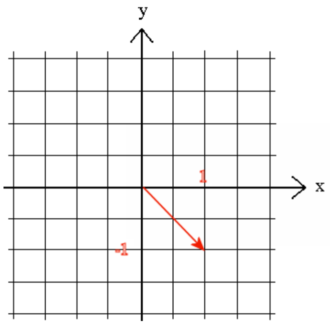
Problem 1: (A)

Sinusoidal plane waves: $\hat{z}\cdot\vec{r} = z$, exp(i(kz + ωt) represents a wave moving in the negative z-direction.

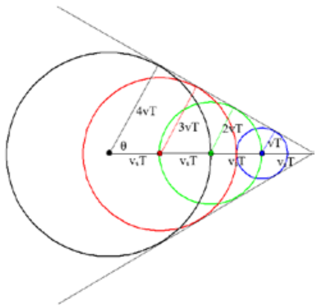
$\hat{x} - \hat{y}$ is a real vector pointing along the diagonal.

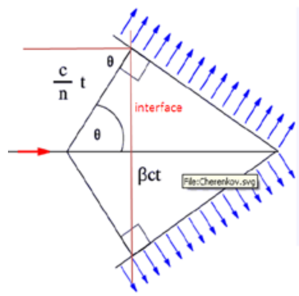


Problem 2: (E)

Critical angle for total internal reflection: sinθ = (1/n) = 2/3, cosθ = $(5/9)^{1/2}$.

What is the angle for the shockwave? (When do we have constructive interference?)
Consider the emission of two successive crests.





We have constructive interference when cosθ = $vT/(v_sT) = v/v_s$.
Here v_s = βc and v = c/n. Therefore cosθ = 1/(βn).
$(9/5)^{1/2}$ = nβ, β = (2/3) $(9/5)^{1/2}$ = (36/45)$1^{/2}$ = $(4/5)^{1/2}$.

Problem 3: (C)

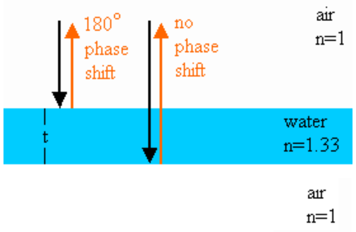
Doppler shift for sound: Both observer and source are moving with the same velocity with respect to the medium.
[Let v = speed of sound.
$f = f_0(v - v_{obs})/(v - v_s)$
where v_{obs} and v_s are not the speeds, but the components of the observer's and the source's velocity in the direction of the velocity of the sound reaching the observer.
f increases if the source and the observer approach each other and decreases if they recede from each other.]

Problem 4: (B)

Thin film interference: When a light wave reflects from a medium with a larger index of refraction, then the phase shift of the reflected wave with respect to the incident wave is π (180^o). When a light wave reflects from a medium with a smaller index of refraction, then the phase shift of the reflected wave with respect to the incident wave is zero.

$2n_{water}t = (m + 1/2)\,\lambda$, m = 0,1,2,…. For constructive interference

$\lambda = 2*1.33*t/(m+1/2)$, $\lambda_1/\lambda_0 = 0.5/1.5 = 1/3$. $\lambda_1 = 540/3$ nm.



Problem 5: (E)

Focal length of a thin lens: $1/f = (n-1)(1/R_1 - 1/R_2)$

Problem 6: (D)

Diffraction: $w \sin\theta = m\,\lambda$ → diffraction minima

$0.14m/1.41 = \lambda = 350/f$.

Problem 7: (B)

Interference: A hologram is an interference pattern.

Problem 8: (E)

Phase: 6 boxes = 360^o, phase difference = 2 boxes = 120^o.

Problem 9: (D)

Double slit interference: We only get zero intensity at the minima of the double slit interference pattern if the single slit intensity at that position is the same for both slits.

Problem 10: (C)

Resolution limit: $\theta_{min} = 1.22\,\lambda/D \sim \lambda/D$.

$D \sim \lambda/\theta_{min} = 0.07$ m.

Problem 11: (D)

Linear polarizers: $I = I_0 \cos^2(\theta)$, where θ is the angle between the polarization and the transmission axis.

Unpolarized light → first polarizer transmits 50%. Second polarizer transmits 50% of the light that passed through the first polarizer.

Problem 12: (E)

Doppler shift for EM waves: $f' = f*([1- v/c)/(1 + v/c)]^{1/2}$,

$(1/16)(1 + v/c) = (1 - v/c)$. $15/16 = (v/c)(17/16)$, $v/c = 15/17$.

Problem 13: (B)

Fourier Series: Let f(t) be a periodic function. Then we may write

$f(t) = A_0/2 + \Sigma_{n=1}^{\infty} A_n\cos(\omega_n t) + \Sigma_{n=1}^{\infty} B_n\sin(\omega_n t)$

For the given f(t) = V(t), an odd function, all the A_n must be zero. The B_n with n = even also must be zero, since the associated sine functions look the same in the interval where V(t) is positive and where V(t) is negative.

Problem 14: (E)

Mirror equation: $1/x_o + 1/x_i = 1/f = 2/R$ (Remember the sign convention!)

Here the radius of curvature is negative. $1/R + 1/x_i = -2/R$, $x_i = -R/3$.

Problem 15: (D)

Superposition of waves: The displacements add vectorially.