ANSWER KEY OF
F.E. Semester – I (RC 2019-20) March 2021Examination
PHYSICS

Part – A

Answer **any two** questions:

1. a) <u>**Band theory of solids**</u>

Diagram showing band structure of Conductors, Insulators & semiconductors **……. 2 marks**

Explanation of each with one example **…..3marks**

b) <u>**Determining wavelength of light using Newton's Rings**</u>

Ray Diagram **…… 1 mark**

Brief explanation **…….1mark**

Diameters of n^{th} and $(n+p)^{th}$ dark rings:

$D_n^2 = 4\, n\, \lambda\, R$

$D_{n+p}^2 = 4\,(n+p)\,\lambda\, R$ } **…….1mark**

Putting together and obtaining final expression:

$\lambda = \frac{D_{n+p}^2 - D_n^2}{4\, p\, R}$ **…….2marks**

c) <u>**Diamagnetism**</u>

Diagrams showing filled electron orbitals and atomic dipoles in absence and presence of magnetic field……..**1 mark**

Brief explanation of diamagnetism ……. **2 marks**

Any 4 properties ……..**2 marks**

d) <u>**Numerical Problem**</u>

$\lambda_u = \frac{2n\lambda}{sin\theta}$ ……..**1 mark**

$= \frac{2\times1\times6328\times10^{-10}}{sin10°15'} = 7.11 \times 10^{-6} m$ ……. **2 marks**

$v = f.\lambda_u = 200 \times 10^6 \times 7.11 \times 10^{-6}$ = 1422.5 m/s ……. **2 marks**

2. a) <u>**Interference in Wedge shaped film**</u>

Ray diagram **…..1mark**

Applying the theory of thin film interference for reflected light, using conditions for minima & maxima:

$2\,\mu\, t \cos r = n\,\lambda$

$2\,\mu\, t \cos r = (2n+1)\frac{\lambda}{2}$ } **1 mark**

Using normal incidence assumption and then putting n = 0,1,2,3…. and obtaining different values of 't' **….. 1mark**

From the figure, obtaining expression for fringe width:

$\beta = \frac{\lambda}{2\,\mu\,\theta}$ **….2marks**

b) <u>**Acoustic Diffraction Grating**</u>

Diagram of experimental setup **……1 mark**

Explanation of setup **…..1marks**

Applying the theory of diffraction we have for maxima,

$d\; sin\theta = n\,\lambda$ **……1 mark**

In the acoustic grating, the grating element,

$d = \lambda_u/2$ ……**1 mark**

Combining the equations and obtaining

$\lambda_u = \frac{2n\lambda}{sin\theta}$

$v = f.\lambda_u$ ……**1 mark**

c) **Definition & Units**

Magnetizing field, magnetization, magnetic susceptibility, Magnetic induction **……1 mark each**

Units **……1 mark**

d) Explanation of drift current **……1 mark**

Numerical problem

For p-type semiconductor,

$\sigma = e \cdot p \cdot \mu_h$ **……1mark**

$p = \frac{\sigma}{e \cdot \mu_h} = \frac{1}{\rho \cdot e \cdot \mu_h} = \frac{1}{0.2 \times 1.6 \times 10^{-19} \times 0.14} = 2.23 \times 10^{20} /m^3$ **……3marks**

3. a) Expression for conductivity of a semiconductor

Diagram **…….. 1mark**

Using definition of current (I =Q/t) obtaining expression for J:

$J = n\, e\, v_d$ **…… 1½marks**

Using Ohm's law obtaining another expression for J:

$J = \sigma E$ **….. 1½marks**

Combining the above two and obtaining final expression

$\sigma = n\, e\, \mu$ **…… 1mark**

b) **Numerical Problem**

$\lambda = \frac{D_{n+p}^2 - D_n^2}{4\, p\, R}$ **….. 1mark**

$= \frac{0.6^2 - 0.3^2}{4 \times 15 \times 6000 \times 10^{-8}}$ **…….. 1 mark**

$= 75$ cm **……. 1 mark**

$D_5^2 = 4 \times 5 \times \lambda R/\mu$

$= 4 \times 5 \times 6000 \times 10^{-8} \times 75/1.33$

$= 0.068$

$D_5 = \sqrt{0.068} = 0.26$cm **……. 2 marks**

c) **Cathode ray oscilloscope (CRO)**

Block diagram of CRO **……3marks**

Explanation of CRT **……2marks**

Explanation of vertical circuits **……1marks**

Explanation of horizontal circuits **……2marks**

Explanation of trigger circuit & power supply section **……2marks**

Part – B

Answer **any two** questions:

4. a) Four level pumping scheme

Energy level diagrams (before & after pumping) ……..**1 mark**

Explanation of how population inversion is achieved and laser is produced ……….. **3 marks**

Advantages of four level over three level pumping scheme ……….. **1 marks**

b) **Types of optical fibres**

i) Single-mode Step-index fibre (ii) Multimode step-index fibre (iii) GRIN fibre

RI profile diagrams **….1 mark**

Cross-sectional view diagrams **....2 marks**
Brief explanation of each type of fibre **.....2 marks**

c) Davisson-Germer Experiment

Diagram of experimental setup **...... 1mark**

Brief explanation of setup **...... 1mark**

Oservations from experiment**.......1 marks**

Analysis showing electrons behave like x-rays **.....2marks**

d) Numerical problem

Bragg's Law of x-ray diffraction,
$2d\sin\theta = n\lambda$ **.....1 mark**

$n = \frac{2d\sin\theta}{\lambda}$
For highest n, $\sin\theta = 1$
Hence, $n_{max} = \frac{2d}{\lambda} = \frac{2\times3.9}{1.54} = 5.06$
Hence highest order = 5
} **......2marks**

Again from Bragg's law,
$2d\sin\theta = n\lambda$
$\Rightarrow \theta = \sin^{-1}\frac{n\lambda}{2d} = \sin^{-1}\frac{3\times1.54}{2\times3.9} = 36.32°$
} **......2marks**

5. a) Expression for Acceptance Angle & Acceptance cone

Ray diagram **...... 1 mark**

Limiting condition: when $i = i_{max}, \theta = i_c$ **...... 1 mark**
Using Snell's Law and critical angle formula and finally obtaining the expression:

$i_{max} = \sin^{-1}\left(\frac{\sqrt{(\mu_1^2-\mu_2^2)}}{\mu_0}\right)$ **...... 2 marks**

Acceptance cone explanation **...... 1 mark**

b) X-ray diffraction and Bragg's Law

Explanation of x-ray diffraction **...... 1 mark**

Ray diagram **...... 1 mark**

Obtaining path difference between lower and upper x-ray, $\Delta = 2d\sin\theta$ **...... 2 marks**

Using maxima condition and obtaining final expression for Bragg's Law,

$2d\sin\theta = n\lambda$ **...... 1 mark**

c) Stimulated emission

Energy level diagram **...... 1 mark**
Explanation of process of stimulated emission**..... 2mark**
Light amplification using stimulated emission (with diagram) **.... 2marks**

d) Numerical Problem

Compton shift, $\lambda' - \lambda = \frac{h}{m_0c}(1-\cos\theta)$ **.......1mark**

$$\Rightarrow \lambda' = \lambda + \frac{h}{m_0c}(1-\cos\theta)$$

$$= 0.03\times10^{-10} + \frac{6.63\times10^{-34}}{9.1\times10^{-31}\times3\times10^{8}}(1-\cos60)$$ **.....1mark**

$$= 0.042\times10^{-10}\text{m}$$ **......2marks**

Compton shift = $\lambda' - \lambda$ = 0.012 $\times10^{-10}$m **.....1mark**

6. a) **Optical fibre communication system**

Block diagram **…….2marks**

Explanation of block diagram **…..2marks**

Any two advantages of optical fibres over copper wires **….1mark**

b) **Numerical problem**

$\nu_m = \frac{mc}{2L}$ **….1mark**

$\Rightarrow L = \frac{mc}{2\nu_m} = \frac{1\times3\times10^8}{2\times1500\times10^6}$ =0.1 m **…..2marks**

$P = \frac{E}{t} = \frac{n\cdot h\nu}{t} = \frac{n\cdot h\cdot c}{\lambda\cdot t}$

$\Rightarrow n = \frac{P\cdot\lambda\cdot t}{h\cdot c} = \frac{5\times10^{-3}\times6328\times10^{-10}\times1}{6.63\times10^{-34}\times3\times10^8} = 1.59\text{x}10^{16}$

c) **Expression for Compton Shift**

Diagram showing collision between photon and electron **….1mark**

Values of energy & momentum of photon and electron before and after collision **….2marks**

Equation of law of conservation of energy,

$h\nu + m_0c^2 = h\nu' + mc^2$ **….1mark**

Equation of law of conservation of momentum along horizontal direction,

$\frac{h\nu}{c} + 0 = \frac{h\nu'}{c}cos\theta + mvcos\varphi$ **….1mark**

Equation of law of conservation of momentum along vertical direction,

$0 + 0 = \frac{h\nu'}{c}sin\theta - mvsin\varphi$ **….1mark**

Working on above equations and finally obtaining expression for Compton Shitf:

$\lambda' - \lambda = \frac{h}{m_0c}(1 - cos\theta)$ **….3marks**

Showing that the wavelength of modified component is greater than that of unmodified component **….1mark**

Part – C

Answer **any one** question:

7. a) **Diameter of dark rings in Newton's Rings for transmitted light**

General expression for diameter: $D_n^2 = 8\,R\,t$ **….1mark**

Using the theory of interference in thin films for transmitted light, condition for <u>mimima</u> is:
$2\,\mu\,t\cos r = (2n+1)\lambda/2$ **…..1mark**

Using normal incidence assumption we get $2\,\mu\,t = (2n+1)\lambda/2$

$\Rightarrow t = \frac{(2n+1)\lambda}{4\,\mu}$ **…..1mark**

Substituting in general expression and solving we get,

$D_n = \sqrt{\frac{2\,\lambda\,R}{\mu}} \cdot \sqrt{(2n+1)}$

$\Rightarrow D_n \propto \sqrt{(2n+1)}$ (since $\sqrt{\frac{2\,\lambda\,R}{\mu}}$ is a constant)

….2marks

b) **Optical Resonator**

Diagram of optical resonator **…..1mark**

Brief explanation **….2 marks**

Requirement of optical resonator in laser: feedback of photons & selection of direction. Brief explanation. **……..2marks**

c) Applications of USW

i) Detection of flaws in metals (with diagram) **….2½marks**

ii) SONAR (with diagram) **….2½marks**

d) Numerical Problem

$\frac{1}{\lambda_{K_\alpha}} = \frac{3}{4}R(z-1)^2$ **….1mark**

$(z-1)^2 = \frac{4}{3\,\lambda_{K_\alpha} R} = \frac{4}{3\times1.55\times10^{-10}\times1.097\times10^{7}} = 784.1$

$z - 1 = \sqrt{784.1} = 28$

$z = 28 + 1 = 29$

3 marks

The target element is Copper (atomic number 29) **…….1mark**

8. a) Expression for conductivity of a semiconductor

Four differences between paramagnetic and ferromagnetic substances. **…….1mark each**

Two examples each of paramagnetic and ferromagnetic substances **…….1mark**

b) Numerical Problem

V-number of optical fibre,

$V = \frac{2\pi a}{\lambda}\cdot(N.A.)$ **…….1mark**

$= \frac{2\times3.14\times25\times10^{-6}}{0.96\times10^{-6}} \times 0.21$ =34.34 **…….2marks**

Number of modes (for step index fibre),

$N_m \approx V^2/2 = 34.34^2/2$ =589 **…….2marks**

c) Helium-Neon Laser

Diagram of He-Ne laser setup **…….1marks**

Explanation of setup **…….2marks**

Energy level diagram of He-Ne laser **…….2marks**

Working of He-Ne laser **…….3marks**

Advantages of He-Ne laser over ruby laser **…….2marks**

---------------xxxx-------------------xxxx--------------------xxxx--------------------xxxx--------------------xxx--------------