Date. 21. Oct. 19.

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Phase and Group velocity of EM waves

Aim: To understand the nature of EM waves travelling in a medium with the help of phase and group velocities.

Theory:

Any real signal consists of travelling waves of many diff. frequencies, which travel together as a group, at a speed that will always be less than or equal to speed of light in vacuum. To gain some insight into what may happen when real signal travels through a dispersive medium, we consider adding two waves of equal amplitude $f_1(z,t) = \cos(k_1 z - \omega_1 t)$ and $f_2(z,t) = \cos(k_2 z - \omega_2 t)$ are added we get

$$f_1(z,t) + f_2(z,t) = 2\cos\left(\frac{\Delta k z - \Delta \omega t}{2}\right) \times \cos(\bar{k} z - \bar{\omega} t)$$

$$\bar{k} = \frac{k_1 + k_2}{2}, \quad \bar{\omega} = \frac{\omega_1 + \omega_2}{2}$$

(Note: $\frac{\Delta k}{2} = \frac{k_1 + k_2}{2}$, $\frac{\Delta \omega}{2} = \frac{\omega_1 + \omega_2}{2}$)

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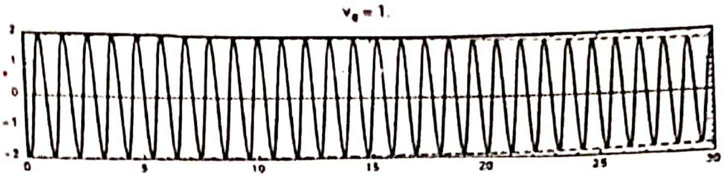
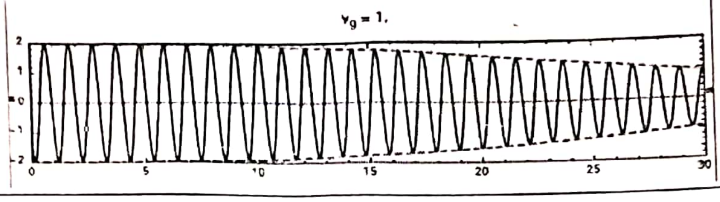
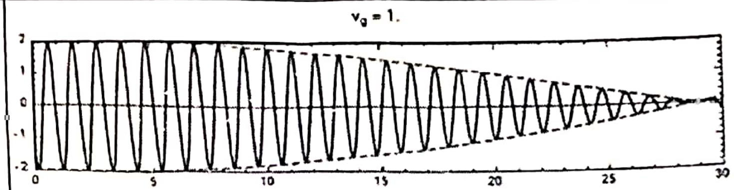
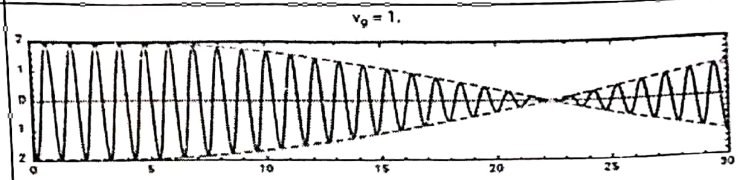
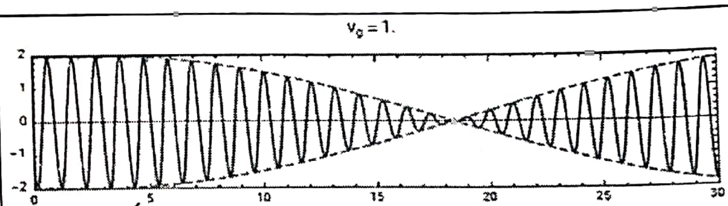
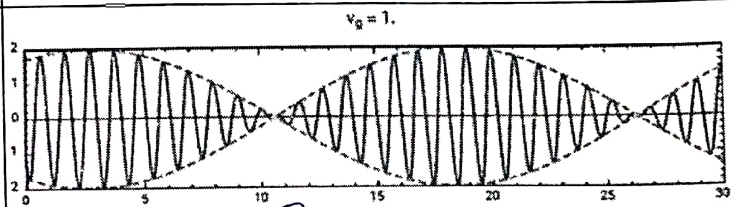
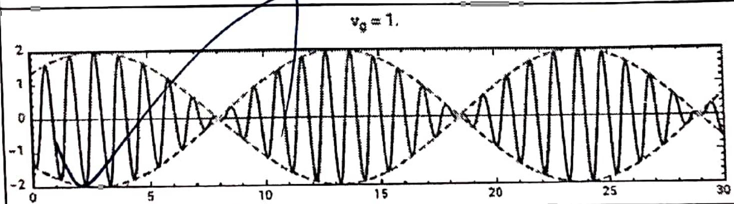
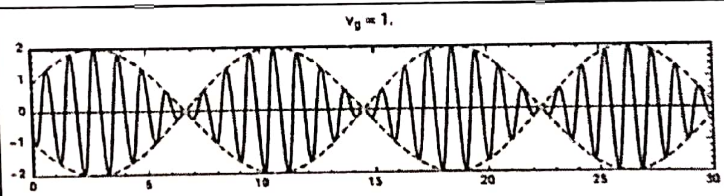
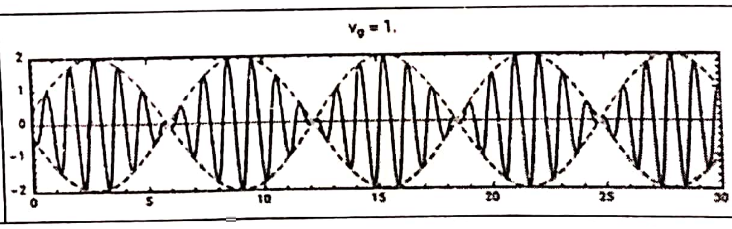
S.No.	Δω	ΔK	wave pattern of resultant waves	V_g.
1	0.02	0.02		
2	0.04	0.04		
3	0.06	0.06		
4	0.08	0.08		
5	0.1	0.1		
6	0.2	0.2		
7	0.3	0.3		
8	0.4	0.4		
9	0.5	0.5		

no.	Δω	Δk	Wave pattern of the resultant waves	V_g
	0.02	0.02		1m/s
2	0.04	0.04		1m/s
3	0.06	0.06		1m/s
4	0.08	0.08		1m/s
5	0.1	0.1		1m/s
6	0.2	0.2		1m/s
7	0.3	0.3		1m/s
8	0.4	0.4		1m/s
9	0.5	0.5		1m/s

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The result is fast oscillating waves that travels with phase velocity $V_p = \bar{\omega}/\bar{k}$ and the amplitude of this wave is being modulated in space and time by $2\cos\left(\frac{\Delta k z}{2} - \frac{\Delta \omega t}{2}\right)$. This modulated wave ~~exists~~ travels at the group velocity is given by $V_g = \frac{\Delta\omega}{\Delta k}$

Inference:

1. Are the wave patterns for various values of $\Delta\omega$ and Δk same? if not, why?

2. Comment on the phase velocity (V_p) of the waves for increased values of $\Delta\omega$ and ΔK.

3. When do we see V_p and V_g being same.

4. Draw a typical dispersion relation ~~curve~~ curve (ω-k) curve

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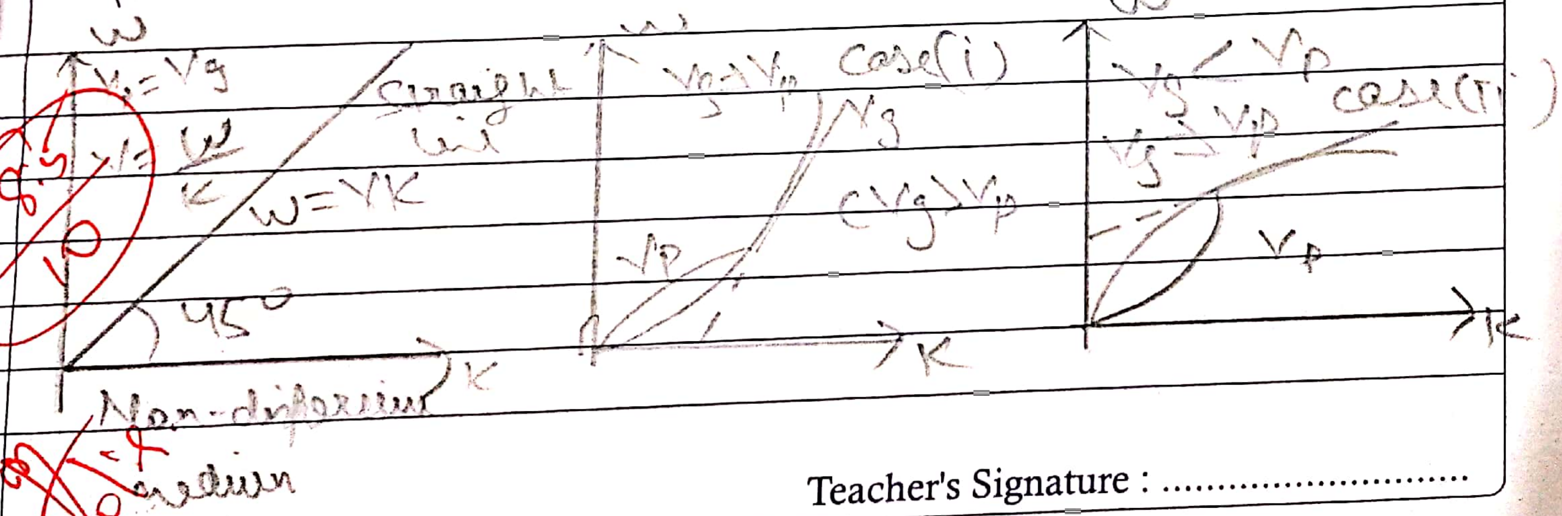
Answers -

(1) No, the wave patterns of various values of Δw and ΔK are different because the modulation of the wave propagation through space and time and this is written as $2\cos\left(\frac{\Delta K}{2}z - \frac{\Delta w}{2}t\right)$

(2) There will be no change of phase velocity (V_p) for various increased value of Δw and ΔK are related, so, phase velocity for the waves for increased values of Δw and ΔK is same.

(3) In non-dispersive medium, we see V_p and V_g being the same or equal because of when two monochromatic waves are propagating in ~~other~~ vaccum, they have the same velocity c, the speed of light in vaccum and the superposed waves phase velocity is equal to group velocity



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