Physics 3034 – Spring 2026 – The formula sheet in your head

1. Write down Snell's law.
2. Calculate the critical angle.
3. Write down the lensmaker's equation
4. Relate object, image and focal distances
5. Draw 3 principal rays for a lens
6. Draw 3 principal rays for a mirror
7. Know the difference between real and virtual image
8. Know the difference positive and negative radii of curvature
9. Know how to combine lenses in contact
10. Know the assumptions behind the simple lens formulae
11. Given the T and R matrices, know how to combine them for arbitrary optics.
12. Know the assumptions behind matrix optics.
13. Know what it means when certain elements of the System matrix are 0.

14. Write down all four Maxwell Equations in vacuum in differential form.
15. Write their names next to them.
16. Use appropriate math to change them all to integral form. Justify your steps.
17. In the differential form above, replace B and E with D and H (where appropriate) assuming a linear medium.
18. Identify the Maxwell displacement current term in the previous two answers (circle it).
19. Write down the equation for the Poynting vector and express in words the meaning of the Poynting vector.
20. $u =$? (where u is the total electromagnetic energy density)
21. What is the equation that defines self-inductance?
22. What is the energy in an inductor carrying a current I?
23. What is the energy in a capacitor with a charge Q?
24. Write down Poynting's theorem in differential form assuming no work is being done on free charges.
25. Convert it to integral form.
26. What is the continuity equation for charge?
27. What is the relation betwee $\vec{J}$ and $\vec{E}$ for a conductor?
28. What are the units for Poynting vector? What are the units for light intensity?
29. What is the expression for light intensity that has an E^2 in it?
30. What is the relation between index of refraction and permittivity and susceptibility constants?
31. Write a valid equation relating λ, ω, and c.
32. Write a valid equation relating λ and k.
33. What's the speed of a mechanical wave in a stretched string? Can you derive it?
34. What are the reflected/transmitted amplitudes of a mechanical wave in a string?
35. $E_r = E_i \frac{n_2 - n_1}{n_2 + n_1}$. What is the reflection coefficient R?
36. Given the formula for E_r above, what is the formula for E_t in terms of E_i?
37. What is the transmission coefficient T, and how is it defined?
38. Show how to get from Maxwell's equations to the wave equation.

Constant	Value
Elementary charge	1.6×10^{-19} C
ϵ_0	8.86×10^{-12} (SI units)
μ_0	1.26×10^{-6} (SI units)
Proton mass	1.67×10^{-27} kg
Electron mass	9.11×10^{-31} kg

Vector Operators – Cartesian Coords

$$\nabla f = \frac{\partial f}{\partial x}\hat{x} + \frac{\partial f}{\partial y}\hat{y} + \frac{\partial f}{\partial z}\hat{z} \tag{1}$$

$$\nabla \cdot \vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \tag{2}$$

$$\nabla \times \vec{A} = \left[\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}\right]\hat{x} + \left[\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}\right]\hat{y} + \left[\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right]\hat{z} \tag{3}$$

Vector Operators – Spherical Coords

$$d\vec{l} = dr\,\hat{r} + rd\theta\,\hat{\theta} + rsin\theta d\phi\,\hat{\phi}; \quad d\tau = r^2 sin\theta\,dr\,d\theta\,d\phi \tag{4}$$

$$\nabla f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{1}{r\,sin\theta}\frac{\partial f}{\partial \phi}\hat{\phi} \tag{5}$$

$$\nabla \cdot \vec{A} = \frac{1}{r^2}\frac{\partial (r^2 A_r)}{\partial r} + \frac{1}{r\,sin\theta}\frac{\partial (sin\theta A_\theta)}{\partial \theta} + \frac{1}{r\,sin\theta}\frac{\partial A_\phi}{\partial \phi} \tag{6}$$

$$\nabla \times \vec{A} = \frac{1}{r\,sin\theta}\left[\frac{\partial (sin\theta A_\phi)}{\partial \theta} - \frac{\partial A_\theta}{\partial \phi}\right]\hat{r} + \frac{1}{r}\left[\frac{1}{sin\theta}\frac{\partial A_r}{\partial \phi} - \frac{\partial (rA_\phi)}{\partial r}\right]\hat{\theta} + \frac{1}{r}\left[\frac{\partial (rA_\theta)}{\partial r} - \frac{\partial A_r}{\partial \theta}\right]\hat{\phi} \tag{7}$$

Vector Operators – Cylindrical Coords

$$d\vec{l} = ds\,\hat{s} + s\,d\phi\,\hat{\phi} + dz\,\hat{z}; \quad d\tau = s\,ds\,d\phi\,dz \tag{8}$$

$$\nabla f = \frac{\partial f}{\partial s}\hat{s} + \frac{1}{s}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{\partial f}{\partial z}\hat{z} \tag{9}$$

$$\nabla \cdot \vec{A} = \frac{1}{s}\frac{\partial (sA_s)}{\partial s} + \frac{1}{s}\frac{\partial A_\theta}{\partial \theta} + \frac{\partial A_z}{\partial z} \tag{10}$$

$$\nabla \times \vec{A} = \left[\frac{1}{s}\frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z}\right]\hat{s} + \left[\frac{\partial A_s}{\partial z} - \frac{\partial A_z}{\partial s}\right]\hat{\theta} + \frac{1}{s}\left[\frac{\partial (sA_\theta)}{\partial s} - \frac{\partial A_s}{\partial \theta}\right]\hat{z} \tag{11}$$

Spherical Coordinates

$$\begin{aligned}
\hat{x} &= sin\theta\,cos\phi\,\hat{r} + cos\theta\,cos\phi\hat{\,}\theta - sin\phi\,\hat{\phi} && (12)\\
\hat{y} &= sin\theta\,sin\phi\,\hat{r} + cos\theta\,sin\phi\hat{\,}\theta + cos\phi\,\hat{\phi} && (13)\\
\hat{z} &= cos\theta\,\hat{r} - sin\theta\,\hat{\theta} && (14)\\
\hat{r} &= sin\theta\,cos\phi\,\hat{x} + sin\theta\,sin\phi\,\hat{y} + cos\theta\,\hat{z} && (15)\\
\hat{\theta} &= cos\theta\,cos\phi\,\hat{x} + cos\theta\,sin\phi\,\hat{y} - sin\theta\,\hat{z} && (16)\\
\hat{\phi} &= -sin\phi\,\hat{x} + cos\phi\hat{\,}y && (17)\\
& && (18)
\end{aligned}$$

Vector Identities

$$\begin{aligned}
\vec{A}\cdot(\vec{B}\times\vec{C}) &= \vec{B}\cdot(\vec{C}\times\vec{A}) = \vec{C}\cdot(\vec{A}\times\vec{B}) && (19)\\
\vec{A}\times(\vec{B}\times\vec{C}) &= \vec{B}(\vec{A}\cdot\vec{C}) - \vec{C}(\vec{A}\cdot\vec{B}) && (20)\\
\nabla\cdot(\nabla\times\vec{A}) &= 0 && (21)\\
\nabla\times(\nabla f) &= 0 && (22)\\
\nabla\times(\nabla\times\vec{A}) &= \nabla(\nabla\cdot\vec{A}) - \nabla^2\vec{A} && (23)
\end{aligned}$$