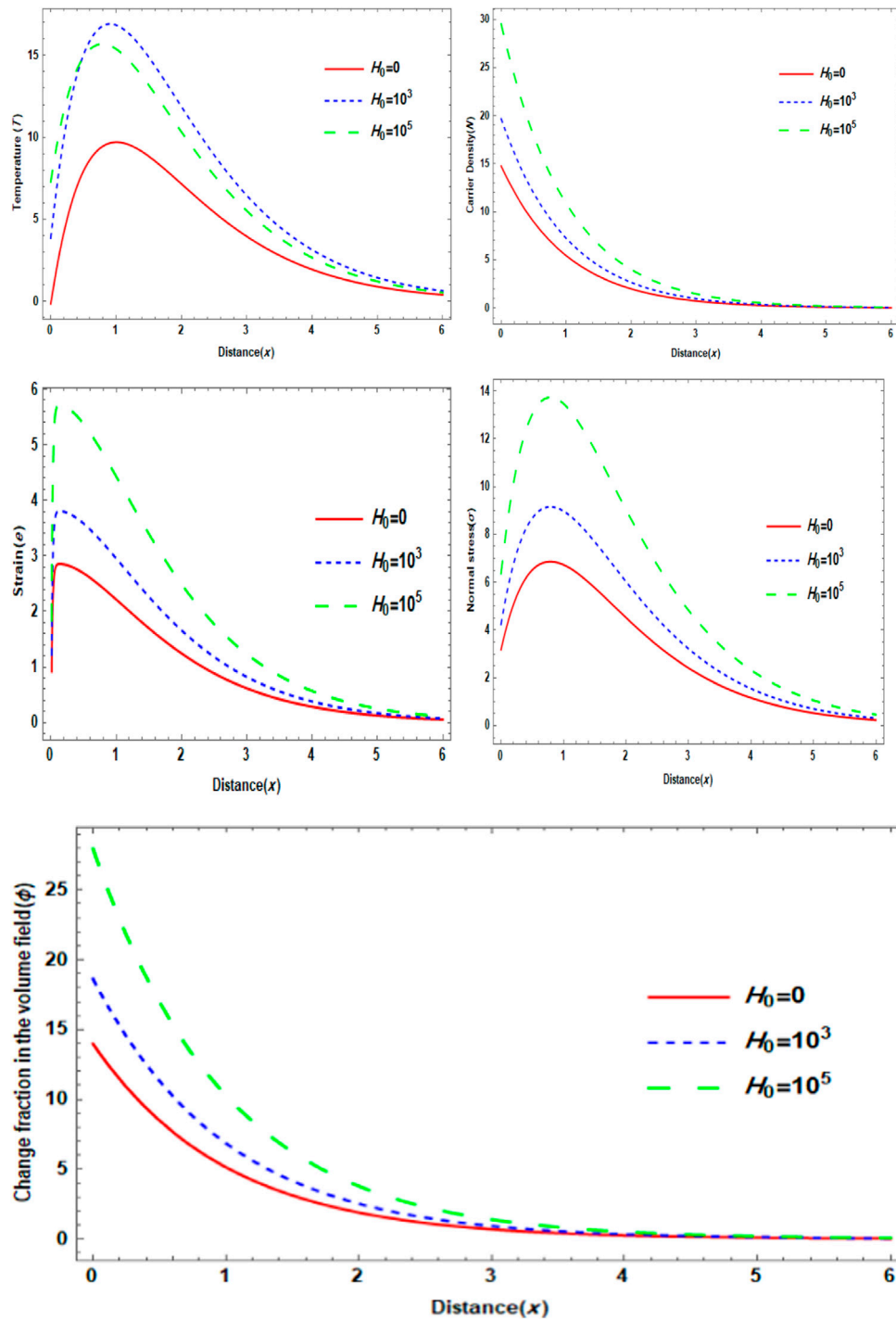
### Numerical results and discussions

To be used in numerical simulation with the Mathematica program, silicon (Si) is an elastic semiconductor material. Its physical constants are utilized in the computational analysis and investigation of fundamental quantity fields, which have diverse applications in modern industries and plasma physics technologies. The mentioned physical constants for Si material, specifically for the n-type, are as follows [39–43]: are taken in SI units:

$$\begin{aligned} \lambda &= 3.64 \times 10^{10} \text{ N/m}^2, \mu = 5.46 \times 10^{10} \text{ N/m}^2, \rho = 2330 \text{ kg/m}^3, \\ T_0 &= 800 \text{ K}, \tau = 5 \times 10^{-5} \text{ s}, d_n = -9 \times 10^{-31} \text{ m}^3, \\ D_E &= 2.5 \times 10^{-3} \text{ m}^2/\text{s}, E_g = 1.11 \text{ eV}, s = 2 \text{ m/s}, \alpha_i = 4.14 \times 10^{-6} \text{ K}^{-1}, \\ K &= 150 \text{ Wm}^{-1} \text{ K}^{-1}, C_e = 695 \text{ J/(kgK)}, j = 0.2 \times 10^{-19} \text{ m}^2, \\ \gamma &= 0.779 \times 10^{-9} \text{ N}, k = 10^{10} \text{ Nm}^{-2}, t = 0.008 \text{ s}, \\ z &= 1, b = 0.9, \tau_0 = 0.00005 \text{ s}, \nu_0 = 0.0005 \text{ s}, n_0 = 10^{20} \text{ m}^{-3}, \\ H_0 &= 10^5 \text{ col/cm.sec}, \mu_o = 4\pi \times 10^{-7} \text{ H/m}, \\ \sigma_o &= 9.36 \times 10^5 \text{ col}^2/\text{cal.cm.sec}, \epsilon_o = 8.85 \times 10^{-12} \text{ F/m}, \\ \zeta &= 0.9 \text{ rad/sec}, k_o = 386 \text{ N/K.sec}, \lambda_o = 1.13849 \times 10^{10}, \\ \alpha &= 3.688 \times 10^{-5}, \psi = 1.753 \times 10^{-15}, \omega_o = 0.0787 \times 10^{-3}, \\ \varsigma_1 &= 1.475 \times 10^{10}. \end{aligned}$$

During the phase of the numerical approach that was described earlier, the real components of the elastic wave ( $u$ ), temperature ( $T$ ), normal stress ( $\sigma$ ), strain (dilation) ( $e$ ) the change in volume fraction field ( $\phi$ ), induced magnetic field ( $h$ ) and photo-electronic or plasma (carrier density) ( $N$ ) are the primary areas of concentration for us. In the Mathematica program for numerical simulation, silicon (Si) is considered an elastic semiconductor material. Its physical constants play a significant role in computational analysis and exploration of various fundamental quantity fields [40, 41]. These fields find extensive applications in modern industries and plasma physics technologies. Specifically for the n-type, the physical constants associated with Si material are as follows:

Figure 1 presents the relationship between different levels of an externally induced magnetic field and the propagation of photo-thermal-elastic-electric waves over a distance. This was the first category explored in the study. Every computation was checked using a short amount of time,  $t = 0.008$  while the influence of porosity was being considered and the effect of the Peltier coefficient  $\Pi_0 = 10$ . The different magnitudes of the magnetic field  $H_0 = 100000$ ,  $H_0 = 1000$  and  $H_0 = 0$  (without magnetic field) are represented by different curves. Within the range  $0 \leq x \leq 6$ , the temperature distribution, strain, and normal stress display a curve that gradually



**FIGURE 1**  
Variation of the main physical distributions with respect to the distance for different values of Induced magnetic field.

risers to a certain point and then gradually declines until it becomes zero. The amount of temperature distributions is directly linked to the strength of the magnetic field. The carrier density distribution represents the electric wave, and the change in the volume fraction field starts at its highest positive point, gradually decreases as the distance increases, and eventually becomes zero.

Figure 2 illustrates how different values of the Peltier coefficient affected the distribution of the physical field in the photo-thermo-elastic model with porosity when time  $t = 0.008$  and  $H_0 = 100000$ . It is important to highlight that all field distributions demonstrate the same behavior, as shown in Figure 1.

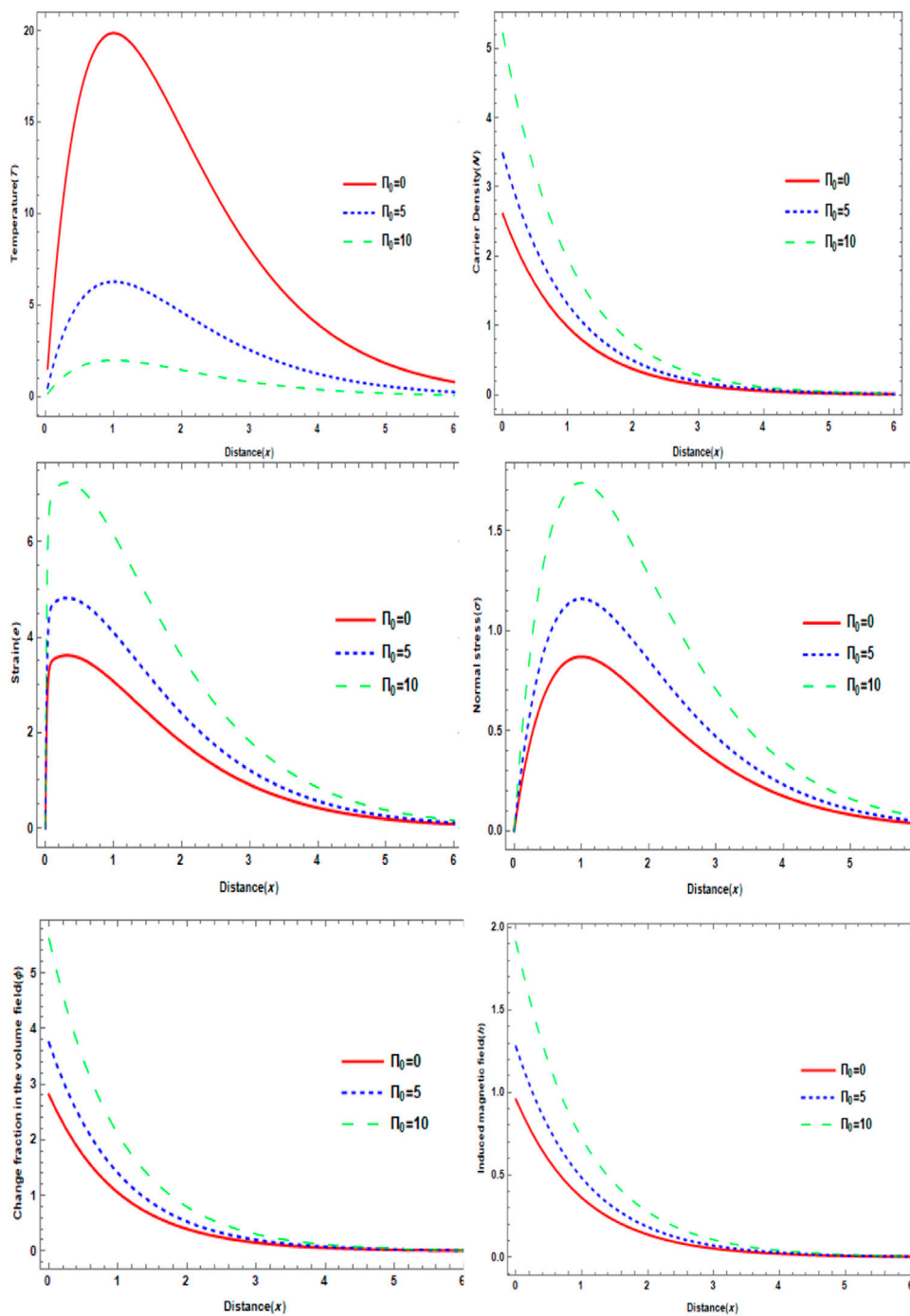


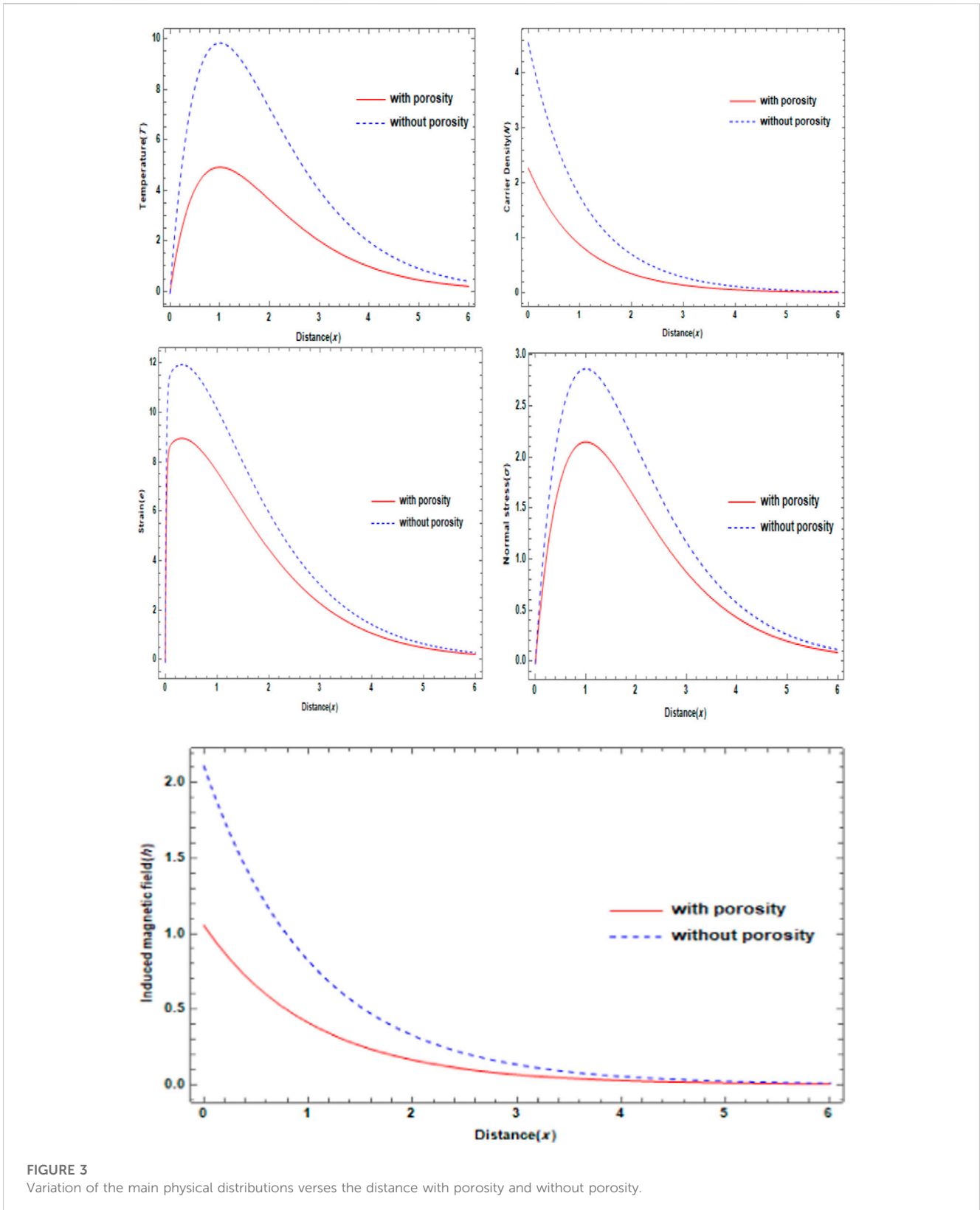
FIGURE 2 Variation of the main physical distributions against the distance for different values of Peltier coefficient.

Figure 3 presents the impact of different values of porosity parameters (both with and without porosity) on the physical field distribution in the photo-thermo-elastic model when time  $t = 0.008$  and  $H_0 = 100000$  an assumed constant of the magnetic field and the effect of the Peltier coefficient  $\Pi_0 = 10$  are used. The substitution of the volume fraction field with the distribution of the induced magnetic field (electromagnetic waves) is observed. It is important to mention that all field distributions demonstrate identical patterns, as illustrated in Figure 1.

### Conclusion

In this study, we look into how a magnetic field affects a porous, generalized photo-thermo-elastic solid medium. The impact of the Thomson effect on some physical parameters is also investigated. The findings demonstrate that the magnetic field has a positive effect on all physical fields, with the carrier density displaying a distinct oscillating structure. Figure 1 also illustrates numerical computations showing the variation in field





and stress distributions with horizontal distance for various values of the initial uniform magnetic field. The fluctuation of dimensionless physical variables as a function of distance is shown in Figure 2 for a range of Peltier coefficients, porosities, and magnetic fields. Figure 3

similarly illustrates how porosity parameters affect the scatter in these metrics. When a magnetic field and the Peltier coefficient are taken into account, it is clear that the primary fields are enhanced. The principal fields are profoundly impacted by the porosity

characteristics. It is shown that the distribution of all physical fields in the photo-thermo-elastic model is greatly impacted by the porosity parameters, the initial magnetic field, and the Peltier coefficient. The results of this study can be used to improve the performance and longevity of electronic devices, energy harvesting systems, sensors, structural health monitoring materials, and infrastructure in a variety of environments, including those with varying magnetic field strengths, air gaps, Peltier coefficient effects, and temperatures.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

## Author contributions

WA: Project administration, Resources, Investigation, Writing—original draft. ME: Conceptualization, Methodology, Software, Data curation, Supervision, Formal analysis, Writing—review and editing. HC: New software; Validation; Writing—reviewing and editing. RC: New software; Validation; Writing—reviewing and editing. AE-B: Conceptualization, Methodology, Visualization, Software, Validation, Writing—review and editing. NA: Software, Validation, Supervision, Investigation, Visualization, Writing—review and editing. RT: Resources, Writing—original draft, Writing—review and editing, Software, Supervision, Visualization, Investigation. KL: Conceptualization, Methodology, Software, Data curation, Formal Analysis, Funding acquisition, Resources, Writing—original draft.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Appendix

Equations 38–48 have the primary variables which can be represented as:

$$\begin{aligned}
 q_1 &= \frac{kt^*}{\rho c_E D_E}, q_2 = \frac{k}{\rho c_E D_E}, \varepsilon_3 = \frac{\kappa K \delta_n t^*}{\gamma \rho c_E D_E}, a_1 = \frac{\mu + \lambda}{\rho c_T^2}, a_2 = \frac{k + \mu}{\rho c_T^2}, \\
 a_3 &= \frac{2\mu + \lambda}{\rho c_T^2} (1 + \nu_o \omega), a_4 = \frac{2\mu + \lambda}{\rho c_T^2}, a_5 = \mu_0 \sigma_0 H_0, a_6 = \frac{\mu_0^2 \sigma_0 H_0 k t^*}{\rho^2 c_E}, \\
 a_7 &= \frac{\mu_0 H_0 t^*}{\rho}, a_8 = \frac{\rho c_E c_T^2 t^*}{K} (n_1 + \tau_o s), a_9 = \frac{\gamma^2 T_0 t^* c_T^2}{(2\mu + \lambda) K} (n_1 + n_o \tau_o s) + \Pi_0, \\
 \Pi_0 &= \frac{\Pi \rho_q^0 \zeta \gamma T_0 t^* c_T^2}{(2\mu + \lambda) K}, a_{10} = \frac{E_g \gamma t^{*2} c_T^2}{\tau \delta_n K}, a_{11} = \frac{2\mu + \lambda}{\mu}, a_{12} = \frac{\lambda}{\mu}, \\
 a_{13} &= \frac{2\mu + \lambda}{\mu} (1 + \nu_o \omega), \\
 a_{14} &= \frac{d_n (2\mu + \lambda)}{\mu \delta_n} (2\mu + 3\lambda), a_{15} = \frac{\rho c_E t^* c_T^2}{\sigma_0 k}, a_{16} = \mu_0 t^* c_T^2, b_1 = \mu_0 \varepsilon_0 c_T^2, \\
 b_2 &= \frac{\lambda_o}{\psi \rho t^{*2}}, b_4 = \frac{b_2}{a_1 + a_2}, b_5 = \frac{\gamma^2 T_0 c_T^4}{(2\mu + \lambda) K t^* \psi}, b_8 = \frac{(2\mu + \lambda) \lambda_o \psi t^{*4}}{\alpha}, \\
 b_6 &= \frac{\rho \psi^2 t^{*2}}{\alpha} \omega^2 + \frac{\omega_o \psi t^{*3}}{\alpha} \omega - \frac{\varsigma_1 \psi t^{*4}}{\alpha}, b_7 = \frac{\lambda_o \psi t^{*4}}{\alpha}, b_9 = \frac{\lambda_o c_T^2}{\mu \psi t^{*2}}, \\
 b_{10} &= 1 + \frac{\mu + k}{\mu}, b_{11} = \frac{\mu + k}{\mu}, b_{12} = b_5 \omega, a_{24} = \frac{1}{a_1 + a_2}, a_{19} = \frac{a_3}{a_1 + a_2}, \\
 a_{20} &= \frac{a_4}{a_1 + a_2}, a_{21} = \frac{b_2}{a_1 + a_2}, a_{22} = \frac{a_5 a_6}{a_1 + a_2}, a_{23} = \frac{a_5 a_7}{a_1 + a_2}, a_{22} = \frac{\rho}{\mu}, \\
 a_{25} &= q^2 - a_{18} s + a_{17} s^2, a_{26} = q^2 + a_{23} s + a_{24} s^2, a_{27} = a_{22} s, \\
 a_{28} &= \sigma_0 (a_{15} - a_{16} \mu_0 H_0), a_{29} = a_{17} \mu_0 H_0, a_{30} = -a_{28} s + a_{29} s^2, \\
 a_{31} &= q^2 + a_8 s, a_{32} = a_9 s, a_{33} = b_5 s, a_{34} = q^2 + b_6, \alpha_3 = q_1 + q_2 s + q^2.
 \end{aligned}$$

Coefficients of Eq. 57:

$$A[1] = -(q^2 - a_{26} - a_{31} - a_{19} a_{32} - a_{34} + a_{21} b_7 - \alpha_3)$$

$$\begin{aligned}
 A[2] &= (q^2 a_{26} + a_{27} a_{30} + q^2 a_{31} + a_{26} a_{31} + 2q^2 a_{19} a_{32} + q^2 a_{34} \\
 &\quad + a_{26} a_{34} + a_{31} a_{34} + a_{19} a_{32} a_{34} - 2q^2 a_{21} b_7 - a_{21} a_{31} b_7 \\
 &\quad - a_{19} a_{33} b_7 - a_{21} a_{32} b_8 + a_{33} b_8 + q^2 \alpha_3 + a_{26} \alpha_3 + a_{31} \alpha_3 \\
 &\quad + a_{19} a_{32} \alpha_3 + a_{34} \alpha_3 - a_{21} b_7 \alpha_3 - a_{10} \varepsilon_3 + a_{20} a_{32} \varepsilon_3) \\
 A[3] &= -(-q^2 a_{26} a_{31} - a_{27} a_{30} a_{31} - q^4 a_{19} a_{32} - q^2 a_{26} a_{34} - a_{27} a_{30} a_{34} \\
 &\quad - q^2 a_{31} a_{34} - a_{26} a_{31} a_{34} - 2q^2 a_{19} a_{32} a_{34} \\
 &\quad + q^4 a_{21} b_7 + 2q^2 a_{21} a_{31} b_7 + 2q^2 a_{19} a_{33} b_7 + 2q^2 a_{21} a_{32} b_8 \\
 &\quad - q^2 a_{33} b_8 - a_{26} a_{33} b_8 - q^2 a_{26} \alpha_3 - a_{27} a_{30} \alpha_3 - q^2 a_{31} \alpha_3 \\
 &\quad - a_{26} a_{31} \alpha_3 - 2q^2 a_{19} a_{32} \alpha_3 - q^2 a_{34} \alpha_3 - a_{26} a_{34} \alpha_3 - a_{31} a_{34} \alpha_3 \\
 &\quad - a_{19} a_{32} a_{34} \alpha_3 + 2q^2 a_{21} b_7 \alpha_3 + a_{21} a_{31} b_7 \alpha_3 + a_{19} a_{33} b_7 \alpha_3 \\
 &\quad + a_{21} a_{32} b_8 \alpha_3 - a_{33} b_8 \alpha_3 + q^2 a_{10} \varepsilon_3 + a_{10} a_{26} \varepsilon_3 - 2q^2 a_{20} a_{32} \varepsilon_3 \\
 &\quad + a_{10} a_{34} \varepsilon_3 - a_{20} a_{32} a_{34} \varepsilon_3 - a_{10} a_{21} b_7 \varepsilon_3 + a_{20} a_{33} b_7 \varepsilon_3) \\
 A[4] &= (q^2 a_{26} a_{31} a_{34} + a_{27} a_{30} a_{31} a_{34} + q^4 a_{19} a_{32} a_{34} - q^4 a_{21} a_{31} b_7 \\
 &\quad - q^4 a_{19} a_{33} b_7 - q^4 a_{21} a_{32} b_8 + q^2 a_{26} a_{33} b_8 + a_{27} a_{30} a_{33} b_8 \\
 &\quad + q^2 a_{26} a_{31} \alpha_3 + a_{27} a_{30} a_{31} \alpha_3 + q^4 a_{19} a_{32} \alpha_3 \\
 &\quad + q^2 a_{26} a_{34} \alpha_3 + a_{27} a_{30} a_{34} \alpha_3 + q^2 a_{31} a_{34} \alpha_3 \\
 &\quad + a_{26} a_{31} a_{34} \alpha_3 + 2q^2 a_{19} a_{32} a_{34} \alpha_3 \\
 &\quad - q^4 a_{21} b_7 \alpha_3 - 2q^2 a_{21} a_{31} b_7 \alpha_3 - 2q^2 a_{19} a_{33} b_7 \alpha_3 \\
 &\quad - 2q^2 a_{21} a_{32} b_8 \alpha_3 + q^2 a_{33} b_8 \alpha_3 + a_{26} a_{33} b_8 \alpha_3 - q^2 a_{10} a_{26} \varepsilon_3 \\
 &\quad - a_{10} a_{27} a_{30} \varepsilon_3 + q^4 a_{20} a_{32} \varepsilon_3 - q^2 a_{10} a_{34} \varepsilon_3 \\
 &\quad - a_{10} a_{26} a_{34} \varepsilon_3 + 2q^2 a_{20} a_{32} a_{34} \varepsilon_3 + 2q^2 a_{10} a_{21} b_7 \varepsilon_3 \\
 &\quad - 2q^2 a_{20} a_{33} b_7 \varepsilon_3) \\
 A[5] &= -(-q^2 a_{26} a_{31} a_{34} \alpha_3 - a_{27} a_{30} a_{31} a_{34} \alpha_3 - q^4 a_{19} a_{32} a_{34} \alpha_3 \\
 &\quad + q^4 a_{21} a_{31} b_7 \alpha_3 + q^4 a_{19} a_{33} b_7 \alpha_3 + q^4 a_{21} a_{32} b_8 \alpha_3 \\
 &\quad - q^2 a_{26} a_{33} b_8 \alpha_3 - a_{27} a_{30} a_{33} b_8 \alpha_3 + q^2 a_{10} a_{26} a_{34} \varepsilon_3 \\
 &\quad - a_{10} a_{27} a_{30} a_{34} \varepsilon_3 - q^4 a_{20} a_{32} a_{34} \varepsilon_3 - q^4 a_{10} a_{21} b_7 \varepsilon_3 \\
 &\quad - q^4 a_{20} a_{33} b_7 \varepsilon_3)
 \end{aligned}$$

The main parameters in equations (64-73) can be expressed as:

$$\begin{aligned}
 a_n^* &= -\frac{\varepsilon_3}{k_n^2 - \alpha_3}, b_n^* = \frac{-k_n^4 - k_n^2 (a_n^* a_{10} - a_{31} - a_{34}) + a_n^* a_{10} a_{34} - a_{31} a_{34} - a_{33} b_8}{k_n^2 a_{32} - a_{32} a_{34} + a_{33} b_7}, \\
 c_n^* &= -\frac{-k_n^2 b_7 - a_n^* a_{10} b_7 + a_{31} b_7 + a_{32} b_8}{k_n^2 a_{32} - a_{32} a_{34} + a_{33} b_7}, d_n^* = \frac{a_{30} b_n^*}{-k_n^2 + q^2}, e_1 = -iq.
 \end{aligned}$$

## Nomenclature

$\lambda, \mu$	Counterparts of Lamé's parameters
$\delta_n$	The difference of deformation potential of conduction and valence band
$T$	Absolute temperature (thermodynamic temperature)
$T_0$	Temperature of the medium in its natural state assumed to be $ \frac{T-T_0}{T_0}  < 1$
$\gamma = (3\lambda + 2\mu + k)\alpha_t$	The volume thermal expansion
$\alpha_t$	The linear thermal expansion coefficient
$\sigma_{ij}$	Components of the stress tensor
$\rho$	Density of the medium
$e$	Cubical dilatation
$C_e$	Specific heat at constant strain of the solid plate
$k$	The thermal conductivity of the sample
$D_E$	The carrier diffusion coefficient
$\tau$	The photogenerated carrier lifetime
$E_g$	The energy gap of the semiconductor
$e_{ij}$	Components of strain tensor
$m_{ij}$	Couple stress tensor
$\tau_0, \nu_0$	Thermal relaxation times
$\alpha, \lambda_0, \varsigma_1, \omega_0, m, \psi$	The material constants due to presence of voids
$\varphi$	The change in volume fraction field
$d_n$	The deformation potential difference
$K$	The thermal conductivity in the general case
$h$	The induced magnetic field
$H_0$	The initial uniform magnetic field
$E$	The induced electric field
$\epsilon_0$	The electric permeability for free space
$\mu_0$	The magnetic permeability for free space
$J$	The current density