MCQ 50 marks

1. **D.** 43.2 g
Explanation: $E = Pt = 1500 \times 10^6 \times 30 \times 86400 = 3.89 \times 10^{15}$ J
$m = \frac{E}{c^2} = 0.0432$ kg $= 43.2$ g

2. **B.** 2.17×10^{-6} A
Explanation: Photons per second: $n = \frac{P\lambda}{hc}$
$I = 0.002\, n\, e = \frac{0.002 \times 3 \times 10^{-3} \times 1.6 \times 10^{-19} \times 450 \times 10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^8}$
$I = 2.17 \times 10^{-6}$ A

3. **C.** 2×10^8 ms^{-1}
Explanation: $v = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{3 \times 10^8}{\sqrt{1.25 \times 1.8}}$
$= \frac{3 \times 10^8}{1.5} = 2 \times 10^8$ ms^{-1}

4. **A.** $\frac{1}{3}$
Explanation: $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi = 5I + 2(2I)(-\frac{1}{2}) = 3I$
$I_{max} = (\sqrt{4I} + \sqrt{I})^2 = 9I$
Ratio $= \frac{3I}{9I} = \frac{1}{3}$

5. **A.** 9.6 m
Explanation: $L = L_0\sqrt{1 - \frac{v^2}{c^2}} = 12 \times 0.8 = 9.6$ m

6. **C.** 0.8c
Explanation: $90 = 150\sqrt{1 - \frac{v^2}{c^2}} \Rightarrow$
$\sqrt{1 - \frac{v^2}{c^2}} = 0.6$
$v = 0.8c$

7. **D. 3125**
Explanation: $640n = 480(n + 1) \Rightarrow n = 3$
$d = \frac{3 \times 640 \times 10^{-9}}{0.6} = 3.2 \times 10^{-6}$ m
$N = \frac{1}{3.2 \times 10^{-4}\text{ cm}} = 3125$ cm^{-1}

8. **A.** 32°, **1.6**
Explanation: $\mu = \tan\theta_p = 1.6$
$\theta_p + r = 90° \Rightarrow r = 32°$

9. **B. 5 years**
Explanation: Time for the astronaut: $t_0 = 25 \times 0.8 = 20$ years
Ages: 43 on Earth, 38 for the astronaut
Difference = 5 years

10. **C.** 4.8 μm
Explanation: $(\mu - 1)t = n\lambda$
$t = \frac{6 \times 480 \times 10^{-9}}{0.6} = 4.8$ μm

11. **A.** 1.96 V
Explanation: $e(V_1 - V_2) = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$
$V_1 - V_2 = 1.242$ V
$V_2 = 1.96$ V

12. **B.** 1.5×10^{-8} T**, along** $+\hat{k}$
Explanation: $B_0 = \frac{E_0}{c} = \frac{4.5}{3 \times 10^8} = 1.5 \times 10^{-8}$ T
Because of $(ky + \omega t)$, the wave travels in the $-\hat{j}$ direction
$\vec{E} \times \vec{B} \parallel -\hat{j}$ is required; $\hat{i} \times \hat{k} = -\hat{j}$
So the direction of $\vec{B}$ is $+\hat{k}$

13. **D.** 7.17×10^{14} Hz
Explanation: $hf = hf_0 + K_{max}$
$f_0 = 1.2 \times 10^{15} - \frac{2 \times 1.6 \times 10^{-19}}{6.626 \times 10^{-34}} = 7.17 \times 10^{14}$ Hz

14. **D.** 4.63 km
Explanation: $\gamma = \frac{1}{\sqrt{1 - 0.99^2}} = 7.09$
$T = \gamma T_0 = 15.6$ μs
Distance $= 0.99c \times T = 4.63$ km (greater than 4.5 km, so it reaches the ground)

15. **D.** 450 m
Explanation: $2.5 = \gamma \times 2 \Rightarrow \gamma = 1.25$, $v = 0.6c$
$|\Delta x'| = \gamma v \Delta t = 1.25 \times 1.8 \times 10^8 \times 2 \times 10^{-6} = 450$ m

16. **C.** 0.917c
Explanation: $E = K + E_0 = 2.5E_0 \Rightarrow \gamma = 2.5$
$v = c\sqrt{1 - \frac{1}{6.25}} = 0.917c$

17. **D.** 3λ
Explanation: $\frac{hc}{\lambda} = \phi + 4e$, $\frac{hc}{2\lambda} = \phi + 1e$
Subtracting: $\frac{hc}{2\lambda} = 3e \Rightarrow \frac{hc}{\lambda} = 6e$, $\phi = 2e$
$\lambda_0 = \frac{hc}{\phi} = 3\lambda$

18. **B.** 960 m^2
Explanation: The diagonal along the direction of motion contracts; the

perpendicular diagonal is unchanged

$A = A_0\sqrt{1-\frac{v^2}{c^2}} = 1600 \times 0.6 = 960\ m^2$

19. **A.** 0.915c

Explanation: $u = \frac{u'+v}{1+\frac{u'v}{c^2}} = \frac{1.3c}{1.42}$

$= 0.915c$

20. **D.** 0.2048 nm

Explanation: Maximum shift at $\theta = 180°$

$\Delta\lambda = \frac{2h}{m_0c} = 4.85 \times 10^{-12}\ m$

$\lambda' = 0.2048\ nm$

21. **D.** $\frac{I_0}{4}$

Explanation: First polarizer: $\frac{I_0}{2}$

Second: $\frac{I_0}{2}\cos^2 45° = \frac{I_0}{4}$

22. **A. 49 : 9**

Explanation: $\frac{a_1}{a_2} = \sqrt{\frac{25}{4}} = \frac{5}{2}$

$\frac{I_{max}}{I_{min}} = \left(\frac{5+2}{5-2}\right)^2 = \frac{49}{9}$

23. **C.** 4 μm

Explanation: The extra optical paths of the two plates must be equal

$(\mu_1 - 1)t_1 = (\mu_2 - 1)t_2$

$0.5 \times 2 = 0.25\, t_2 \Rightarrow t_2 = 4\ \mu m$

24. **D.** $\frac{4}{3}$

Explanation: $2\theta \approx \frac{2\lambda}{a} \propto \lambda$

In the liquid, $\lambda' = \frac{\lambda}{\mu}$

$\frac{1}{\mu} = 0.75 \Rightarrow \mu = \frac{4}{3}$

25. **C. 30**

Explanation: In a fixed portion, $n\lambda$ = constant

$n_2 = \frac{40\times4500}{6000} = 30$

26. **B.** 100 nm

Explanation: A phase change of π occurs on reflection at the upper surface

Condition for brightness: $2\mu t = (n + \frac{1}{2})\lambda$

$t_{min} = \frac{\lambda}{4\mu} = \frac{560}{4\times1.4} = 100\ nm$

27. **A. 7**

Explanation: $d = \frac{1}{4\times10^5} = 2.5\ \mu m$

$n \le \frac{d}{\lambda} = 3.85 \Rightarrow n_{max} = 3$

Total maxima $= 2 \times 3 + 1 = 7$

28. **C.** c

Explanation: The speed of light is the same in all inertial frames

$u = \frac{c+0.95c}{1+0.95} = c$

29. **C.** 50.2°

Explanation: $\tan\theta_p = \frac{\mu_g}{\mu_w} = \frac{1.6}{\frac{4}{3}} = 1.2$

$\theta_p = 50.19°$

30. **B.** 9.75 mm

Explanation: $\beta = \lambda\frac{D}{a} = \frac{500\times10^{-9}\times1.5}{0.5\times10^{-3}} = 1.5\ mm$

Fourth bright fringe: $4\beta = 6$ mm

Third dark fringe: $2.5\beta = 3.75$ mm

They are on opposite sides, so the distance = $6 + 3.75 = 9.75$ mm

31. **A. 833**

Explanation: $a\sin\theta = n\lambda,\ \sin\theta < 1$

$n < \frac{a}{\lambda} = \frac{0.25\times10^{-3}}{600\times10^{-9}} = 416.7$

$n_{max} = 416$

Total bright fringes $= 2 \times 416 + 1 = 833$

32. **B. 66.7% decrease**

Explanation: $\lambda = \frac{h}{\sqrt{2mK}} \propto \frac{1}{\sqrt{K}}$

$\lambda' = \frac{\lambda}{3}$

Decrease $= \frac{2}{3} \times 100\% = 66.7\%$

33. **D.** 1.8 μm

Explanation: Secondary maxima: $a\sin\theta = (2n + 1)\frac{\lambda}{2}$, $n = 1$

$a = \frac{3\times600\times10^{-9}}{2\times0.5} = 1.8\ \mu m$

34. **A.** 68.4 cm

Explanation: Only the x component contracts

$L_x = 80\cos30° \times 0.8 = 55.43$ cm, $L_y = 40$ cm

$L = \sqrt{L_x^2 + L_y^2} = 68.4\ cm$

35. **A.** 15°

Explanation: $I = \frac{I_0}{2}\cos^2\theta\sin^2\theta = \frac{I_0}{8}\sin^2 2\theta$

$\sin^2 2\theta = \frac{1}{4} \Rightarrow 2\theta = 30°$

$\theta = 15°$ (or 75°)

36. **B.** $0.75m_0c$

Explanation: $\gamma = 1.25 \Rightarrow v = 0.6c$

$p = \gamma m_0 v = 1.25 \times 0.6\, m_0c = 0.75m_0c$

37. **A.** 0.927c

Explanation: If B's initial age is b and the Earth time is t: $b + t = (b + 8 + 6) + 2 \Rightarrow t = 16$ years

$6 = 16\sqrt{1-\frac{v^2}{c^2}}$

$v = c\sqrt{1-\frac{36}{256}} = 0.927c$

38. **C.** $31.5°$

Explanation: $d = \frac{2.54\times10^{-2}}{12000} = 2.12 \times 10^{-6}\ m$

$\theta_1 = \sin^{-1}(\frac{\lambda}{d}) = 13.66°$

$\theta_3 = \sin^{-1}(\frac{3\lambda}{d}) = 45.13°$

Difference $= 31.5°$

39. **B.** $4\ mm$

Explanation: $w = \frac{2\lambda D}{a} = \frac{2\times500\times10^{-9}\times1.6}{0.4\times10^{-3}}$

$w = 4 \times 10^{-3}\ m = 4\ mm$

40. **D.** $0.727c$

Explanation: $u_{CB} = \frac{u_{CA}-v}{1-\frac{u_{CA}v}{c^2}}$

$0.5(1 - 0.9v) = 0.9 - v$

$0.55v = 0.4 \Rightarrow v = 0.727c$

41. **A.** $6\ mm$

Explanation: $n_1\lambda_1 = n_2\lambda_2 \Rightarrow 750n_1 = 500n_2$

Minimum: $n_1 = 2,\ n_2 = 3$

$x = \frac{2\times750\times10^{-9}\times2}{0.5\times10^{-3}} = 6\ mm$

42. **C.** $1.2\ \mu m$

Explanation: $a\sin\theta = \lambda$

$a = \frac{600\times10^{-9}}{0.5} = 1.2\ \mu m$

43. **B. 3072**

Explanation: Time in the vehicle: $t_0 = 250 \times 0.6 = 150$ days

Number of doublings $= \frac{150}{15} = 10$

Number $= 3 \times 2^{10} = 3072$

44. **B.** $5\ J\,c^{-2}$

Explanation: $E^2 = p^2c^2 + m_0^2c^4$

$m_0^2c^4 = 169 - 144 = 25$

$m_0 = 5\ J\,c^{-2}$

45. **D.** $\frac{16}{11}$

Explanation: Sixth dark fringe: $x = \frac{11}{2}\frac{\lambda D}{a}$

Eighth bright fringe in the liquid: $x = 8\frac{\lambda D}{\mu a}$

$\frac{11}{2} = \frac{8}{\mu} \Rightarrow \mu = \frac{16}{11}$

46. **B.** $3.75\ s$

Explanation: $T = \frac{T_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{3}{0.8} = 3.75\ s$

47. **C.** $27.5\ Wm^{-2}$

Explanation: $I = \frac{I_0}{2}(\cos^2\theta)^{n-1}$

$= 40\cos^6 20° = 27.54\ Wm^{-2}$

48. **A.** $480\ nm$

Explanation: Condition for brightness: $2\mu t = (m - \frac{1}{2})\lambda \Rightarrow \lambda = \frac{4\mu t}{2m-1}$

$4\mu t = 4 \times 1.6 \times 375 = 2400\ nm$

$\lambda = 2400,\ 800,\ 480,\ 343\ nm$

Only $480\ nm$ lies in the visible range

49. **D.** $1.2 \times 10^8\ ms^{-1}$

Explanation: $\Delta t' = \gamma(\Delta t - v\Delta\frac{x}{c^2}) = 0$

$v = \frac{c^2\Delta t}{\Delta x} = \frac{9\times10^{16}\times8\times10^{-6}}{6\times10^3} = 1.2 \times 10^8\ ms^{-1}$

50. **C.** $0.462c$**, along** $-x$

Explanation: $u = \frac{u'+v}{1+\frac{u'v}{c^2}} = \frac{-0.9c+0.75c}{1-0.675}$

$= -0.462c$ (along $-x$)