DSSSB AE/JE 2026

COMPLETE
ENGINEERING PHYSICS NOTES

Complete Theory • Detailed Hinglish Explanation • Formula Sheet
Important Derivations • Practice Questions

Prepared By

CIVILGYAN WITH SATISH

https://civilgyantests.com

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How to use this book: Read Complete Theory, reinforce it with the Hinglish Explanation, memorize the formula box, then attempt the ten questions without viewing the solutions. Question labels are original DSSSB-style practice, not claimed verbatim previous-year questions.

Constants used

1. $c = 2.998\times10^{8}$ m/s
2. $h = 6.626\times10^{-34}$ J·s
3. $\hbar = h/(2\pi)$
4. $e = 1.602\times10^{-19}$ C
5. $\varepsilon_0 = 8.854\times10^{-12}$ F/m
6. $\mu_0 = 4\pi\times10^{-7}$ H/m
7. $g \approx 9.81$ m/s^2.

How to Study This Book

Exam Method: Units, Assumptions and Checks

A reliable physics solution begins before numerical substitution. First identify the system, observation frame and requested quantity. Draw a compact diagram or free-body diagram, assign a sign convention, and list known data in SI units.

Next select a governing principle - kinematics, momentum conservation, energy conservation, a field law, a wave condition or a quantum relation - rather than choosing a formula merely because its symbols resemble the data. State the assumptions: constant acceleration, negligible air resistance, paraxial rays, an ideal capacitor, a long solenoid, a non-relativistic particle or an infinite potential well. Only then rearrange symbolically and substitute values.

A symbolic rearrangement exposes missing factors and usually prevents unit errors. Finish by checking sign, direction, order of magnitude and physical limiting behaviour. For example, fringe width should increase with wavelength; capacitance should fall when plate separation rises; and a relativistic formula should approach its classical form when v/c tends to zero.

Dimensional analysis is a fast rejection tool: terms added together must have identical dimensions, trigonometric arguments must be dimensionless, and an expression for energy must reduce to kg m squared per second squared. In MCQs, inspect dimensions and limiting cases before doing long arithmetic. Keep signs with vector components and use magnitudes only after direction has been settled.

Convert nanometres, electron-volts, dioptres and centimetres explicitly. Treat statements containing always, only or never with care because many laws depend on stated conditions. Finally, distinguish an ideal model from a real device: a real laser has finite linewidth, a real lens has aberrations, a conductor may cease to be ohmic when temperature changes, and constant-acceleration equations cannot be extended to arbitrary motion.

This method soon becomes the fastest dependable exam routine. During revision, make a one-page error log containing wrong signs, forgotten units, false assumptions and formulas used outside their conditions. Re-solve those items after one day and again after one week.

In a timed paper, secure direct conceptual questions first, mark calculation-heavy items for a second pass, and reserve the final minutes for unit, option-number and negative-marking checks.

CHAPTER 1 — PHYSICS OF MOTION

1. Introduction

Physics of motion, or mechanics, describes how position changes with time and why that change occurs. It connects measurements of displacement, velocity and acceleration with force, momentum, energy and rotation. Engineers use mechanics to size brakes, lifts, machines, foundations and moving components. DSSSB commonly tests sign convention, motion graphs, Newton’s laws, friction, work–energy, momentum and circular motion through direct concepts and short numericals.

2. Complete Theory

Kinematics: position, velocity and acceleration

A particle is an idealized body whose size is negligible for the problem. Position vec(r) locates it relative to an origin.

Distance is total path length and is a non-negative scalar; displacement Δvec(r) = vec(r)$_2$ − vec(r)$_1$ is a vector and depends only on endpoints. Average velocity is Δvec(r)/Δt, whereas average speed is distance/Δt.

Instantaneous velocity vec(v) = dvec(r)/dt is tangent to the path; acceleration vec(a) = dvec(v)/dt may change speed, direction, or both. For straight motion with constant acceleration: $v = u + at$, $s = ut + ½at^2$ and $v^2 = u^2 + 2as$.

These equations are invalid when acceleration varies with time.

Hinglish Explanation

Agar simple language me samjhein, speed batati hai ‘kitni tezi’, velocity batati hai ‘kitni tezi aur kis direction me’. Gol track ka ek round complete karne par distance circumference hota hai, lekin displacement zero.

Isi liye average speed zero nahi, average velocity zero hoti hai. Graph me displacement–time ka slope velocity aur velocity–time ka slope acceleration hota hai; velocity–time graph ke neeche ka signed area displacement deta hai.

Exam me sabse common galti distance aur displacement ko same maan lena hai.

Dynamics, momentum and impulse

Newton’s first law defines inertia and inertial frames. The second law is vec(F)_net = dvec(p)/dt; for constant mass it becomes vec(F)_net = mvec(a).

The third law states that interaction forces are equal and opposite but act on different bodies, so they do not cancel on one free-body diagram. Linear momentum vec(p) = mvec(v) is conserved for an isolated system.

Impulse vec(J) = ∫vec(F)dt = Δvec(p). Friction opposes relative motion or its tendency: static friction adjusts up to f_s,max = $\mu_s N$, while kinetic friction is approximately $f_k = \mu_k N$.

Hinglish Explanation

Imagine karo bus suddenly brake lagati hai: body forward jati hui lagti hai because inertia purani velocity maintain karna chahta hai. Seat belt impulse ka time badha kar average force kam karta hai, kyunki $F_{avg} = \Delta p/\Delta t$.

Static friction hamesha $\mu_s N$ nahi hota; woh requirement ke according zero se maximum tak adjust karta hai. Yeh statement DSSSB me trap ke roop me aata hai.

Work, energy, power and conservative forces

Work by a constant force is W = vec(F)·vec(s) = Fs cosθ. Net work equals change in kinetic energy: W_{net} = ΔK, with K = ½mv^2.

Near Earth, gravitational potential energy U = mgh; elastic energy U = ½kx^2. For conservative forces, work depends only on endpoints and mechanical energy K + U remains constant if non-conservative work is absent.

Power is the rate of doing work, P = dW/dt = vec(F)·vec(v), measured in watt.

Hinglish Explanation

Real life me crane ka motor load ko height deta hai, so gravitational potential energy badhti hai. Same load ko half time me lift karne par work same, power double.

‘Energy conserved’ ka matlab kinetic energy alone constant nahi; kinetic aur potential aapas me convert hote hain. Friction ho to mechanical energy heat me convert hoti hai, lekin total energy phir bhi conserved rehti hai.

Circular and rotational motion

In uniform circular motion speed is constant but velocity changes direction, producing centripetal acceleration $a_c = v^2/r = \omega^2 r$ toward the centre and required inward force $F_c = mv^2/r$. Centripetal force is not a new force; it is the radial resultant supplied by tension, gravity, friction or normal reaction.

For rigid rotation, angular displacement θ, angular velocity ω and angular acceleration α correspond to s = rθ, v = rω and tangential acceleration a_t = rα. Torque $\vec{\tau}$ = vec(r)×vec(F) and τ = Iα.

Rotational kinetic energy is ½Iω^2 and angular momentum vec(L) = I$\vec{\omega}$ for rotation about a fixed principal axis.

Hinglish Explanation

Turning car me friction hi centripetal force deti hai. ‘Centrifugal force’ inertial frame me real interaction force nahi; rotating frame ka apparent force hai.

Door ko hinge se door push karna easy hota hai because torque τ = rF sinθ badhta hai. Mass ko axis se door shift karoge to moment of inertia I badhega, isliye same angular momentum par ω ghatega.

3. Formula Section

Formula Box
1. $v = u + at$
2. $s = ut + ½at^2$
3. $v^2 = u^2 + 2as$
4. vec(F) = dvec(p)/dt
5. vec(p) = mvec(v)
6. vec(J) = Δvec(p)
7. $W = Fs \cos\theta$
8. $K = ½mv^2$
9. $U_g = mgh$
10. P = vec(F)·vec(v)
11. $a_c = v^2/r = \omega^2 r$
12. τ□ = vec(r)×vec(F)
13. $K_{rot} = ½I\omega^2$.

4. Important Derivation

For constant a, a = (v − u)/t gives v = u + at. Average velocity is (u + v)/2, so s = [(u + v)/2]t. Substituting v gives $s = ut + ½at^2$. Eliminating t using t = (v − u)/a gives $2as = (u + v)(v − u) = v^2 − u^2$, hence $v^2 = u^2 + 2as$.

5. Practical Examples

• Stopping-sight distance combines reaction distance and braking distance.

• Elevator cable tension follows a free-body equation and changes with acceleration.

• Flywheels store rotational energy and smooth engine-speed fluctuations.

• Impact hammers use momentum change over a short time; protective pads increase impact time.

6. Comparison Table

Quantity	Scalar/Vector	Key meaning
Distance	Scalar	Actual path length
Displacement	Vector	Endpoint change
Speed	Scalar	Rate of distance
Velocity	Vector	Rate of displacement

7. Important DSSSB Exam Points

• Static friction is self-adjusting; its limiting value is $\mu_s N$.

• Zero velocity at an instant does not imply zero acceleration.

• Action and reaction act on different bodies.

• Centripetal acceleration points inward even at constant speed.

• Use SI units before substituting in a numerical.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. A runner completes one lap of a circular track. The displacement is

(A) equal to circumference
(B) zero
(C) equal to radius
(D) twice the radius

Correct Answer: (B)
Initial and final positions coincide.

Q2. The slope of a velocity–time graph gives

(A) displacement
(B) speed
(C) acceleration
(D) jerk

Correct Answer: (C)
Slope is dv/dt.

Q3. A body starts from rest with $a = 2\ m/s^2$ for 5 s. Its final speed is

(A) 5 m/s
(B) 7 m/s
(C) 10 m/s
(D) 25 m/s

Correct Answer: (C)
$v = u + at = 0 + 2\times5 = 10$ m/s.

Q4. Newton’s second law in its most general form is

(A) vec(F) = mvec(a)
(B) vec(F) = dvec(p)/dt
(C) F = mv
(D) F = m/a

Correct Answer: (B)
Momentum form also covers variable mass.

Q5. Maximum static friction equals

(A) $\mu_k N$
(B) $\mu_s N$
(C) mg always
(D) zero

Correct Answer: (B)
Limiting static friction is $\mu_s N$.

Q6. Net work on a particle equals change in

(A) momentum
(B) potential energy
(C) kinetic energy
(D) power

Correct Answer: (C)
This is the work–energy theorem.

Q7. A 20 N force moves a body 3 m perpendicular to itself. Work is

(A) 60 J
(B) 20 J
(C) 3 J
(D) 0 J

Correct Answer: (D)
W = Fs cos90° = 0.

Q8. In uniform circular motion, acceleration is

(A) zero
(B) tangential
(C) outward
(D) toward centre

Correct Answer: (D)
Velocity direction changes, giving inward v^2/r.

Q9. The SI unit of torque is

(A) N
(B) J/s
(C) N·m
(D) kg·m/s

Correct Answer: (C)
Torque is force×lever arm.

Q10. If collision time doubles for the same Δp, average force

(A) doubles
(B) halves
(C) is unchanged
(D) becomes zero

Correct Answer: (B)
$F_{avg} = \Delta p/\Delta t$.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 2 — OPTICS

1. Introduction

Optics studies the production, propagation and interaction of light. Geometrical optics treats light as rays; wave optics explains interference, diffraction and polarization. Optical principles govern surveying instruments, cameras, microscopes, fibre communication and laser alignment. DSSSB questions frequently target sign conventions, mirror/lens equations, refractive index, total internal reflection and wave phenomena.

2. Complete Theory

Reflection, refraction and refractive index

Reflection obeys i = r, with incident ray, reflected ray and normal coplanar. Refraction occurs because phase speed changes at an interface.

Absolute refractive index n = c/v, and Snell's law is $n_1 \sin i = n_2 \sin r$. Frequency remains constant across a stationary boundary, while speed and wavelength change.

Apparent depth for near-normal viewing from air is real depth/n. Dispersion arises because n depends on wavelength.

Hinglish Explanation
Paani me coin upar dikhai deta hai because rays water se air me aate hue normal se door bend karti hain. Frequency source decide karta hai, isliye boundary par frequency same rahatii hai; v change hone par λ change hoti hai.

Students often say light 'slows, therefore frequency decreases'—yeh wrong hai.

Mirrors and thin lenses

For spherical mirrors, 1/f = 1/v + 1/u and magnification $m = h_i/h_o = -v/u$ under the Cartesian convention. A concave mirror converges paraxial rays; a convex mirror diverges them.

For a thin lens in air, 1/f = 1/v − 1/u and m = v/u. Lens power P = 1/f when f is in metres, unit dioptre.

Powers add for thin lenses in contact. Real images can be caught on a screen; virtual images cannot.

Hinglish Explanation
Mirror aur lens formula me sign convention sabse important hai. Direction of incident light ko positive axis maan kar coordinates assign karo, formula ratne ke bajay signs carefully lagao.

Convex lens usually converging hai, but object focal point ke andar ho to enlarged virtual image deta hai—magnifying glass isi principle par kaam karta hai.

Total internal reflection and optical fibre

When light travels from higher to lower refractive index, the refracted angle exceeds the incident angle. At the critical angle C, r = 90° and $\sin C = n_2/n_1$.

For i > C, total internal reflection (TIR) occurs with nearly complete reflection. Both conditions—denser-to-rarer travel and incidence above C—are essential.

Optical fibres use a higher-index core and lower-index cladding; numerical aperture in air is $NA = \sqrt{(n_1^2 - n_2^2)}$ for step-index fibre.

Hinglish Explanation
Imagine karo fibre ke core me light zig-zag bounce karte hue aage badhatii hai. Sirf 'angle badaa hai' enough nahi; ray ko high-n core se low-n cladding ki taraf jana chahiye.

Diamond ka sparkle small critical angle aur repeated TIR se hota hai.

Interference, diffraction and polarization

Coherent waves of stable phase difference superpose to produce interference. In Young's double-slit experiment, fringe width $\beta = \lambda D/d$; bright fringes satisfy path difference $m\lambda$ and dark fringes $(m + ½)\lambda$.

Diffraction is spreading at an aperture or edge and becomes prominent when aperture size is comparable to λ. Polarization restricts transverse vibration directions and demonstrates the transverse nature of light; unpolarized intensity after an ideal polarizer is half, and Malus's law is $I = I_0\cos^2\theta$ for polarized incidence.

Hinglish Explanation

Interference do coherent sources ka ordered addition hai; diffraction ek aperture ke different parts ki interference hai. β badhaane ke liye wavelength ya screen distance badhaao, slit separation ghataao.

Polarization longitudinal sound waves me nahi hoti, isliye yeh light ke transverse nature ka strong evidence hai.

3. Formula Section

Formula Box
1. $n = c/v$
2. $n_1 \sin i = n_2 \sin r$
3. $1/f_m = 1/v + 1/u$
4. $1/f_l = 1/v - 1/u$
5. $P = 1/f\ (m^{-1})$
6. $\sin C = n_2/n_1$
7. $NA = \sqrt{(n_1^2 - n_2^2)}$
8. $\beta = \lambda D/d$
9. $I = I_0\cos^2\theta$.

4. Important Derivation

In YDSE, for $d << D$, path difference $\delta \approx d \sin\theta \approx dy/D$. Successive bright fringes have $\delta = m\lambda$ and $(m + 1)\lambda$, so their positions differ by $\beta = [(m + 1)\lambda D/d] - [m\lambda D/d] = \lambda D/d$.

5. Practical Examples

• Convex mirrors provide a wide field of view in vehicles.

• Auto-levels and theodolites use lenses and reticles for surveying.

• Optical fibres carry low-loss digital signals and support medical endoscopy.

• Polarizing filters suppress reflected glare; diffraction limits instrument resolution.

6. Comparison Table

Feature	Convex lens	Concave lens
Action	Converges parallel rays	Diverges parallel rays
f and P	Positive	Negative
Real image	Possible	Not for real object
Common use	Camera, magnifier	Myopia correction

7. Important DSSSB Exam Points

• Frequency does not change during refraction.

• TIR needs high-n to low-n travel and i > C.

• Lens power uses focal length in metres.

• Polarization proves transverse character.

• In YDSE, β □ $\lambda D/d$.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. During refraction at a stationary interface, which remains unchanged?

(A) speed
(B) wavelength
(C) frequency
(D) direction

Correct Answer: (C)
Frequency is fixed by the source.

Q2. Refractive index is

(A) v/c
(B) c/v
(C) cλ
(D) vλ

Correct Answer: (B)
n = c/v.

Q3. A lens of focal length +0.5 m has power

(A) −2 D
(B) +0.5 D
(C) +2 D
(D) +5 D

Correct Answer: (C)
P = 1/f = 2 D.

Q4. A virtual image can be

(A) projected on screen
(B) formed by apparent ray intersection
(C) always inverted
(D) always diminished

Correct Answer: (B)
Virtual rays only appear to meet.

Q5. TIR can occur when light travels

(A) rarer to denser
(B) denser to rarer with i > C
(C) at any interface
(D) only normally

Correct Answer: (B)
Both direction and angle conditions are necessary.

Q6. If slit separation doubles in YDSE, fringe width

(A) doubles
(B) halves
(C) quadruples
(D) unchanged

Correct Answer: (B)
$\beta = \lambda D/d$.

Q7. The central diffraction maximum is generally

(A) dark
(B) narrowest
(C) bright and widest
(D) absent

Correct Answer: (C)
Single-slit central maximum is bright and twice the width of secondary maxima.

Q8. Polarization establishes that light is

(A) longitudinal
(B) transverse
(C) a particle only
(D) stationary

Correct Answer: (B)
Only transverse waves show polarization.

Q9. An ideal polarizer receives unpolarized intensity I. Output is

(A) I
(B) I/2
(C) I/4
(D) zero

Correct Answer: (B)
Averaging $\cos^2\theta$ gives 1/2.

Q10. Optical fibre cladding has refractive index

(A) greater than core
(B) equal to core
(C) less than core
(D) zero

Correct Answer: (C)
Core must have higher n for TIR.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 3 — ELECTROMAGNETISM

1. Introduction

Electromagnetism unifies electric charge, fields, circuits, magnetism and electromagnetic induction. It underlies power systems, motors, generators, transformers, sensors and communication. DSSSB emphasizes Coulomb's law, field and potential, capacitance, Ohm's law, magnetic force, Biot–Savart/Ampere ideas, Faraday–Lenz law and basic electromagnetic waves.

2. Complete Theory

Electric field, flux and potential

Charge is quantized in units of e and conserved. Coulomb force between point charges is F = $(1/4\pi\varepsilon_0)|q_1q_2|/r^2$ along their line.

Electric field vec(E) = vec(F)/q_0 is force per positive test charge. Superposition is vectorial.

Electric flux Φ_E = ∫vec(E)·dvec(A); Gauss's law closed-integralvec(E)·dvec(A) = $Q_{enclosed}/\varepsilon_0$ is most useful with symmetry. Potential difference is work per unit charge, ΔV = −∫vec(E)·dvec(l), and vec(E) = −nablaV.

Hinglish Explanation

Field ko slope aur potential ko height jaisa imagine karo. Positive charge naturally high potential se low potential ki taraf move karti hai; electron opposite.

Gauss law har closed surface ke liye true hai, lekin field nikaalane me tabhii easy hai jab symmetry ho. Enclosed charge matter karta hai, outside charge net flux change nahi karta.

Capacitance and DC circuits

A capacitor stores separated charge and field energy: C = Q/V. Parallel-plate capacitance is C = εA/d, and energy U = ½CV^2 = $Q^2/(2C)$.

Capacitances add directly in parallel and reciprocally in series. Ohm's law V = IR describes ohmic conductors under constant physical conditions.

Resistance R = ρL/A, electrical power P = VI = I^2R = V^2/R. Kirchhoff's junction rule expresses charge conservation; loop rule expresses energy conservation.

Hinglish Explanation

Capacitor battery nahi banata; charge separation store karta hai. Plate area badhe to C badhataa, gap badhe to C ghatataa.

Resistors series me same current share karte hain, parallel me same voltage. Exam me P = V^2/R aur P = I^2R ko situation ke anusaara use karo: fixed voltage par R badhane se power ghatatii, fixed current par badhatii.

Magnetic force and fields

A moving charge experiences Lorentz force vec(F) = q(vec(E) + vec(v)×vec(B)). Magnetic force qvBsinθ is perpendicular to velocity, so a static magnetic field does no work and changes direction rather than speed.

A current element experiences dvec(F) = I dℓ□×vec(B). The field of a long straight wire is B = $\mu_0 I/(2\pi r)$; inside a long solenoid B ≈ $\mu_0 nI$.

Torque on a current loop is τ = NIABsinθ, basis of motors and moving-coil instruments.

Hinglish Explanation

Right-hand rule se direction decide hoti hai; negative charge ke liye reverse. Magnetic force velocity ke perpendicular hai, isalie kinetic energy change nahi hoti.

Motor me current-carrying coil par torque milta hai; generator me motion se emf banatii hai—cause-effect ulta hai.

Electromagnetic induction and waves

Faraday's law states induced emf emf = −N $d\Phi_B/dt$, where Φ_B = ∫vec(B)·dvec(A). The minus sign is Lenz's law: induced current opposes the change producing it, consistent with energy conservation.

Self-inductance obeys emf = −L di/dt and stores U = ½LI^2. An ideal transformer satisfies $V_s/V_p = N_s/N_p$ and V_{pI}–p = V_{sI}–s.

Maxwell's equations imply transverse electromagnetic waves traveling in vacuum at c = 1/√($\mu_0\varepsilon_0$), with vec(E), vec(B) and propagation mutually perpendicular.

Hinglish Explanation

Magnet ko coil ke paas move karo to flux change, tabhii emf. Magnet stationary ho aur flux constant ho to field present hone ke baavajuuda emf zero.

Lenz law 'opposes flux' nahi, flux ke change ko oppose karta hai. Transformer DC par steady operation nahi karta because dΦ/dt required hai.

3. Formula Section

Formula Box
1. F = $|q_1q_2|/(4\pi\varepsilon_0r^2)$
2. vec(E) = vec(F)/q
3. Φ_E = closed-integralvec(E)·dvec(A)
4. C = Q/V
5. C = εA/d
6. U_C = ½CV^2
7. V = IR
8. R = ρL/A
9. vec(F) = qvec(v)×vec(B)
10. $B_{wire} = \mu_0I/(2\pi r)$
11. emf = −N $d\Phi_B/dt$
12. c = 1/√($\mu_0\varepsilon_0$).

4. Important Derivation

For a parallel-plate capacitor with negligible edge effects, Gauss's law gives E = σ/ε = Q/(εA). The potential difference is V = Ed = Qd/(εA). Therefore C = Q/V = εA/d.

5. Practical Examples

• Earthing and shielding control electric potential and fields.

• Capacitor banks improve power factor and support starting circuits.

• Motors convert electrical to mechanical energy; generators reverse the conversion.

• Transformers distribute AC efficiently; induction sensors detect metal and motion.

6. Comparison Table

Property	Electric field	Magnetic field
Source	Charge	Moving charge/current
Force on rest charge	Yes	No
Work on point charge	Can do work	Does no work alone
SI unit	N/C or V/m	tesla

7. Important DSSSB Exam Points

• Gauss law uses enclosed charge, not total nearby charge.

• Magnetic force does no work on a point charge.

• Lenz sign enforces energy conservation.

• Transformer requires changing flux.

• Resistance depends on geometry; resistivity mainly on material and temperature.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. SI unit of electric field is

(A) C/N
(B) N/C
(C) J/C
(D) C·m

Correct Answer: (B)
E = F/q gives N/C.

Q2. Net electric flux through a closed surface depends on

(A) surface shape only
(B) external charge only
(C) enclosed charge
(D) surface area only

Correct Answer: (C)
Gauss law gives $Q_{enclosed}/\varepsilon_0$.

Q3. Capacitance of parallel plates increases when

(A) d increases
(B) A decreases
(C) dielectric is inserted
(D) charge is removed

Correct Answer: (C)
C = εA/d, so higher ε increases C.

Q4. Two equal resistors R in parallel have equivalent

(A) 2R
(B) R
(C) R/2
(D) R^2

Correct Answer: (C)

$1/R_{eq} = 2/R$.

Q5. Magnetic force on a moving charge is maximum when θ is

(A) 0°
(B) 30°
(C) 60°
(D) 90°

Correct Answer: (D)

$F = qvB\sin\theta$ is maximum at 90°.

Q6. A magnetic field alone changes a charged particle's

(A) speed only
(B) kinetic energy
(C) direction of velocity
(D) rest mass

Correct Answer: (C)

Force is perpendicular to v.

Q7. Lenz's law determines induced current's

(A) magnitude only
(B) direction
(C) resistance
(D) frequency only

Correct Answer: (B)

It states opposition to flux change.

Q8. A transformer operates on

(A) steady DC
(B) changing current
(C) electrostatic field only
(D) chemical energy

Correct Answer: (B)

Changing flux is essential.

Q9. Field inside a long solenoid is approximately

(A) $\mu_0 nI$
(B) $\mu_0 I/2\pi r$
(C) zero
(D) $\varepsilon_0 nI$

Correct Answer: (A)

Solenoid field is $\mu_0 nI$.

Q10. Electromagnetic waves in vacuum are

(A) longitudinal
(B) transverse
(C) material waves
(D) slower than sound

Correct Answer: (B)

E and B are perpendicular to propagation.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 4 — QUANTUM IDEAS

1. Introduction

Quantum ideas arose because classical physics could not explain blackbody radiation, the photoelectric effect and atomic spectra. Energy and momentum can be exchanged in discrete quanta, and matter has wave properties. These foundations support photo-detectors, electron microscopes, semiconductor devices and spectroscopy. DSSSB usually asks Planck–Einstein relations, photoelectric laws, de Broglie wavelength and uncertainty.

2. Complete Theory

Photons and the photoelectric effect

Planck proposed energy quanta $E = h\nu$. Einstein treated light as photons with energy $h\nu$ and momentum $p = h/\lambda$.

In photoemission, one photon transfers energy to one electron: $h\nu = \varphi + K_{max}$, where φ is work function. Threshold frequency $\nu_0 = \varphi/h$.

Stopping potential V_s satisfies $eV_s = K_{max}$. Increasing intensity above threshold raises photoelectric current, not K_{max}; increasing frequency raises K_{max}.

Hinglish Explanation

Light ko energy packets—photons—ki stream samjho. Intensity badhaane se photons per second badhate hain, isalie emitted electrons zyada, current zyada.

Lekin ek electron ko milne wali energy $h\nu$ frequency decide karti hai. Threshold se kama frequency par kitni bhi intense light ho, emission nahi hoga.

Matter waves and wave–particle duality

de Broglie assigned wavelength $\lambda = h/p$ to every particle. For non-relativistic momentum $p = mv$; an electron accelerated through potential V has $\lambda = h/\sqrt{(2m_e eV)}$.

Matter waves are not mechanical waves in a material medium; $|\psi|^2$ later gives probability density. Electron diffraction confirms wave behaviour, while localized detection shows particle behaviour.

Large objects have imperceptibly small λ because their momentum is enormous compared with h.

Hinglish Explanation

Cricket ball ki bhi de Broglie wavelength theoretically hoti hai, but itni tiny ki observe nahi kar sakte. Electron ka mass chhotaa hai, so laboratory-scale diffraction possible.

'Particle kabhi wave ban jata hai' literal transformation nahi; experiment ke setup ke anusaara wave-like or particle-like behavior dikhaaii detaa hai.

Uncertainty and atomic stability

Heisenberg's principle states $\Delta x \Delta p_x \geq \hbar/2$ and $\Delta E \Delta t \geq \hbar/2$ in their standard forms. It is intrinsic to quantum states, not merely instrument error.

Strong localization requires a broad momentum distribution. The principle helps explain why an electron cannot remain motionless inside a nucleus-sized region.

Quantum states, rather than classical planetary orbits, describe stable atoms.

Hinglish Explanation

Electron ko exact position me lock karne kii koshisha karoge to momentum uncertainty bahuta badhegii. Yeh kharaaba microscope ki problem nahi; nature ka wave-packet property hai.

Exam me $h/4\pi$ aur $\hbar/2$ equivalent forms hain because $\hbar = h/2\pi$.

3. Formula Section

Formula Box
1. $E = h\nu = hc/\lambda$
2. $p_\gamma = h/\lambda$
3. $h\nu = \varphi + K_{max}$
4. $eV_s = K_{max}$
5. $\nu_0 = \varphi/h$
6. $\lambda_{dB} = h/p$
7. $\lambda_e = h/\sqrt{(2m_e eV)}$
8. $\Delta x \Delta p_x \geq \hbar/2$.

4. Important Derivation

An electron accelerated from rest through potential V gains kinetic energy $eV = p^2/(2m_e)$. Hence $p = \sqrt{(2m_e eV)}$. Substitution into $\lambda = h/p$ gives $\lambda = h/\sqrt{(2m_e eV)}$, so λ decreases as $1/\sqrt{V}$.

5. Practical Examples

• Photocells and photodiodes detect light and control automatic systems.

• Electron microscopes exploit short matter wavelengths for high resolution.

• Spectroscopy identifies materials through discrete transitions.

• Quantum tunnelling is used in scanning tunnelling microscopy and modern electronics.

6. Comparison Table

Change	Photoelectric current	K_{max}
Increase intensity, fixed $\nu > \nu_0$	Increases	Unchanged
Increase frequency, comparable intensity	May vary	Increases
$\nu < \nu_0$	Zero	No emission

7. Important DSSSB Exam Points

• Threshold depends on material work function.

• Intensity controls number of photons, frequency controls photon energy.

• Uncertainty is intrinsic, not experimental carelessness.

• de Broglie wavelength is inversely proportional to momentum.

• Use eV as an energy unit: $1 \text{ eV} = 1.602 \times 10^{-19}$ J.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Photon energy is

(A) h/v
(B) hv
(C) hcv
(D) v/h

Correct Answer: (B)
Planck relation is E = hv.

Q2. Below threshold frequency, photoemission occurs if intensity is

(A) very high
(B) doubled
(C) infinite
(D) not at all

Correct Answer: (D)
Each photon lacks φ.

Q3. Stopping potential measures maximum

(A) current
(B) kinetic energy per charge
(C) wavelength
(D) work function directly

Correct Answer: (B)
$eV_s = K_{max}$.

Q4. Increasing light intensity above threshold mainly increases

(A) K_{max}
(B) electron count per second
(C) v_0
(D) work function

Correct Answer: (B)
More photons produce more electrons.

Q5. de Broglie wavelength equals

(A) hp
(B) h/p
(C) p/h
(D) mv/h

Correct Answer: (B)
λ = h/p.

Q6. Electron wavelength after acceleration through V varies as

(A) V
(B) 1/V
(C) √V
(D) 1/√V

Correct Answer: (D)
λ = h/√(2meV).

Q7. Uncertainty relation is

(A) $\Delta x \Delta p = 0$
(B) $\Delta x \Delta p \geq \hbar/2$
(C) $\Delta x = \Delta p$
(D) $\Delta x \Delta p \leq \hbar/2$

Correct Answer: (B)

The product has a nonzero lower bound.

Q8. A photon has rest mass

(A) $h\nu/c^2$
(B) zero
(C) infinite
(D) electron mass

Correct Answer: (B)

Photon invariant rest mass is zero though it has energy and momentum.

Q9. Matter-wave effects are strongest for

(A) macroscopic trucks
(B) high-momentum balls
(C) low-momentum microscopic particles
(D) stationary buildings

Correct Answer: (C)

Small momentum gives observable λ.

Q10. The photoelectric equation conserves

(A) charge only
(B) photon number
(C) energy
(D) mass number

Correct Answer: (C)

$h\nu$ divides into work function and electron kinetic energy.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 5 — PHYSICS OF MATERIALS

1. Introduction

Materials physics links atomic bonding and crystal structure to mechanical, electrical, thermal and magnetic properties. It guides selection of steel, concrete constituents, semiconductors, magnetic cores and insulating materials. DSSSB questions commonly cover crystal systems, defects, stress–strain terms, band theory, semiconductors, dielectric and magnetic classification.

2. Complete Theory

Bonding, crystals and defects

Ionic, covalent, metallic and secondary bonds produce different stiffness, conductivity and melting behaviour. Crystalline solids possess long-range periodic order; amorphous solids have only short-range order.

A unit cell generates a lattice by translation. Common cubic structures are simple cubic (coordination 6), BCC (8) and FCC (12).

Vacancies and interstitials are point defects; dislocations are line defects. Defects can strengthen alloys but also promote diffusion and failure.

Hinglish Explanation

Crystal ko 3-D repeating tile samjho. Unit cell smallest repeating block hai, molecule hona jaruurii nahiin.

FCC packing dense hai, BCC less dense. Defect ka meaning hameshaa ‘bad’ nahi: controlled dislocations aur solute atoms metal ko strengthen karte hain, while excessive flaws crack initiation karaa sakate hain.

Elasticity and mechanical response

Normal stress $\sigma = F/A$ and strain $\varepsilon = \Delta L/L$. In the linear elastic region, $\sigma = E\varepsilon$, where E is Young’s modulus.

Shear modulus G relates shear stress to shear strain; bulk modulus K relates pressure to volumetric strain. Elastic deformation is recoverable; plastic deformation remains.

Yield strength marks onset of significant plastic flow, ultimate strength is maximum engineering stress, and toughness is energy per volume to fracture (area under the whole stress–strain curve). Resilience concerns recoverable elastic energy.

Hinglish Explanation

Rubber easily stretch hota hai, but iska matlab high elasticity in engineering sense nahi; high Young’s modulus vaalaa steel same stress par kama strain deta hai. Stiffness, strength aur toughness alaga hain.

Glass stiff and strong in compression ho sakataa hai but brittle; mild steel ductile and tough.

Band theory and semiconductors

In solids, atomic levels broaden into bands. A conductor has a partially filled band or band overlap; an insulator has a large forbidden gap; a semiconductor has a moderate gap.

Intrinsic semiconductors have equal electron and hole concentrations. Donor doping creates n-type material with electrons as majority carriers; acceptor doping creates p-type material with holes as majority carriers.

Doping preserves overall electrical neutrality. A p–n junction conducts readily in forward bias and weakly in reverse bias until breakdown.

Hinglish Explanation

n-type me 'negative material' nahi banta; crystal overall neutral rahataa hai. n sirf majority carrier electron ko indicate karta hai.

Forward bias barrier ghataataa hai, reverse bias badhaataa hai. Semiconductor resistance temperature badhane para generally ghatatii hai because carrier concentration rises—metals ke opposite.

Dielectric and magnetic materials

A dielectric polarizes in an electric field, reducing internal field and increasing capacitance. Relative permittivity $\varepsilon_r = \varepsilon/\varepsilon_0$.

Diamagnetic materials have small negative susceptibility and are weakly repelled; paramagnetic materials have small positive susceptibility and are weakly attracted; ferromagnets show domains, large positive response and hysteresis. Soft magnetic materials have narrow hysteresis loops and low coercivity for transformers; hard magnets have high coercivity and remanence.

Hinglish Explanation

Transformer core ko baara-baara magnetize–demagnetize karanaa hotaa hai, isalie narrow hysteresis loop vaalaa soft magnetic material chaahie; 'soft' mechanical softness nahiin. Permanent magnet ko magnetization retain karna hai, so high coercivity.

Diamagnetic response applied field ke opposite induced hota hai.

3. Formula Section

Formula Box
1. $\sigma = F/A$
2. $\varepsilon = \Delta L/L$
3. $E = \sigma/\varepsilon$
4. G = shear stress/shear strain
5. $K = -p/(\Delta V/V)$
6. $C = \varepsilon A/d$
7. $\varepsilon_r = \varepsilon/\varepsilon_0$
8. $\sigma_{electrical} = nq\mu$ (single carrier)
9. $\rho = 1/\sigma_{electrical}$.

4. Important Derivation

For an axially loaded bar in the linear region, $\varepsilon = \sigma/E = F/(AE)$. Since $\varepsilon = \Delta L/L$, extension is $\Delta L = FL/(AE)$. The result assumes uniform area, axial load, homogeneous material and linear elasticity.

5. Practical Examples

• Young's modulus controls structural deflection, while strength controls failure margin.

• Alloying and heat treatment manipulate defects and microstructure.

• Silicon p–n junctions form rectifiers, sensors and solar cells.

• Soft ferrites reduce eddy-current loss in high-frequency magnetic cores.

6. Comparison Table

Property	Conductor	Semiconductor	Insulator
Band gap	None/overlap	Small–moderate	Large
Conductivity	High	Intermediate, controllable	Very low
Temperature effect on R	Usually increases	Usually decreases	Remains very high

7. Important DSSSB Exam Points

• Stiffness is not strength; toughness is not hardness.

• n-type and p-type materials remain neutral.

• Semiconductor resistance usually falls with temperature.

• Soft magnetic means low coercivity, not low mechanical hardness.

• Area under stress–strain curve to fracture represents toughness.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Coordination number of FCC is

(A) 6
(B) 8
(C) 12
(D) 14

Correct Answer: (C)
FCC has 12 nearest neighbours.

Q2. Young's modulus equals

(A) strain/stress
(B) stress×strain
(C) stress/strain
(D) force×area

Correct Answer: (C)
In linear elasticity $E = \sigma/\varepsilon$.

Q3. Area under complete stress–strain curve represents

(A) stiffness
(B) toughness
(C) hardness
(D) density

Correct Answer: (B)
It is energy absorbed per volume to fracture.

Q4. Majority carriers in n-type semiconductor are

(A) holes
(B) protons
(C) electrons
(D) ions

Correct Answer: (C)
Donors supply electrons.

Q5. Doping an intrinsic semiconductor generally

(A) destroys neutrality
(B) changes majority concentration
(C) makes perfect insulator
(D) removes band gap

Correct Answer: (B)
Carrier balance changes but bulk remains neutral.

Q6. A p–n junction in forward bias has

(A) higher barrier
(B) lower barrier
(C) no carriers
(D) infinite resistance

Correct Answer: (B)
Forward voltage reduces depletion barrier.

Q7. Diamagnetic susceptibility is

(A) large positive
(B) small positive
(C) small negative
(D) infinite

Correct Answer: (C)
Diamagnets oppose applied field weakly.

Q8. Transformer cores prefer

(A) hard magnets
(B) soft magnetic material
(C) diamagnetic material
(D) air only

Correct Answer: (B)
Low coercivity and narrow loop reduce hysteresis loss.

Q9. For a bar, ΔL is proportional to

(A) AE/FL
(B) FL/AE
(C) FA/EL
(D) EFL/A

Correct Answer: (B)
$\Delta L = FL/(AE)$.

Q10. An amorphous solid lacks

(A) atoms
(B) short-range order
(C) long-range periodic order
(D) mass

Correct Answer: (C)
It may retain local order but not periodic long-range order.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 6 — RELATIVITY

1. Introduction

Special relativity describes measurements in inertial frames when relative speeds approach the speed of light. It replaces absolute time with invariant spacetime relations while preserving physical laws. Relativistic corrections matter in particle accelerators, satellite timing and high-energy radiation. DSSSB usually asks Einstein's postulates, time dilation, length contraction, Lorentz factor and mass–energy equivalence.

2. Complete Theory

Postulates and Lorentz factor

Einstein's special relativity rests on two postulates: physical laws have the same form in all inertial frames, and vacuum light speed c is identical for all inertial observers regardless of source or observer motion. The Lorentz factor is $\gamma = 1/\sqrt{(1 - v^2/c^2)}$.

At $v << c$, $\gamma \approx 1$ and Newtonian results are recovered. No material object with nonzero rest mass can be accelerated to c because required energy diverges.

Hinglish Explanation

Train ke andar torch forward shine karne par passenger aur platform observer dono c measure karenge, c+train speed nahiin. Is consistency ke lie time aur length measurements adjust hote hain.

Everyday speeds par v^2/c^2 tiny hai, so γ lagabhaga 1 and classical mechanics perfectly adequate.

Time dilation, length contraction and simultaneity

Proper time Δτ is measured by a clock present at both events; another inertial frame measures $\Delta t = \gamma\Delta\tau$, so a moving clock runs slow relative to that frame. Proper length L_0 is measured in the object's rest frame; a frame seeing it move parallel to its length measures $L = L_0/\gamma$.

Contraction occurs only along motion. Events simultaneous in one frame need not be simultaneous in another.

These effects are reciprocal comparisons between frames, not mechanical damage to clocks or rods.

Hinglish Explanation

Proper quantity identify karna sabase badaa exam step hai. Clock ke saatha chalane vaalaa observer proper time measure karta hai; rod ke saatha rest observer proper length.

Moving observer ko clock slow aur rod contracted dikhate hain. Rod physically dabatii nahiin; measurement of simultaneous endpoints frame-dependent hai.

Relativistic momentum and energy

Relativistic momentum is $\vec{p} = \gamma m_0 \vec{v}$ and total energy $E = \gamma m_0 c^2$. Rest energy is $E_0 = m_0 c^2$ and kinetic energy $K = (\gamma - 1)m_0 c^2$.

The invariant relation $E^2 = p^2c^2 + m_0^2c^4$ applies to particles. For photons $m_0 = 0$, hence $E = pc$.

Modern treatment keeps invariant rest mass m_0 rather than speaking of velocity-dependent relativistic mass.

Hinglish Explanation

$E = mc^2$ ko sirpha nuclear explosion formula mata samajho; rest mass itself energy ka form hai. Particle accelerate karne par invariant mass nahiin badhataa, total energy and momentum badhate hain.

Photon ka rest mass zero hai but E and p nonzero, so gravitational and interaction effects possible.

3. Formula Section

Formula Box
1. $\gamma = 1/\sqrt{(1 - v^2/c^2)}$
2. $\Delta t = \gamma \Delta \tau$
3. $L = L_0/\gamma$
4. $p = \gamma m_0 v$
5. $E = \gamma m_0 c^2$
6. $K = (\gamma - 1) m_0 c^2$
7. $E^2 = p^2c^2 + m_0^2c^4$
8. $E_{photon} = pc$.

4. Important Derivation

A light clock has mirror separation d. In its rest frame one half-tick takes $\Delta\tau/2 = d/c$. Seen from a frame where the clock moves sideways, light follows a diagonal: $(c\Delta t/2)^2 = d^2 + (v\Delta t/2)^2$. Replacing $d = c\Delta\tau/2$ and rearranging gives $\Delta t^2(c^2 - v^2) = c^2\Delta\tau^2$, hence $\Delta t = \gamma\Delta\tau$.

5. Practical Examples

• Particle accelerators require relativistic momentum and energy.

• GPS combines special-relativistic motion and general-relativistic gravity corrections.

• Muon survival in the atmosphere demonstrates time dilation.

• Mass defects determine nuclear binding and released energy.

6. Comparison Table

Quantity	Proper value	Moving-frame value
Time interval	Clock at both events: $\Delta\tau$	$\Delta t = \gamma\Delta\tau$
Length parallel to motion	Object rest length L_0	$L = L_0/\gamma$
Transverse length	Rest value	Unchanged

7. Important DSSSB Exam Points

• Proper time is the shortest time between timelike events.

• Proper length is the maximum measured length.

• Length contraction is parallel to motion only.

• Use invariant rest mass in modern convention.

• At low speed, relativity reduces to Newtonian mechanics.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. The speed of light in vacuum is invariant for

(A) source frame only
(B) all inertial observers
(C) stationary observers only
(D) sound waves

Correct Answer: (B)
This is Einstein's second postulate.

Q2. Lorentz factor γ is

(A) $\sqrt{(1-v^2/c^2)}$
(B) $1/\sqrt{(1-v^2/c^2)}$
(C) $1-v/c$
(D) c/v

Correct Answer: (B)
This is the definition.

Q3. As v approaches c, γ approaches

(A) zero
(B) one
(C) infinity
(D) −one

Correct Answer: (C)
Denominator tends to zero.

Q4. A moving clock is observed to run

(A) faster
(B) slower
(C) backward
(D) unchanged at all v

Correct Answer: (B)
$\Delta t = \gamma\Delta\tau > \Delta\tau$.

Q5. Length contraction occurs

(A) in all directions
(B) only perpendicular
(C) parallel to motion
(D) only for light

Correct Answer: (C)
Only the longitudinal component contracts.

Q6. Proper length is measured in

(A) any moving frame
(B) object's rest frame
(C) photon frame
(D) accelerating frame only

Correct Answer: (B)
Both endpoints are stationary in the rest frame.

Q7. Rest energy is

(A) m_0c
(B) m_0c^2
(C) ½m_0c^2
(D) pc for every particle

Correct Answer: (B)

$E_0 = m_0c^2$.

Q8. Photon rest mass is

(A) zero
(B) $h\nu/c^2$ as invariant mass
(C) electron mass
(D) infinite

Correct Answer: (A)

Photon invariant rest mass is zero.

Q9. Relativistic kinetic energy is

(A) γm_0c^2
(B) $(\gamma-1)m_0c^2$
(C) m_0c^2/γ
(D) pc always

Correct Answer: (B)

Subtract rest energy from total.

Q10. At v << c, relativistic mechanics

(A) fails
(B) approaches Newtonian mechanics
(C) requires γ □ 1
(D) forbids momentum

Correct Answer: (B)

$\gamma \approx 1$ gives classical expressions.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 7 — LASERS

1. Introduction

A laser produces highly directional, coherent and nearly monochromatic radiation through stimulated emission and optical feedback. Lasers support alignment, ranging, cutting, communication, medicine and metrology. DSSSB questions focus on spontaneous versus stimulated emission, population inversion, metastable state, pumping, resonator action and laser properties.

2. Complete Theory

Absorption and emission processes

For levels $E_2 > E_1$, absorption requires $h\nu = E_2 - E_1$. An excited atom may emit spontaneously with random phase and direction, or an incident photon may stimulate emission of a second photon identical in frequency, phase, direction and polarization.

Stimulated emission therefore provides coherent amplification. Einstein coefficients describe probabilities: A_{21} for spontaneous emission and B coefficients for stimulated processes.

Hinglish Explanation

Ek excited atom ko sahii energy ka photon ‘trigger’ kare to outgoing two photons twins jaise hote hain—same frequency, phase and direction. yahii chain amplification laser banaatii hai.

Ordinary bulb me spontaneous emission random hai, isalie light incoherent and divergent.

Population inversion, pumping and metastable state

At thermal equilibrium the lower level is more populated. Net optical gain needs population inversion, $N_2 > N_1$, produced by pumping with optical, electrical, chemical or other energy.

A metastable upper level has a relatively long lifetime, allowing excited atoms to accumulate. A true two-level system cannot maintain steady population inversion with simple pumping; practical lasers use three- or four-level schemes.

Hinglish Explanation

Population inversion ka matalaba ‘hara atom excited’ nahiin; relevant upper laser level ki population lower level se adhika. Metastable level waiting room jaisaa hai—atoms enough time jamaa hote hain.

Pumping external energy supply hai; laser free energy source nahiin.

Optical resonator and laser properties

The active medium lies between two mirrors, one nearly fully reflecting and one partially transmitting as output coupler. Photons traveling along the axis make repeated passes and stimulate further emission.

Only resonant modes meeting approximately $2nL = q\lambda$ persist strongly. Gain must exceed losses at threshold.

Laser light is highly directional, coherent, intense and narrow in spectral width, though no real laser is perfectly monochromatic or perfectly collimated.

Hinglish Explanation

Mirrors feedback dete hain; random directions vaale photons jaldii escape, axis-aligned photons repeatedly amplify. Output mirror 100% reflecting nahiin honaa chaahie, varanaa useful beam baahara nahiin aaegii.

‘Laser perfectly monochromatic’ exam language me often idealized hai, scientifically better phrase is highly monochromatic.

3. Formula Section

Formula Box

1. $h\nu = E_2 - E_1$
2. $\lambda = hc/(E_2 - E_1)$
3. population inversion: $N_2 > N_1$
4. resonator condition $2nL = q\lambda$
5. photon energy $E = hc/\lambda$.

4. Important Derivation

In a cavity of optical length nL, a round trip covers 2nL. Constructive self-reproduction requires round-trip phase $2\pi q$, equivalent to $2nL = q\lambda$. Adjacent longitudinal frequencies are separated by $\Delta\nu = c/(2nL)$.

5. Practical Examples

• Laser levels establish straight lines, grades and alignment in construction.

• LiDAR measures distance from pulse travel time.

• Industrial lasers cut, weld and heat-treat materials.

• Fibre-optic systems use lasers as narrow, high-speed sources.

6. Comparison Table

Property	Spontaneous emission	Stimulated emission
Trigger	Natural decay	Incident matching photon
Phase/direction	Random	Matches stimulating photon
Result	Incoherent light	Coherent amplification

7. Important DSSSB Exam Points

• Population inversion is essential for net gain.

• Metastable lifetime enables population buildup.

• One mirror is partially transmitting.

• Laser light is highly, not perfectly, monochromatic.

• Stimulated photons are coherent copies.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Laser action primarily relies on

(A) spontaneous absorption
(B) stimulated emission
(C) thermal conduction
(D) nuclear fission

Correct Answer: (B)
Stimulated emission creates coherent copies.

Q2. Population inversion means

(A) $N_1 > N_2$
(B) $N_2 > N_1$
(C) all atoms ionized
(D) equal populations always

Correct Answer: (B)
Upper laser level exceeds lower.

Q3. A metastable state has

(A) very short lifetime
(B) relatively long lifetime
(C) zero energy
(D) infinite population

Correct Answer: (B)
Long lifetime permits accumulation.

Q4. Pumping supplies

(A) feedback only
(B) external excitation energy
(C) mirror loss
(D) vacuum pressure

Correct Answer: (B)
It raises atoms to excited states.

Q5. The output coupler is

(A) perfectly opaque
(B) partially transmitting
(C) absent
(D) a polarizer only

Correct Answer: (B)
It retains feedback while releasing useful light.

Q6. Stimulated photon matches the incident photon in

(A) phase and frequency
(B) mass only
(C) random direction
(D) energy but opposite phase always

Correct Answer: (A)
Stimulated copies are coherent.

Q7. Laser directionality mainly arises from

(A) cavity selection
(B) gravity
(C) high temperature alone
(D) diffusion

Correct Answer: (A)
Repeated axial paths are preferentially amplified.

Q8. Resonance condition is approximately

(A) $nL = \lambda/4$ always
(B) $2nL = q\lambda$
(C) $L = c\lambda$
(D) $q = 0$ only

Correct Answer: (B)
Round-trip phase must be integral.

Q9. Compared with ordinary light, laser light is more

(A) incoherent
(B) divergent
(C) coherent
(D) random

Correct Answer: (C)
Stimulated emission and cavity feedback produce coherence.

Q10. A laser is perfectly monochromatic

(A) for every real device
(B) only as an idealization
(C) because Δv is infinite
(D) because mirrors absorb all light

Correct Answer: (B)
Real lasers have finite linewidth.

> Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 8 — QUANTUM THEORY

1. Introduction

Quantum theory supplies the mathematical framework behind quantum ideas. A state is represented by a wavefunction, measurable quantities by operators, and outcomes by probabilities. The Schrödinger equation predicts bound-state energies and wave evolution. Engineering applications include tunnelling devices, nanostructures, semiconductor wells and spectroscopy. DSSSB generally tests interpretation, normalization, operators and the particle-in-a-box model.

2. Complete Theory

Wavefunction and Born interpretation

A wavefunction ψ may be complex and is not itself directly observable. The probability density is $|\psi|^2 = \psi^*\psi$.

A physically acceptable bound-state wavefunction is finite, single-valued, continuous, normalizable and normally has a continuous first derivative where potential is finite. Normalization requires $\int|\psi|^2 d\tau = 1$.

Probability in region a to b is $\int_a^b|\psi|^2dx$. An overall phase factor does not change measurable probabilities.

Hinglish Explanation

ψ ko physical water wave mata samajho; usakaa modulus square probability density detaa hai. Agar normalization integral infinite ho, particle ko meaningful total probability 1 assign nahiin kara sakate.

ψ negative or complex ho sakatii hai, lekina $|\psi|^2$ hameshaa real and non-negative.

Operators and expectation values

Each observable corresponds to a Hermitian operator, ensuring real eigenvalues. In one dimension, position operator is $\hat{x} = x$ and momentum operator $\hat{p}_x = -i\hbar\partial/\partial x$.

Energy operator is $i\hbar\partial/\partial t$. If $\hat{A}\psi = a\psi$, ψ is an eigenstate with definite value a.

The expectation value is $\langle A\rangle = \int\psi^*\hat{A}\psi\, d\tau$; it is the ensemble average, not necessarily the result of every individual measurement. Noncommuting operators underpin uncertainty.

Hinglish Explanation

Operator ek mathematical instruction hai. Momentum measure karane ke lie wavefunction para $-i\hbar$ derivative apply karate hain.

Expectation value class ke average marks jaisaa hai; jaruurii nahiin kisii student ka exact mark average ke baraabara ho. Eigenstate me vahii observable nishchita milataa hai.

Schrödinger equation

The time-dependent equation is $i\hbar\partial\psi/\partial t = \hat{H}\psi$, with Hamiltonian $\hat{H} = -(\hbar^2/2m)\text{nabla}^2 + V$. For time-independent V and stationary states, separation gives $-(\hbar^2/2m)\text{nabla}^2\psi + V\psi = E\psi$.

It is a non-relativistic equation and does not by itself include spin or particle creation. Boundary conditions select allowed eigenfunctions and quantized energies.

Hinglish Explanation

Classical mechanics me force trajectory detaa hai; quantum mechanics me potential V aur boundary conditions wavefunction aura allowed energies dete hain. Equation ko arbitrary E par solution mil sakta dikhe, but physical boundary conditions only selected E sviikaara karate hain—yahii quantization.

Particle in a one-dimensional box

For an infinite well $0 < x < L$, $V = 0$ inside and infinite outside, so ψ vanishes at $x = 0$ and L. Normalized eigenfunctions are $\psi_n = \sqrt{(2/L)}\sin(n\pi x/L)$, $n = 1,2,\ldots$, and energies $E_n = n^2\pi^2\hbar^2/(2mL^2) = n^2h^2/(8mL^2)$.

Ground energy is nonzero. Levels increase as n^2 and become closer on a relative scale at large n.

Hinglish Explanation

Box me n = 0 allowed nahiin because wavefunction everywhere zero hogii—particle exist hii nahiin karegaa. Lowest n = 1, so zero-point energy nonzero.

Box chhotaa karoge to confinement badhegaa and E □ $1/L^2$ tejii se badhegii; nanostructures me yahii size-dependent energy detaa hai.

3. Formula Section

Formula Box
1. $\int|\psi|^2 d\tau = 1$
2. $P(a \le x \le b) = \int_a^b |\psi|^2 dx$
3. $\hat{p}_x = -i\hbar\partial/\partial x$
4. $i\hbar\partial\psi/\partial t = \hat{H}\psi$
5. $\hat{H} = -(\hbar^2/2m)\text{nabla}^2 + V$
6. $\psi_n = \sqrt{(2/L)}\sin(n\pi x/L)$
7. $E_n = n^2h^2/(8mL^2)$.

4. Important Derivation

Inside the box, $d^2\psi/dx^2 + k^2\psi = 0$, so $\psi = A \sin kx + B \cos kx$. Boundary $\psi(0)=0$ gives B=0; $\psi(L)=0$ gives $\sin kL=0$, hence $kL=n\pi$. With $E=\hbar^2k^2/(2m)$, $E_n=n^2\pi^2\hbar^2/(2mL^2)$. Normalization gives $A=\sqrt{(2/L)}$.

5. Practical Examples

• Quantum wells tune semiconductor lasers and detectors.

• Tunnelling enables scanning tunnelling microscopy and tunnel diodes.

• Operator methods predict spectra and nanoscale transport.

• Confinement explains size-dependent optical properties of quantum dots.

6. Comparison Table

Item	Meaning
ψ	Probability amplitude; may be complex
$|\psi|^2$	Real probability density
Eigenvalue	Possible definite measurement result
Expectation value	Average over repeated identical preparations

7. Important DSSSB Exam Points

• Normalize $|\psi|^2$, not ψ.

• n = 0 is forbidden in the infinite box.

• Ground-state energy is nonzero.

- Expectation value need not be an allowed single-shot result.
- Schrödinger equation here is non-relativistic.

8. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Direct probability density is

(A) ψ
(B) ψ^2 always
(C) $|\psi|^2$
(D) dψ/dx

Correct Answer: (C)
Born rule uses ψ*ψ.

Q2. Normalization requires

(A) ∫ψdx = 0
(B) $\int|\psi|^2 d\tau = 1$
(C) ψ = 1 everywhere
(D) energy = 1

Correct Answer: (B)
Total probability must be unity.

Q3. Momentum operator in x is

(A) iħx
(B) −iħ∂/∂x
(C) $\hbar^2\partial^2/\partial x^2$
(D) mx

Correct Answer: (B)
This is the canonical representation.

Q4. Hermitian operators have

(A) imaginary eigenvalues only
(B) real eigenvalues
(C) no eigenfunctions
(D) zero expectation always

Correct Answer: (B)
Observables must yield real values.

Q5. For an energy eigenstate, Ĥψ equals

(A) ψ/E
(B) Eψ
(C) zero always
(D) iψ only

Correct Answer: (B)
This is the eigenvalue equation.

Q6. Infinite-box energies vary as

(A) n
(B) 1/n
(C) n^2
(D) √n

Correct Answer: (C)
$E_n = n^2h^2/(8mL^2)$.

Q7. Allowed n values in an infinite box begin at

(A) −1
(B) 0
(C) 1
(D) 1/2

Correct Answer: (C)

n=0 gives the zero wavefunction.

Q8. Ground-state energy of an infinite box is

(A) zero
(B) negative infinite
(C) $h^2/(8mL^2)$
(D) mc^2

Correct Answer: (C)

Set n=1.

Q9. If box length doubles, E_1 becomes

(A) $2E_1$
(B) $4E_1$
(C) $E_1/2$
(D) $E_1/4$

Correct Answer: (D)

$E \propto 1/L^2$.

Q10. An expectation value is

(A) always one eigenvalue
(B) ensemble average
(C) always zero
(D) measurement error

Correct Answer: (B)

It averages repeated identical preparations.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.