Midterm: Monday Nov 2, 2026 Name:_____

Allowed: Formula sheet (given), calculator, 1 hour 50 mins

PART 1 – answer questions **1-8** in your exam booklet and **then** use your scratch card:
One scratch = **100%**; two scratches = **33%**; three scratches = **25%** (part 1 total is 50%)
PART 2 – answer questions **9 & 10** in the exam booklet provided (each question is worth 25%)

Qu's 1-2) A 100 mW laser beam with propagation constant k and angular frequency ω travelling in the the $+\hat{\mathbf{z}}$ direction has a radius of 1 mm .

1) What is the intensity averaged across the beam?

A. 68 kW/m^2 **B.** 54 kW/m^2 **C.** 32 kW/m^2 **D.** 76 kW/m^2 **E.** 88 kW/m^2

2) What is the most realistic expression for the electric field of this beam?

A. $\vec{\mathbf{E}} = 155\cos(kz-\omega t)\hat{\mathbf{z}}$ V/m **B.** $\vec{\mathbf{E}} = 125\cos(ky-\omega t)\hat{\mathbf{y}}$ V/m **C.** $\vec{\mathbf{E}} = 155\cos(ky-\omega t)\hat{\mathbf{y}}$ V/m

D. $\vec{\mathbf{E}} = 125\cos(kz-\omega t)\hat{\mathbf{y}}$ V/m **E.** $\vec{\mathbf{E}} = 155\cos(kz-\omega t)\hat{\mathbf{y}}$ V/m

Qu's 3-4) Three waves that are similarly linearly polarized overlap at point P in space with the following individual electric fields:

$E_1(P,t) = 12\cos(1.05-\omega t)$ V/m ; $E_2(P,t) = 7\sin(0.780-\omega t)$ V/m ; $E_3(P,t) = 20\cos(0.628-\omega t)$ V/m

3) What is the maximum value of the resultant electric field at point P?

A. 32.1 V/m **B.** 29.6 V/m **C.** 54.2 V/m **D.** 16.8 V/m **E.** 89.8 V/m

4) What is the initial phase of the resultant electric field at point P, presuming this is represented by a cosine?

A. 0.36 rad **B.** 0.28 rad **C.** 0.24 rad **D.** 0.20 rad **E.** 0.57 rad

Qu's 5-6) A monochromatic light beam has a Jones vector given by $\mathbf{V} = \begin{pmatrix} 6 \\ 2+4i \end{pmatrix}$.

5) Which of the following Jones vectors represents light in the same polarization state?

A. $\begin{pmatrix} 3-6i \\ 5 \end{pmatrix}$ **B.** $\begin{pmatrix} 3+6i \\ 5 \end{pmatrix}$ **C.** $\begin{pmatrix} 1 \\ 6-3i \end{pmatrix}$ **D.** $\begin{pmatrix} 3+5i \\ 6 \end{pmatrix}$ **E.** $\begin{pmatrix} 3-5i \\ 6 \end{pmatrix}$

6) What angle does the major axis of the polarization ellipse of this beam make with the *x*-axis when looking into the beam?

A. 26.6° **B.** 28.2° **C.** 56.3° **D.** 52.8° **E.** 63.4°

7) A plane wave is travelling within the *xy*-plane at an angle of $21.2°$ *above* the *x*-axis (so travelling away from the origin towards the first quadrant of the *xy*-plane). Which of the following best represents its (scalar) field?

A. $E(\mathbf{r},t) = E_t \cos\left(\frac{2\pi}{\lambda}(0.93x + 0.36y) - \omega t\right)$ **B.** $E(\mathbf{r},t) = E_t \cos\left(\frac{2\pi}{\lambda}(0.84x - 0.54y) - \omega t\right)$

C. $E(\mathbf{r},t) = E_t \cos\left(\frac{2\pi}{\lambda}(0.36x - 0.93y) - \omega t\right)$

D. $E(\mathbf{r},t) = E_t \cos\left(\frac{2\pi}{\lambda}(0.36x + 0.93y) - \omega t\right)$ **E.** $E(\mathbf{r},t) = E_t \cos\left(\frac{2\pi}{\lambda}(0.76x + 0.65y) - \omega t\right)$

8) Initially unpolarized light with intensity I_0 passes in turn through three linear polarizers with transmission axes set at $0°$, $30°$, and $60°$, respectively, relative to the horizontal. What is the intensity of the emerging light?

A. $0.36I_0$ **B.** $0.32I_0$ **C.** $0.28I_0$ **D.** $0.40I_0$ **E.** $0.44I_0$

PART II – answer the following two questions in your exam booklet

9 (a) The refractive index of glass can be reasonably well represented in terms of the vacuum wavelength of light by the empirical equation: $n(\lambda_0) = A + B/\lambda_0^2$, with $A = 1.60$ and $B = 2.5\times10^5$ nm^2 for a particular glass. Find the group velocity of a wavepacket of light in this glass with a peak constituent vacuum wavelength of 500 nm.

(b) Figure (a) shows the two cosine factors of the beat signal from two overlapping beams with the same amplitude and different frequencies at $x = x_0$:

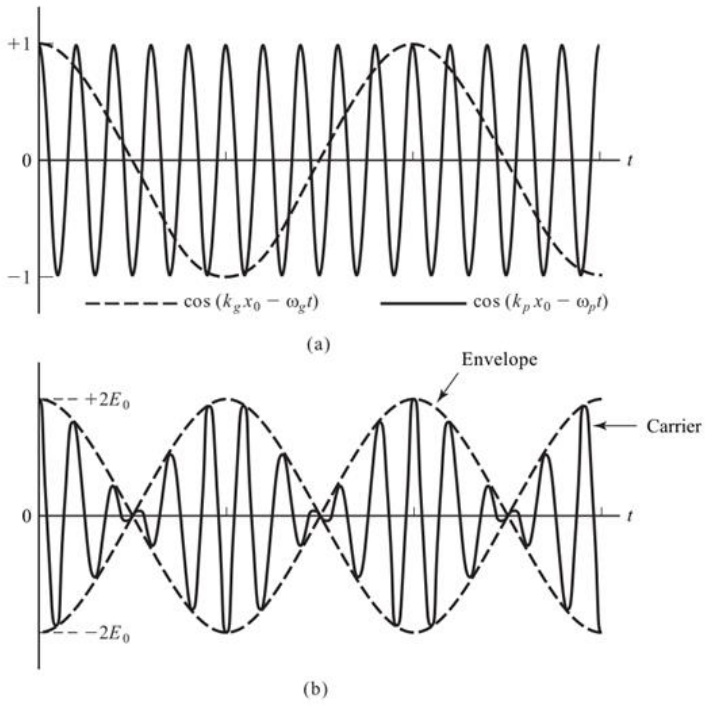
$$E_R(x_0,t) = 2E_0\cos(k_p x_0 - \omega_p t)\cos(k_g x_0 - \omega_g t).$$

Figure (b) shows the resultant field, with the solid line being $E_R(x_0,t)$. Assume that both plots show a time duration of 30 fs.

(i) Determine values for ω_p and ω_g.

(ii) What are the frequencies of the two incoming waves of form $\cos(kx - 2\pi\nu t)$ that superpose to form the resultant electric field?

(iii) What beat frequency is present in the resultant signal? What approximate range of response times of a photodetector would best preferentially observe the beat signal and why?



10. (a) Unpolarized light travelling horizontally from a source immersed in oil of refractive index 1.62 strikes a flat vertical face of a diamond (with $n = 2.42$), also immersed in the oil.

(i) Determine the angle of incidence at which the maximum linear polarization occurs for the reflected beam.

(ii) At this incident angle, what is the angle of transmission within the diamond?

(iii) Find the normalized Stokes vectors that represents the incident light, and the reflected light at the angle of incidence described in parts (i) and (ii)?

b) The refractive indicies experienced by the ordinary ray and a particular extraordinary ray in quartz for light of wavelength 546 nm are 1.5462 and 1.5553, respectively.,

(i) What is the minimum thickness required for a zeroth-order $\lambda/4$-plate of quartz?

(ii) If a multiple-order quartz plate 0.735 mm thick operates as a $\lambda/4$-plate, what is its order, *m*?