Photothermoelastic deformation in dual phase lag model due to concentrated inclined load

Nidhi Sharma*
Department of Mathematics
MMDU, Mullana
Ambala
nidhi_kuk26@rediffmail.com

Rajneesh Kumar
Department of Mathematics
Kurukshetra University
Kurukshetra
India
rajneesh_kuk@rediffmail.com

Abstract. Existing problem is regarding the deformation of photothermoelastic solid with dual phase lag (DPL) by applying inclined load.Here inclined is considered as the consolidation of horizontal and vertical strengths. The displacement, stress, temperature distribution and carrier density are obtained by using Laplace and Fourier transform. These are also computed numerically for silicon material and presented graphically to analyze the photothermal effect on considered physical variables. Notable cases are drawn out from this problem.

Keywords: photo-thermal, semiconductor, inclined load, Laplace and Fourier transforms.

1. Introduction

Generalized thermoelasticity have many applications in various fields of engineering including soil dynamics, oil extraction, mineral exploration, earthquake prediction and many more. With the advancement in the technologies, semiconducting materials (as silicon (Si)) were used in various branches of engineering and material science.

Over the past few years, the study of semiconductor materials through both photoacoustic and photothermal technologies [1,2] are regarded as accepted approach. Mandelis and Hess [3] explored the effective personification in the analysis of photoacoustic and photothermal technologies. The new law of heat conduction take the place of the classical Fourier law and was established as the generalized thermoelastic theory with one relaxation time suggested by Lord and Shulman [4]. Green and Lindsay [5] popularized another generalized thermoelasticity theory with two relaxation times. For an anisotropic body the theories

*. Corresponding author

of generalized thermoelasticity were continued by Sherief and Dhaliwal [6]. Tzou [7] examined the heat conduction from imperceptible to perceptible extend. The analytical and empirical sense of the Dual phase lag model have been supported in Tzou [8]. Abbas and Zenkor [9] explored the deformation problem with special function applied on temperature in dual phase lag model. Numerical study of heat transfer and Hall current impact on peristaltic propulsion of particle-fluid suspension with compliant wall properties have been examined by Bhatti et al. [10]. Many authors [11-13] studied the effects of electronic deformation in photothermoelastic materials.

Zenkor, Abouelregal and Aifantis [14] discussed the deformation problem in two-temperature dual-phase-lags theory due to inclined load. Marin, Agarwal and Codarcea [15] studied a mathematical model for three-phase-lag dipolar thermoelastic bodies. By applying fractional order photo-thermoelasticity, Hobiny and Abbas [16] studied problem of wave propagation in photothermoelastic medium. Photothermal interactions with dual phase lag in a semiconductor medium containing a sphere with a hole using spherical polar coordinates was discussed by Hobiny and Abbas [17]. Lotfy [18] studied photo-thermal elastic waves in semiconductor medium with pluse heat flux. The study of Photo-thermal-elastic waves in a functionally graded material was investigated by Lotfy and Tantawi [19].

Different authors [20-24] discussed different problems in various mediums such as elastic, thermoelastic and micropolar elastic by applying inclined load. Regardless of this, the problem of photothermoelastic medium due to inclined load was not done before.

2. Basic equations

Following [4, 7, 25, 26] as

$$K\left(1+t_T\frac{\partial}{\partial t}\right)\theta_{,jj} = -\frac{E_g}{\tau}N+\left(1+t_q\frac{\partial}{\partial t}+m\frac{t_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left(\rho C_e\frac{\partial\theta}{\partial t}+\gamma_t T_0\frac{\partial u_{j,j}}{\partial t}\right), \tag{1}$$

$$D_e N_{,jj}=\frac{\partial N}{\partial t}+\frac{N}{\tau}-k\frac{\theta}{\tau}, \tag{2}$$

$$(\lambda+\mu)u_{j,ij}+\mu u_{i,jj}-\gamma_n N_{,i}-\gamma_t\theta_{,i}=\rho\ddot{u}_i,$$

$$\sigma_{ij}=\left(\lambda u_{j,j}-\gamma_n N-\gamma_t\theta\right)\delta_{ij}+\mu\left(u_{i,j}+u_{j,i}\right), \tag{3}$$

$0 \prec t_T \prec t_q, m = 1$ (DPL model), $t_q = t_0 \succ 0, t_T = m = 0$ (LS theory), $t_q = t_T = m = 0$ (CT theory), where $N = n - n_0$, n_0-initial carrier concentration, $\theta = T - T_0$, T_0-initial temperature, u_i-displacement components,$t_q$and t_T-times, t_0-thermal relaxation time, C_e- specific heat, K-thermal conductivity, ρ-density, σ_{ij}-stress tensors, $\gamma_t = (3\lambda + 2\mu)\alpha_t$, α_t is the linear thermal expansion coefficient, D_e-carrier diffusion coefficient, λ and μ-Lame's constants,

τ-photo-generated carrier lifetime, E_g-semiconductor energy gap, E-excitation energy, $\gamma_n = (3\lambda + 2\mu)\, d_n$, d_n-electronic deformation coefficient and $k = \frac{\partial n_0}{\partial \theta}$, t-time. A superposed dot represents differentiation with respect to time variable t. δ_{ij}-kronecker delta.

3. Construction of the problem and solution methodology

A semiconductor medium with reference temperature T_0 permeated by an inclined line load F_0 acting on the y-axis is considered Figure (a). For two dimensional problem.

The components of displacement vector $\vec{u}$as $u_1 = u_1(x, z, t)$ and $u_3 = u_3(x, z, t)$.

N as $N = N(x, z, t)$, θ as $\theta = \theta(x, z, t)$.

In two dimensional $x - z$ plane (1)-(3) can be written as

$$\begin{aligned} & K\left(1+t_T\frac{\partial}{\partial t}\right)\left(\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial z^2}\right) \\ & = -\frac{E_g}{\tau}N+\left(1+t_q\frac{\partial}{\partial t}+m\frac{t_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left(\rho C_e\frac{\partial\theta}{\partial t}+\gamma_t T_0\left(\frac{\partial^2 u_1}{\partial t\partial x}+\frac{\partial^2 u_3}{\partial t\partial z}\right)\right), \end{aligned} \tag{4}$$

$$D_e\left(\frac{\partial^2 N}{\partial x^2}+\frac{\partial^2 N}{\partial z^2}\right)=\frac{\partial N}{\partial t}+\frac{N}{\tau}-k\frac{\theta}{\tau}, \tag{5}$$

$$(\lambda+2\mu)\frac{\partial^2 u_1}{\partial x^2}+\mu\frac{\partial^2 u_1}{\partial z^2}+(\lambda+\mu)\frac{\partial^2 u_3}{\partial x\partial z}-\gamma_n\frac{\partial N}{\partial x}-\gamma_t\frac{\partial\theta}{\partial x}=\rho\frac{\partial^2 u_1}{\partial t^2}, \tag{6}$$

$$(\lambda+2\mu)\frac{\partial^2 u_3}{\partial z^2}+\mu\frac{\partial^2 u_3}{\partial x^2}+(\lambda+\mu)\frac{\partial^2 u_1}{\partial x\partial z}-\gamma_n\frac{\partial N}{\partial z}-\gamma_t\frac{\partial\theta}{\partial z}=\rho\frac{\partial^2 u_3}{\partial t^2}. \tag{7}$$

To smoothen the solution, the non-dimensional variables are proposed

$$\begin{aligned} & \left(x', z', u_1', u_3'\right)=\eta C\left(x, z, u_1, u_3\right), \left(t_{11}', t_{31}', t_{33}'\right)=\frac{1}{\mu}\left(t_{11}, t_{31}, t_{33}\right), \\ & \theta'=\frac{\theta}{T_0}, \left(t', \tau', \tau_0'\right)=\eta c^2\left(t, \tau, \tau_0\right), N'=\frac{N}{n_0}, F_n'=\frac{F_n}{\mu}, F_t'=\frac{F_t}{\mu}, \end{aligned} \tag{8}$$

where $c^2 = \frac{\lambda+2\mu}{\rho}, \eta = \frac{\rho C_E}{K}$.

In non-dimensional form, (4)-(7) takes the form

$$\begin{aligned} & \left(1+t_T\frac{\partial}{\partial t}\right)\left(\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial z^2}\right) \\ & = -\in_2\frac{N}{\tau}+\left(1+t_q\frac{\partial}{\partial t}+m\frac{t_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left(\frac{\partial\theta}{\partial t}+\in_1\left(\frac{\partial^2 u_1}{\partial t\partial x}+\frac{\partial^2 u_3}{\partial t\partial z}\right)\right), \end{aligned} \tag{9}$$

$$\left(\frac{\partial^2 N}{\partial x^2}+\frac{\partial^2 N}{\partial z^2}\right)=\alpha\frac{\partial N}{\partial t}+\alpha\frac{N}{\tau}-\beta\frac{\theta}{\tau}, \tag{10}$$

$$\frac{\partial^2 u_1}{\partial x^2}+g_2\frac{\partial^2 u_1}{\partial z^2}+g_1\frac{\partial^2 u_3}{\partial x\partial z}-\beta_n\frac{\partial N}{\partial x}-\beta_t\frac{\partial\theta}{\partial x}=\frac{\partial^2 u_1}{\partial t^2}, \tag{11}$$

$$\frac{\partial^2 u_3}{\partial z^2}+g_2\frac{\partial^2 u_3}{\partial x^2}+g_1\frac{\partial^2 u_1}{\partial x\partial z}-\beta_n\frac{\partial N}{\partial z}-\beta_t\frac{\partial\theta}{\partial z}=\frac{\partial^2 u_3}{\partial t^2} \tag{12}$$

where $g_1=\frac{\lambda+\mu}{\lambda+2\mu},\ g_1=\frac{\mu}{\lambda+2\mu},\ \ \beta_n=\frac{\gamma_n n_0}{\lambda+2\mu},\ \ \beta_n=\frac{\gamma_t T_0}{\lambda+2\mu},\ \alpha=\frac{1}{D_e\eta},\ \ \beta=\frac{kT_0}{D_e\eta n_0},$

$$\varepsilon_1=\frac{\gamma_t}{K\eta},\quad \varepsilon_2=\frac{E_g n_0}{T_0\eta K}.$$

The expressions relating displacement components $u_1(x,z,t)$and$u_3(x,z,t)$to the scalar potential functions$\phi(x,z,t)$and $\psi(x,z,t)$ in a dimensionless form are given by

$$u_1=\frac{\partial\phi}{\partial x}-\frac{\partial\psi}{\partial z},u_3=\frac{\partial\phi}{\partial z}+\frac{\partial\psi}{\partial x}. \tag{13}$$

Laplace and Fourier transforms determined as

$$\bar{f}(x,z,s)=\int_0^\infty f(x,z,t)e^{-st}dt \tag{14}$$

$$\hat{f}(\xi,z,s)=\int_{-\infty}^\infty \bar{f}(x,z,s)\ e^{i\xi x}, \tag{15}$$

applied on (9)-(12) along with (13) yields

$$\left\{\left(\frac{d^2}{\partial z^2}-\xi^2\right)(1+t_T s)-\left(1+t_q s+m\frac{t_q^2}{2}s^2\right)s\right\}\hat{\theta}$$
$$+\in_2\frac{\hat{N}}{\tau}-\left\{\in_1 s\left(\frac{d^2}{dz^2}-\xi^2\right)\left(1+t_q s+m\frac{t_q^2}{2}s^2\right)\right\}\hat{\phi}=0, \tag{16}$$

$$\left(\frac{\partial^2}{\partial z^2}-\xi^2-\alpha s-\frac{\alpha}{\tau}\right)\hat{N}+\frac{\beta}{\tau}\hat{\theta}=0, \tag{17}$$

$$\left\{\frac{d^2}{\partial z^2}-\left(\xi^2+s^2\right)\right\}\hat{\phi}-\beta_n\hat{N}-\beta_t\hat{\theta}=0, \tag{18}$$

$$\left\{\frac{d^2\hat{\psi}}{\partial z^2}-\left(\xi^2+\frac{s^2}{g_2}\right)\right\}\hat{\psi}=0. \tag{19}$$

After simplification

$$\left(\frac{d^6}{dz^6}+L\frac{d^4}{dz^4}+M\frac{d^2}{dz^2}+N\right)(\hat{\phi},\hat{\theta},\hat{N})=0, \tag{20}$$

$$\left(\frac{d^2}{dz^2}-\lambda_4^2\right)\hat{\psi}=0, \tag{21}$$

where L,M and N are listed (Appendix A).

$\pm\lambda_j$ $(j = 1, 2, 3)$ specifies roots of (20) whereas$\pm\lambda_4$ give roots of (21).

The initial and regularity conditions are given by

$$u_1(x,z,0) = 0 = \dot{u}_1(x,z,0),$$
$$u_3(x,z,0) = 0 = \dot{u}_3(x,z,0),$$
$$\theta(x,z,0) = 0 = \dot{\theta}(x,z,0),$$
$$N(x,z,0) = 0 = \dot{N}(x,z,0) \text{ for } z \geq 0, -\infty < x < \infty,$$
$$u_1(x,z,t) = u_3(x,z,t) = \theta(x,z,t) = N(x,z,t) = 0,$$

for $t > 0$ when $z \to \infty$.

Using the radiation condition $\hat{\phi}, \hat{\theta}, \hat{N}$ and $\hat{\psi} \to 0$ as $z \to \infty$, the solution of (20) and (21) takes the form

$$\hat{\phi} = A_1 e^{-\lambda_1 z} + A_2 e^{-\lambda_2 z} + A_3 e^{-\lambda_3 z}, \tag{22}$$

$$\hat{\theta} = s_1 A_1 e^{-\lambda_1 z} + s_2 A_2 e^{-\lambda_2 z} + s_3 A_3 e^{-\lambda_3 z}, \tag{23}$$

$$\hat{N} = t_1 A_1 e^{-\lambda_1 z} + t_2 A_2 e^{-\lambda_2 z} + t_3 A_3 e^{-\lambda_3 z}, \tag{24}$$

$$\hat{\psi} = A_4 e^{-\lambda_4 z}. \tag{25}$$

$A_i (i = 1, 2, 3, 4)$ arbitrary constants. The coupling constants $s_l$and t_l are listed (Appendix B) .

4. Boundary conditions

$$(i) \quad t_{33} = -F_n \phi_1(x)\delta(t), \quad (ii) \quad t_{31} = -F_t \phi_2(x)\delta(t), \quad (iii) \ \theta = 0\,, \quad (iv) \quad N = 0, \tag{26}$$

where F_n and F_t-magnitude of forces, $\delta(t)$-Kronecker delta function, $\phi_1(x)$-vertical load distribution $\phi_2(x)$- horizontal load distribution.

Making use of (3), (8) and (13) in (26), applying (14)-(15) then substituting the values of $\hat{\phi}, \hat{\theta}, \hat{N}$and $\hat{\psi}$ from (22)-(25) in emerging mathematical statements, we acquire displacement, stress, temperature distribution and carrier density in Appendix C (C.1)-(C.6).

4.1 Concentrated force

In this case

(*) $\phi_1 = \delta(x), \phi_2(x) = \delta(x)$, with $\hat{\phi}_1(\xi) = 1, \hat{\phi}_2(\xi) = 1$.

Using (*) in (C.1)-(C.6).the required quantities are established for this source.

5. Utilization

F_0 Inclined load with angle of inclination δ is applied on y-axis

(**) $F_n = F_0 \cos\delta, F_t = F_0 \sin\delta$.

Using equation (**) in equations (C.1)-(C.6) and along with (*), we find the components for concentrated force applied on the surface of photothermoelastic medium (semiconductor medium).

6. Particular case

Leaving the photothermal reaction (i.e., $E_g = 0$, D_e=0, τ=0), in (C.1)-(C.6), with (*) and (**) we find the components in generalized thermoelastic half-space.

7. Inversion of the transformation

To acquire the results in the physical domain, invert the transforms in (C.1)-(C.6) by

$$(27)\quad \bar{f}(x,z,s) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\xi x}\hat{f}(\xi,z,s)d\xi = \frac{1}{\pi}\int_{0}^{\infty}(\cos(\xi x)f_e - i\sin(\xi x)f_0)d\xi,$$

where f_e and f_0 are, respectively, even and odd parts of the function $\hat{f}(\xi,z,s)$.

8. Numerical results and discussion

We choose silicon material for numerical purpose to show the theoretical results as by [27] $C_e = 695Jkg^{-1}k^{-1}$, $\mu = 5.46\times10^{10}Nm^{-2}$, $\lambda = 3.64\times10^{10}Nm^{-2}$, $E_g = 1.11eV$, $s_0 = 2ms^{-1}$, $E = 2.33eV$, $D_e = 2.5\times10^{-3}m^2s^{-1}$, $\alpha_t = 3\times10^{-6}k^{-1}$, $K = 150Wm^{-1}k^{-1}$, $\rho = 2330kgm^{-3}$, $\tau = 5\times10^{-5}s$, $n_0 = 10^{20}m^{-3}$, $d_n = -9\times10^{-31}m^3$, $T_0 = 300k$, u_3, t_{33}, θ and N for Dual phase phtothermoelasticity (DP) and without photothermelasticity with dual phase(WPD) (for $\delta = 0^0$ and $\delta = 90^0$ and variations of u_3, t_{33}, θ and N with x. Taking $t = 0.5$ (dimensionless). The solid line and the small dashed without center symbol predict the variations DP for different values of δ whereas the solid and the small dashed and with center symbol predict the variations of WDP for different $\delta's$.

Figure 1 it is noted that for WPD, u_3 starts with its maximum values at $\delta = 0^0$ and shows small variation at $\delta = 90^0$ whereas for DP it follows oscillatory pattern at both angles. Gradually u_3 decrease to lowest values for all the cases. The values of u_3 for WPD are greater DP in the entire range at both angles.

Figure 2 t_{33} follows an oscillatory pattern for both DP and WPD at both initial and extreme angles of inclination. Further the values of t_{33} terminates to zero obeying the boundary conditions. Near the loading surface, t_{33} for WPD at extreme angle is greater than all other cases but with advancement in$x$, attains minimum values with oscillatory pattern.

It is evident from Figure 3 that the trend of variation θ is similar for both DP and WPD at both $\delta's$. Near the loading surface at $\delta = 0^0$the values of $\theta$for

DP is more than for WPD whereas the behavior is reverse at $\delta = 90^0$. Further with increase in x the values start oscillating but magnitude of oscillation is small for DP, showing the photothermal effect. Also, with advancement in x the curves converges to boundary.

The variation of carrier density N as in fig.4.At the point where source is applied, for both initial and extreme angel there is a sharp decrease in N. With increase in x, at $\delta = 0^0$its start increasing in $2 \leq x \leq 5$then follow oscillatory pattern whereas at $\delta = 90^0$ shows small variations near zero.

9. Conclusion

A two-dimensional problem of phothothermoelastic model with dual phase lag has been examined by employing dimensionless quantities. The problem is simplified by using potential functions and then by applying Laplace and Fourier transform to examine the problem. The deformation due to inclined load has been considered to display the application of the problem. From the numerical result obtained the following conclusions are drawn:

1. As viewed figures that photothermo have oscillatory result on the physical quantities obtained after computational process.

2. It is noticed that the field quantities are affected by different angle of inclination with and without dual phage lag.

3. The results obtained in this study are advantageous to analyst involved in material science, engineering, physicists in addition to people active in the area of continuum mechanics.

Appendix A

L, M and N as:

$$
\begin{aligned}
&L = \frac{1}{E}[F - 3\xi^2 E]\ ,\ \ M = \frac{1}{E}[G - 2F\xi^2 + 3\xi^4 E],\\
&N = \frac{1}{E}[F\xi^4 - G\xi^2 + H - E\xi^6], \lambda_4^2 = \xi^2 + \frac{s^2}{g_2},\\
&E = n_1, F = n_2 s\left(-1 + \varepsilon_1 \beta_t\right) + n_1\left(\frac{\alpha}{\tau} - \alpha s + s^2\right),\\
&H = \frac{\beta \varepsilon_2 s^2}{\tau^2} + \frac{\alpha n_2 s^2}{\tau} + \alpha s^3 n_2,\\
&G = \frac{\beta}{\tau}\left(-\varepsilon_2 + \varepsilon_1 s n_2 \beta_n\right) - \alpha n_2\left(s + \frac{1}{\tau}\right) + n_2 s^3 + n_1 \alpha s^2\left(s - \frac{1}{\tau}\right)\\
&\quad + \varepsilon_1 s n_2 \beta_t\left(1 - \alpha s + \frac{1}{\tau}\right),
\end{aligned}
$$

$$n_1 = (1 + t_T s), n_2 = \left(1 + t_q s + m s^2 \frac{t_q^2}{2}\right).$$

Appendix B

s_l and t_l are $s_l = \frac{P^* \lambda_l^2 + Q^*}{R^* \lambda_l^2 + S^*}, t_l = \frac{U^* \lambda_l^2 + V^*}{X^* \lambda_l^2 + T^*}, l = 1, 2, 3,$

$$P^* = \frac{a_1 + 1}{a_1}, U^* = n_1, Q^* = -\left[(\xi^2 + s^2) + \frac{\xi^2}{a_1}\right],$$
$$V^* = \xi^2 (-n_1 + n_2) - \frac{\varepsilon_2 \beta_t}{\tau \beta_n},$$
$$T^* = -\frac{\varepsilon_2 \xi^2}{\beta_n \tau} (1 + \varepsilon_1 s n_2),$$
$$R^* = \frac{1}{\varepsilon_1 a_1 s (1 + \tau_0 s)}, X^* = \frac{\varepsilon_2}{\beta_n \tau} \left(s^2 + \varepsilon_1 s n_2\right),$$
$$S^* = 1 - \frac{1}{\varepsilon_1 a_1 s (1 + \tau_0 s)} (\xi^2 + (1 + \tau_0 s) s).$$

Appendix C

Displacement, stress, and temperature distribution and carrier density are:

(C.1) $\hat{u}_1 = \frac{1}{\Delta}\{F_n \hat{\phi}_1(\xi)[(-i\xi)(\Delta_1 e^{-\lambda_1 z} - \Delta_3 e^{-\lambda_2 z} + \Delta_5 e^{-\lambda_3 z}) + \lambda_4 \Delta_7 e^{-\lambda_4 z}] + F_2 \hat{\phi}_2(\xi)[(-i\xi)(\Delta_2 e^{-\lambda_1 z} - \Delta_4 e^{-\lambda_2 z} + \Delta_6 e^{-\lambda_3 z}) - \lambda_4 \Delta_8 e^{-\lambda_4 z}]\};$

(C.2) $\hat{u}_3 = \frac{-1}{\Delta}\{F_n \hat{\phi}_1(\xi)(\xi)[\lambda_1 \Delta_1 e^{-\lambda_1 z} - \lambda_2 \Delta_3 e^{-\lambda_2 z} + \lambda_3 \Delta_5 e^{-\lambda_3 z}) + i\xi \Delta_7 e^{-\lambda_4 z}] + F_t \hat{\phi}_2(\xi)[\lambda_1 \Delta_2 e^{-\lambda_1 z} - \lambda_2 \Delta_4 e^{-\lambda_2 z} + \lambda_3 \Delta_6 e^{-\lambda_3 z}) - i\xi \Delta_8 e^{-\lambda_4 z}]\};$

(C.3) $\hat{t}_{33} = \frac{1}{\Delta}\{F_n \hat{\phi}_1(\xi)(\xi)[s_1 \Delta_1 e^{-\lambda_1 z} - s_2 \Delta_3 e^{-\lambda_2 z} + s_3 \Delta_5 e^{-\lambda_3 z} + s_4 \Delta_7 e^{-\lambda_4 z}] + F_t \hat{\phi}_2(\xi)\xi)[s_1 \Delta_2 e^{-\lambda_1 z} - s_2 \Delta_4 e^{-\lambda_2 z} + s_3 \Delta_6 e^{-\lambda_3 z} - s_4 \Delta_8 e^{-\lambda_4 z}]\};$

(C.4) $\hat{t}_{31} = \frac{1}{\Delta}\{F_n \hat{\phi}_1(\xi)[\lambda_1 \Delta_1 e^{-\lambda_1 z} - \lambda_2 \Delta_3 e^{-\lambda_2 z} + \lambda_3 \Delta_5 e^{-\lambda_3 z} - m_1 \Delta_7 e^{-\lambda_4 z}] + F_t \hat{\phi}_1(\xi)[\lambda_1 \Delta_2 e^{-\lambda_1 z} - \lambda_2 \Delta_4 e^{-\lambda_2 z} + \lambda_3 \Delta_6 e^{-\lambda_3 z} + m_1 \Delta_8 e^{-\lambda_4 z}]\};$

(C.5) $\hat{\theta} = \frac{1}{\Delta}\{F_n \hat{\phi}_1(\xi)[d_1 \Delta_1 e^{-\lambda_1 z} - d_2 \Delta_3 e^{-\lambda_2 z} + d_3 \Delta_5 e^{-\lambda_3 z}] + F_t \hat{\phi}_2(\xi)[d_1 \Delta_2 e^{-\lambda_1 z} - d_2 \Delta_4 e^{-\lambda_2 z} + d_3 \Delta_6 e^{-\lambda_3 z}]\};$

(C.6) $\hat{N} = \frac{1}{\Delta}\{F_n \hat{\phi}_1(\xi)[t_1 \Delta_1 e^{-\lambda_1 z} - t_2 \Delta_3 e^{-\lambda_2 z} + t_3 \Delta_5 e^{-\lambda_3 z}] + F_t \hat{\phi}_2(\xi)(\xi)[t_1 \Delta_2 e^{-\lambda_1 z} - t_2 \Delta_4 e^{-\lambda_2 z} + t_3 \Delta_6 e^{-\lambda_3 z}]\}.$

where

$$\Delta = \mu\{[-s_4\lambda_1 - m_1 s_1]\Delta_{10} + [s_4\lambda_2 + m_1 s_2]\Delta_{20} + [-s_4\lambda_3 - m_1 s_3]\Delta_{30}\},$$
$$\Delta_{1,2} = (\mu\lambda_3, s_4)\Delta_{10}, \Delta_{3,4} = (\mu\lambda_4, s_4)\Delta_{20},$$
$$\Delta_{5,6} = (\mu\lambda_4, s_4)\Delta_{30}, \Delta_7 = \mu[\lambda_1\Delta_{10} - \lambda_2\Delta_{20} + \lambda_3\Delta_{30}],$$
$$s_l = b_1\lambda_l^2 - b_2 i\xi - b_3 e_l - b_4 d_l, \quad (l = 1, 2, 3), s_4 = (i\xi b_1 + b_2)\lambda_4,$$
$$b_1 = \frac{(\lambda + 2\mu)}{\mu}, b_2 = \frac{\lambda}{\mu}, b_3 = \frac{\gamma_n n_0}{\mu}, b_4 = \frac{\gamma_t T_0}{\mu}, m_1 = \frac{\lambda_4^2 + \xi^2}{2i\xi}.$$

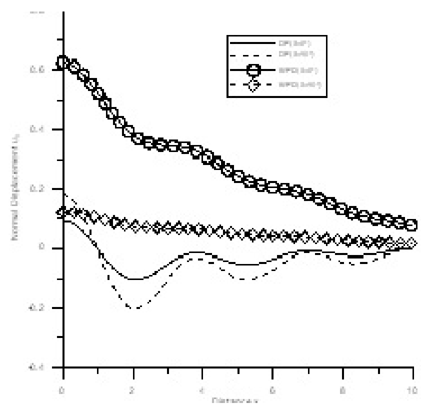

Figure 1: Variation of Normal Displacement with x

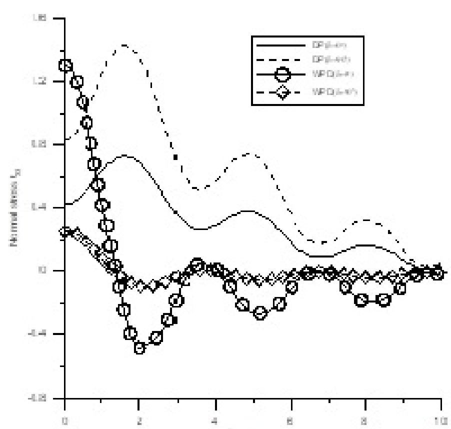

Figure 2: Variation of Normal Stress with x

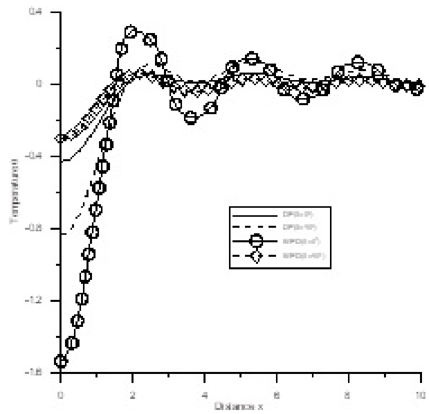

Figure 3: Variation of Temperature with x

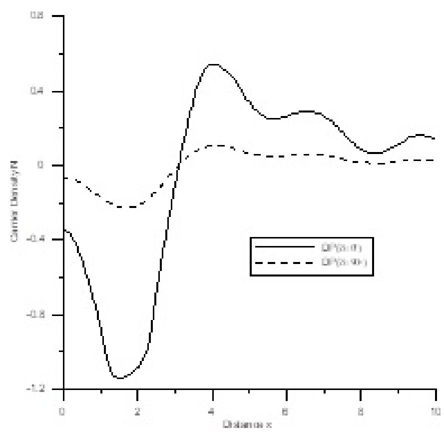

Figure 4: Variation of Carrier Density with x

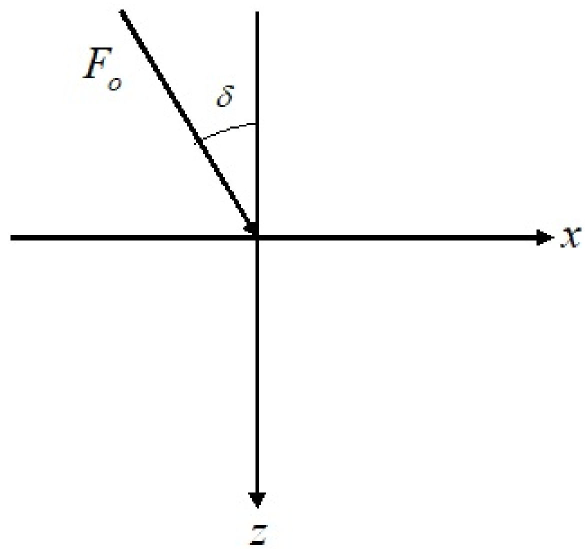

Figure 5: Inclined load over a semiconductor medium

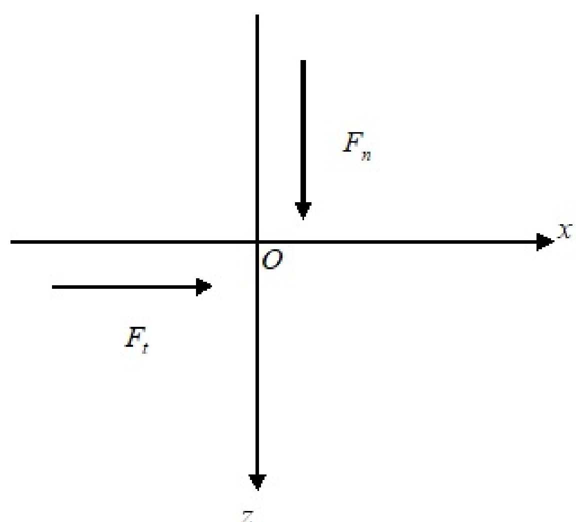

Figure 6: Normal and tangential loadings

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