Engineering Daily 25 [Set 04] EV - Answer Sheet

Physical Optics, Modern Physics

Total Marks: 50 **Negative Marks:** 0.25 **Time:** 1 Hour

MCQ 50 marks

1. **D.** 0.6 mm
Explanation: $I = I_0\cos^2(\frac{\phi}{2}) = \frac{I_0}{4} \Rightarrow \phi = \frac{2\pi}{3}$
Path difference $= \frac{\lambda}{3}$
$x = \frac{\lambda D}{3a} = 0.6$ mm

2. **D. 4 : 1**
Explanation: $\frac{a_1+a_2}{a_1-a_2} = 3 \Rightarrow a_1 = 2a_2$
$I_1 : I_2 = a_1^2 : a_2^2 = 4 : 1$

3. **D.** 600 nm
Explanation: $\Delta\beta = \frac{\lambda\Delta D}{a}$
$\lambda = \frac{5\times10^{-5}\times1.2\times10^{-3}}{0.1} = 6\times10^{-7}$ m

4. **C.** 400 nm
Explanation: Angular width $\propto \lambda$
$\lambda' = 0.8 \times 500 = 400$ nm

5. **A.** 5 min
Explanation: $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{4}{0.8} = 5$ min

6. **A.** 0.315 mm
Explanation: $\theta = \frac{\lambda}{a}$ (in radians)
$0.1° = 1.745\times10^{-3}$ rad
$a = 3.15\times10^{-4}$ m $= 0.315$ mm

7. **A.** 9.06×10^{18}
Explanation: Light power = 3 W
$n = \frac{P\lambda}{hc} = \frac{3\times600\times10^{-9}}{6.626\times10^{-34}\times3\times10^8}$
$= 9.06\times10^{18}$ photons

8. **C.** 12.3 min
Explanation: Relative speed $= \frac{1.4c}{1.48} = 0.9459c$
$t = \frac{4}{\sqrt{1-0.9459^2}} = 12.3$ min

9. **B.** 1.5×10^8 ms^{-1}
Explanation: $v = \frac{c}{\sqrt{\mu_r K}} = \frac{3\times10^8}{\sqrt{4}} = 1.5\times10^8$ ms^{-1}

10. **C.** 1.6×10^{11} m
Explanation: $\Delta x = \gamma(\Delta x' + v\Delta t')$, $\Delta x' = 0$
$\gamma = \frac{5}{3}$
$\Delta x = \frac{5}{3}\times2.4\times10^8\times400 = 1.6\times10^{11}$ m

11. **A.** 0.8c
Explanation: $u' = \frac{0.5c+0.5c}{1+0.25} = 0.8c$

12. **B. 1 : 2**
Explanation: $K_1 = 2\phi$, $K_2 = 8\phi$
$v \propto \sqrt{K} \Rightarrow v_1 : v_2 = \sqrt{2} : \sqrt{8} = 1 : 2$

13. **A.** 1 μm
Explanation: $2\theta = \frac{2\lambda}{a} = \frac{2c}{af}$
$\Delta(2\theta) = \frac{2c}{a}\left(\frac{1}{f_1} - \frac{1}{f_2}\right) = \frac{2\times10^{-7}}{a}$
$0.2 = \frac{2\times10^{-7}}{a} \Rightarrow a = 10^{-6}$ m

14. **D.** 9 μm
Explanation: First secondary maximum: $x = \frac{3\lambda D}{2a}$
$\Delta x = \frac{3D\Delta\lambda}{2a} = \frac{3\times2\times0.6\times10^{-9}}{0.4\times10^{-3}} = 9\times10^{-6}$ m

15. **B.** 6.62×10^{-34} Js
Explanation: $hf = hf_{01} + eV_1 = hf_{02} + eV_2$
$h = \frac{e(V_2-V_1)}{f_{01}-f_{02}} = \frac{1.6\times10^{-19}\times0.455}{1.1\times10^{14}}$
$h = 6.62\times10^{-34}$ Js

16. **B.** 575 eV
Explanation: Maximum kinetic energy when $\theta = 180°$
$\lambda' = \lambda + \frac{2h}{m_0c} = 0.10485$ nm
$K = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = 575$ eV

17. **C.** 0.1 mm **increase**
Explanation: To keep $\beta = \lambda\frac{D}{a}$ constant, $a \propto D$
$a' = 0.4 \times \frac{1.5}{1.2} = 0.5$ mm
Increase = 0.1 mm

18. **D.** 24 mm
Explanation: $\beta = \frac{\lambda D}{a} = 3$ mm
9 fringes have 8 intervals
Distance $= 8\beta = 24$ mm

19. **A.** 0.229°
Explanation: $a\sin\theta = 2\lambda$
$\sin\theta = 4\times10^{-3} \Rightarrow \theta = 0.229°$

20. **A.** $\frac{4}{3}$
Explanation: $v = \frac{\omega}{k} = 4.5\times\frac{10^8}{2} = 2.25\times10^8$ ms^{-1}
$\mu = \frac{c}{v} = \frac{3}{2.25} = \frac{4}{3}$

21. **A. 0.25**

Explanation: $K = (\gamma - 1)m_0c^2$
$\gamma = 1.25 \Rightarrow x = 0.25$

22. **B. 3**
Explanation: $d = \frac{4\times10^{-2}}{20000} = 2 \times 10^{-6}$ m
$\frac{d}{\lambda} = 4$; for $n = 4$, $\theta = 90°$, which does not fall on the screen
So the maximum observable order is 3

23. **A.** 30°
Explanation: $d = a + b = 2\ \mu m$
$\sin\theta_2 = \frac{2\times500\times10^{-9}}{2\times10^{-6}} = 0.5 \Rightarrow \theta_2 = 30°$

24. **B.** 22.5 Wm^{-2}
Explanation: $I_1 = 60$, $I_2 = 60\cos^2 30° = 45$
The angle between the 2nd and 3rd is 45°
$I_3 = 45\cos^2 45° = 22.5\ Wm^{-2}$

25. **C. 5**
Explanation: $n = \frac{(\mu-1)t}{\lambda} = \frac{0.5\times5\times10^{-6}}{500\times10^{-9}} = 5$

26. **B.** 4.5 mm
Explanation: $n(450) = (m - \frac{1}{2})600 \Rightarrow 3n = 4m - 2$
Minimum: $m = 2,\ n = 2$
$x = \frac{2\times450\times10^{-9}\times1.5}{0.3\times10^{-3}} = 4.5$ mm

27. **B.** $\frac{3\pi}{4}$
Explanation: $\delta = 2\pi\frac{\Delta t}{T} = 2\pi f\Delta t$
$= 2\pi \times 250 \times 1.5 \times 10^{-3} = 0.75\pi$

28. **B.** 0.385c
Explanation: $u' = \frac{u-v}{1-\frac{uv}{c^2}} = \frac{0.8c-0.6c}{1-0.48}$
$= 0.385c$

29. **B.** 700 nm
Explanation: $x \propto \lambda$
$\lambda_r = 400 \times \frac{2.8}{1.6} = 700$ nm

30. **A.** 4 min
Explanation: $t = \frac{120}{0.6} = 200$ min
Per process $= \frac{200}{50} = 4$ min

31. **C.** 0.8c
Explanation: $\gamma = \frac{5}{3} \Rightarrow \sqrt{1 - \frac{v^2}{c^2}} = 0.6$
$v = 0.8c$

32. **D.** 10^{-8} s
Explanation: Half-life in the laboratory $= \frac{30}{0.995c} = 1.01 \times 10^{-7}$ s
$\sqrt{1 - 0.995^2} = 0.0999$
Proper half-life $= 10^{-8}$ s

33. **D.** 2.83×10^8 ms^{-1}
Explanation: $\sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{3}$
$v = \frac{2\sqrt{2}}{3}c = 2.83 \times 10^8\ ms^{-1}$

34. **C.** 6 μm
Explanation: Shift $y = \frac{D(\mu-1)t}{a}$
$t = \frac{15\times10^{-3}\times0.2\times10^{-3}}{1\times0.5} = 6 \times 10^{-6}$ m

35. **D.** 1800 MeV
Explanation: $E = mc^2 = 2.88 \times 10^{-10}$ J
$= \frac{2.88\times10^{-10}}{1.6\times10^{-13}} = 1800$ MeV

36. **C.** 500 nm
Explanation: $d = \frac{1}{5\times10^5} = 2 \times 10^{-6}$ m
$\lambda = \frac{d\sin\theta}{n} = \frac{2\times10^{-6}\times0.5}{2} = 500$ nm

37. **B. 256**
Explanation: Time by Earth's reckoning $= \frac{24}{0.96} = 25$ years
Proper time $= 25 \times 0.28 = 7$ years
Number $= 2 \times 2^7 = 256$

38. **D.** 266.7–466.7 nm
Explanation: In the medium the frequency is unchanged, $\lambda' = \frac{\lambda}{\mu}$
$\frac{400}{1.5} = 266.7$ nm, $\frac{700}{1.5} = 466.7$ nm

39. **B. Greater than** 9.11×10^{-31} kg
Explanation: $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} > m_0$

40. **C.** 0.8c
Explanation: $A = A_0\sqrt{1 - \frac{v^2}{c^2}}$
$\sqrt{1 - \frac{v^2}{c^2}} = 0.6 \Rightarrow v = 0.8c$

41. **A.** $540\pi\ m^2$
Explanation: The field appears elliptical: semi-axes 30 m and $30 \times 0.6 = 18$ m
$A = \pi ab = 540\pi\ m^2$

42. **D.** 35.3°
Explanation: $\mu = \tan 60° = \sqrt{3}$
$\sin\theta_c = \frac{1}{\sqrt{3}} \Rightarrow \theta_c = 35.3°$

43. **C.** 2 m
Explanation: Length contraction occurs only along the direction of motion

Since the length is perpendicular to the motion, it is unchanged: 2 m

44. **C.** 3.75 kg

Explanation: Conservation of energy:

$M_0c^2 = 2\gamma m_0c^2$

$M_0 = \frac{2\times1.5}{0.8} = 3.75\,\text{kg}$

45. **A.** 0.45 mm

Explanation: Screen distance from the double slit: $D = 155 - 5 = 150\,\text{cm}$

$\beta = \frac{1.5}{10} = 0.15\,\text{cm}$

$a = \frac{\lambda D}{\beta} = \frac{4.5\times10^{-7}\times1.5}{1.5\times10^{-3}} = 0.45\,\text{mm}$

46. **B.** $5.97 \times 10^7\,\text{ms}^{-1}$

Explanation: $\sqrt{1 - \frac{v^2}{c^2}} = 0.98$

$v = c\sqrt{0.0396} = 0.199c = 5.97 \times 10^7\,\text{ms}^{-1}$

47. **D. 12 years**

Explanation: $v = 0.8c$, $\sqrt{1 - \frac{v^2}{c^2}} = 0.6$

Proper time $t_0 = 18$ years, Earth time $t = \frac{18}{0.6} = 30$ years

Earth twin 55, traveller 43; difference 12 years

48. **D.** $2\sqrt{2}\,m_0c$

Explanation: $E = 3m_0c^2$

$p^2c^2 = E^2 - m_0^2c^4 = 8m_0^2c^4$

$p = 2\sqrt{2}\,m_0c$

49. **C.** 6.66 Å

Explanation: $mvr = \frac{nh}{2\pi} \Rightarrow \lambda = \frac{h}{mv} = \frac{2\pi r}{n}$

$\lambda = \frac{2\pi\times2.12}{2} = 6.66\,\text{Å}$

50. **A.** $18.7\,\text{Wcm}^{-2}$

Explanation: $30 = \frac{I_0}{2}\cos^2 20°\cos^2 30°$

$I_0 = 90.6\,\text{Wcm}^{-2}$

New: $I = \frac{I_0}{2}\cos^2 50° = 18.7\,\text{Wcm}^{-2}$