GATE Electrical Revision Notes

Synchronous Machines and Electromechanical Energy Conversion

ENERGY CONVERSION PRINCIPLES

Meaning :-

Force and torque follow the tendency of a magnetic system to move toward higher co-energy at fixed current.

Physical idea :-

The result must preserve this physical rule: Force and torque follow the tendency of a magnetic system to move toward higher co-energy at fixed current.

Key relation :-

T=partial coenergy/partial theta at constant current

GATE clue :-

When the stem points to energy conversion principles, mark known quantities and begin from T=partial coenergy/partial theta at constant current.

Common mistake :-

Do not use T=partial coenergy/partial theta at constant current before fixing reference directions, operating conditions and units.

→ Rapid recall: Energy conversion principl...

→ Mistake repair: Do not use T=partial coe...

→ Formula cue: Use T=partial coenergy/part...

ENERGY CONVERSION PRINCIPLES : EXAM ROUTE

Recognize the pattern :-

When the stem points to energy conversion principles, mark known quantities and begin from T=partial coenergy/partial theta at constant current.

Start from the model :-

Force and torque follow the tendency of a magnetic system to move toward higher co-energy at fixed current.

Working relation :-

$$\boxed{T = \text{partial coenergy/partial theta at constant current}}$$

Solve in this order :

- → draw the circuit, waveform or reference axes
- → write known values with units and polarity
- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use T=partial coenergy/partial theta at constant current before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Force and torque follow the tendency of a magnetic system to move toward higher co-energy at fixed current.

→ Mini application: Energy conversion prin...

SYNCHRONOUS SPEED AND EXCITATION

Meaning :-

Rotor dc excitation locks to the rotating stator field and produces exact synchronous speed.

Physical idea :-

The result must preserve this physical rule: Rotor dc excitation locks to the rotating stator field and produces exact synchronous speed.

Key relation :-

$$\boxed{N_s = 120\ f/P}$$

GATE clue :-

When the stem points to synchronous speed and excitation, mark known quantities and begin from $N_s=120\ f/P$.

Common mistake :-

Do not use $N_s=120\ f/P$ before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with $N_s=120\ f/P$, simplify symbolically, then check units and the limiting case.

Rapid recall :-

Synchronous speed and excitation: The result must preserve this physical rule: Rotor dc excitation locks to the rotating stator field and produces exact synchronous speed.

SYNCHRONOUS SPEED AND EXCITATION : EXAM ROUTE

Recognize the pattern :-

When the stem points to synchronous speed and excitation, mark known quantities and begin from $N_s = 120\, f/P$.

Start from the model :-

Rotor dc excitation locks to the rotating stator field and produces exact synchronous speed.

Working relation :-

$$\boxed{N_s = 120\, f/P}$$

Solve in this order :

- → draw the circuit, waveform or reference axes
- → write known values with units and polarity
- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use $N_s = 120\, f/P$ before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Rotor dc excitation locks to the rotating stator field and produces exact synchronous speed.

Mini application :-

Synchronous speed and excitation: begin from $N_s = 120\, f/P$.

→ Mini application: Synchronous speed and...

ALTERNATOR EMF EQUATION

Meaning :-

Distributed and short-pitched windings reduce the ideal series emf through winding factors.

Physical idea :-

The result must preserve this physical rule: Distributed and short-pitched windings reduce the ideal series emf through winding factors.

Key relation :-

$$\boxed{E_{phase}=4.44\ k_w\ f\ \Phi\ T}$$

GATE clue :-

When the stem points to alternator emf equation, mark known quantities and begin from Ephase=4.44 kw f Phi T.

Common mistake :-

Do not use Ephase=4.44 kw f Phi T before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with Ephase=4.44 kw f Phi T, simplify symbolically, then check units and the limiting case.

→ Rapid recall: Alternator emf equation: T...

→ Mistake repair: Do not use Ephase=4.44 k...

→ Formula cue: Use Ephase=4.44 kw f Phi T....

ALTERNATOR EMF EQUATION : EXAM ROUTE

Recognize the pattern :-

When the stem points to alternator emf equation, mark known quantities and begin from Ephase=4.44 kw f Phi T.

Start from the model :-

Distributed and short-pitched windings reduce the ideal series emf through winding factors.

Working relation :-

$$E_{phase} = 4.44\, k_w\, f\, \Phi\, T$$

Solve in this order :

→ draw the circuit, waveform or reference axes

→ write known values with units and polarity

→ solve symbolically before inserting numbers

→ check sign, dimensions and extreme cases

Common mistake :-

Do not use Ephase=4.44 kw f Phi T before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Distributed and short-pitched windings reduce the ideal series emf through winding factors.

→ Mini application: Alternator emf equatio...

→ Correction cue: Do not use Ephase=4.44 k...

CYLINDRICAL ROTOR POWER ANGLE

Meaning :-

For negligible resistance, real power varies with sine of load angle and reactive power with excitation.

Physical idea :-

The result must preserve this physical rule: For negligible resistance, real power varies with sine of load angle and reactive power with excitation.

Key relation :-

$$\boxed{P = 3\ V\ E\ \sin(\text{delta})/Xs}$$

GATE clue :-

When the stem points to cylindrical rotor power angle, mark known quantities and begin from P=3 V E sin(delta)/Xs.

Common mistake :-

Do not use P=3 V E sin(delta)/Xs before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with P=3 V E sin(delta)/Xs, simplify symbolically, then check units and the limiting case.

→ Rapid recall: Cylindrical rotor power an...

→ Mistake repair: Do not use P=3 V E sin(d...

→ Formula cue: Use P=3 V E sin(delta)/Xs....

CYLINDRICAL ROTOR POWER ANGLE : EXAM ROUTE

Recognize the pattern :-

When the stem points to cylindrical rotor power angle, mark known quantities and begin from P=3 V E sin(delta)/Xs.

Start from the model :-

For negligible resistance, real power varies with sine of load angle and reactive power with excitation.

Working relation :-

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Solve in this order :

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- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use P=3 V E sin(delta)/Xs before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: For negligible resistance, real power varies with sine of load angle and reactive power with excitation.

→ Mini application: Cylindrical rotor powe...

→ Correction cue: Do not use P=3 V E sin(d...

SALIENT POLE MACHINE

Meaning :-

Different direct and quadrature reactances add a reluctance-power component to excitation power.

Physical idea :-

The result must preserve this physical rule: Different direct and quadrature reactances add a reluctance-power component to excitation power.

Key relation :-

$$\boxed{P=3VE\ \sin(delta)/Xd+3V\ \ 2(Xd-X_q)\sin(2delta)/(2XdX_q)}$$

GATE clue :-

When the stem points to salient pole machine, mark known quantities and begin from $P=3VE$ $\sin(delta)/Xd+3V\ \ 2(Xd-X_q)\sin(2delta)/(2XdX_q)$.

Common mistake :-

Do not use $P=3VE$ $\sin(delta)/Xd+3V\ \ 2(Xd-X_q)\sin(2delta)/(2XdX_q)$ before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with $P=3VE$ $\sin(delta)/Xd+3V\ \ 2(Xd-X_q)\sin(2delta)/(2XdX_q)$, simplify symbolically, then check units and the limiting case.

→ Rapid recall: Salient pole machine: The...

SALIENT POLE MACHINE : EXAM ROUTE

Recognize the pattern :-

When the stem points to salient pole machine, mark known quantities and begin from P=3VE sin(delta)/Xd+3V 2(Xd-Xq)sin(2delta)/(2XdXq).

Start from the model :-

Different direct and quadrature reactances add a reluctance-power component to excitation power.

Working relation :-

P=3VE sin(delta)/Xd+3V 2(Xd-Xq)sin(2delta)/(2XdXq)

Solve in this order :

→ draw the circuit, waveform or reference axes

→ write known values with units and polarity

→ solve symbolically before inserting numbers

→ check sign, dimensions and extreme cases

Common mistake :-

Do not use P=3VE sin(delta)/Xd+3V 2(Xd-Xq)sin(2delta)/(2XdXq) before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Different direct and quadrature reactances add a reluctance-power component to excitation power.

→ Mini application: Salient pole machine:...

ALTERNATOR REGULATION

Meaning :-

Voltage regulation compares no-load generated voltage to rated-load terminal voltage at fixed speed and excitation.

Physical idea :-

The result must preserve this physical rule: Voltage regulation compares no-load generated voltage to rated-load terminal voltage at fixed speed and excitation.

Key relation :-

$$\boxed{\text{percent } VR=(EO-V)100/V}$$

GATE clue :-

When the stem points to alternator regulation, mark known quantities and begin from percent $VR=(EO-V)100/V$.

Common mistake :-

Do not use percent $VR=(EO-V)100/V$ before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with percent $VR=(EO-V)100/V$, simplify symbolically, then check units and the limiting case.

Rapid recall :-

Alternator regulation: The result must preserve this physical rule: Voltage regulation compares no-load generated voltage to rated-load terminal voltage at fixed speed and excitation.

ALTERNATOR REGULATION : EXAM ROUTE

Recognize the pattern :-

When the stem points to alternator regulation, mark known quantities and begin from percent VR=(E0-V)100/V.

Start from the model :-

Voltage regulation compares no-load generated voltage to rated-load terminal voltage at fixed speed and excitation.

Working relation :-

$$\text{percent } VR=(E0-V)100/V$$

Solve in this order :

- → draw the circuit, waveform or reference axes
- → write known values with units and polarity
- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use percent VR=(E0-V)100/V before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Voltage regulation compares no-load generated voltage to rated-load terminal voltage at fixed speed and excitation.

Mini application :-

Alternator regulation: begin from percent VR=(E0-V)100/V.

→ Mini application: Alternator regulation:...

PARALLEL OPERATION

Meaning :-

Incoming voltage, frequency, phase sequence and phase angle must match the live bus before synchronization.

Physical idea :-

The result must preserve this physical rule: Incoming voltage, frequency, phase sequence and phase angle must match the live bus before synchronization.

Key relation :-

$$\boxed{\text{synchronizing conditions: V f sequence phase}}$$

GATE clue :-

When the stem points to parallel operation, mark known quantities and begin from synchronizing conditions: V f sequence phase.

Common mistake :-

Do not use synchronizing conditions: V f sequence phase before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with synchronizing conditions: V f sequence phase, simplify symbolically, then check units and the limiting case.

→ Rapid recall: Parallel operation: The re...

→ Mistake repair: Do not use synchronizing...

PARALLEL OPERATION : EXAM ROUTE

Recognize the pattern :-

When the stem points to parallel operation, mark known quantities and begin from synchronizing conditions: V f sequence phase.

Start from the model :-

Incoming voltage, frequency, phase sequence and phase angle must match the live bus before synchronization.

Working relation :-

$$\boxed{\text{synchronizing conditions: } V \; f \text{ sequence phase}}$$

Solve in this order :

→ draw the circuit, waveform or reference axes

→ write known values with units and polarity

→ solve symbolically before inserting numbers

→ check sign, dimensions and extreme cases

Common mistake :-

Do not use synchronizing conditions: V f sequence phase before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Incoming voltage, frequency, phase sequence and phase angle must match the live bus before synchronization.

→ Mini application: Parallel operation: be...

SYNCHRONOUS MOTOR

Meaning :-

A synchronous motor runs at fixed speed and changes power factor by varying field excitation.

Physical idea :-

The result must preserve this physical rule: A synchronous motor runs at fixed speed and changes power factor by varying field excitation.

Key relation :-

$$\boxed{P = 3VE \sin(\delta)/X_s}$$

GATE clue :-

When the stem points to synchronous motor, mark known quantities and begin from $P=3VE \sin(\delta)/X_s$.

Common mistake :-

Do not use $P=3VE \sin(\delta)/X_s$ before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with $P=3VE \sin(\delta)/X_s$, simplify symbolically, then check units and the limiting case.

Rapid recall :-

Synchronous motor: The result must preserve this physical rule: A synchronous motor runs at fixed speed and changes power factor by varying field excitation.

SYNCHRONOUS MOTOR : EXAM ROUTE

Recognize the pattern :-

When the stem points to synchronous motor, mark known quantities and begin from P=3VE sin(delta)/Xs.

Start from the model :-

A synchronous motor runs at fixed speed and changes power factor by varying field excitation.

Working relation :-

$$\boxed{P=3VE\ \sin(\delta)/X_s}$$

Solve in this order :

- → draw the circuit, waveform or reference axes
- → write known values with units and polarity
- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use P=3VE sin(delta)/Xs before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: A synchronous motor runs at fixed speed and changes power factor by varying field excitation.

Mini application :-

Synchronous motor: begin from P=3VE sin(delta)/Xs.

→ Mini application: Synchronous motor: beg...

V CURVES

Meaning :-

Armature current versus field current forms a V shape, with minimum current near unity power factor.

Physical idea :-

The result must preserve this physical rule: Armature current versus field current forms a V shape, with minimum current near unity power factor.

Key relation :-

> underexcited draws lagging vars; overexcited supplies vars

GATE clue :-

When the stem points to v curves, mark known quantities and begin from underexcited draws lagging vars; overexcited supplies vars.

Common mistake :-

Do not use underexcited draws lagging vars; overexcited supplies vars before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with underexcited draws lagging vars; overexcited supplies vars, simplify symbolically, then check units and the limiting case.

→ Rapid recall: V curves: The result must...

V CURVES : EXAM ROUTE

Recognize the pattern :-

When the stem points to v curves, mark known quantities and begin from underexcited draws lagging vars; overexcited supplies vars.

Start from the model :-

Armature current versus field current forms a V shape, with minimum current near unity power factor.

Working relation :-

$$\boxed{\text{underexcited draws lagging vars; overexcited supplies vars}}$$

Solve in this order :

- → draw the circuit, waveform or reference axes
- → write known values with units and polarity
- → solve symbolically before inserting numbers
- → check sign, dimensions and extreme cases

Common mistake :-

Do not use underexcited draws lagging vars; overexcited supplies vars before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Armature current versus field current forms a V shape, with minimum current near unity power factor.

→ Mini application: V curves: begin from u...

MACHINE LOSSES AND EFFICIENCY

Meaning :-

Copper, core, mechanical and stray losses determine efficiency and temperature rise.

Physical idea :-

The result must preserve this physical rule: Copper, core, mechanical and stray losses determine efficiency and temperature rise.

Key relation :-

$$\boxed{\eta = \text{output}/(\text{output}+\text{total losses})}$$

GATE clue :-

When the stem points to machine losses and efficiency, mark known quantities and begin from eta=output/(output+total losses).

Common mistake :-

Do not use eta=output/(output+total losses) before fixing reference directions, operating conditions and units.

Worked route :-

Mark the reference direction and assumptions first. Start with eta=output/(output+total losses), simplify symbolically, then check units and the limiting case.

→ Rapid recall: Machine losses and efficie...

→ Mistake repair: Do not use eta=output/(o...

→ Formula cue: Use eta=output/(output+tota...

MACHINE LOSSES AND EFFICIENCY : EXAM ROUTE

Recognize the pattern :-

When the stem points to machine losses and efficiency, mark known quantities and begin from eta=output/(output+total losses).

Start from the model :-

Copper, core, mechanical and stray losses determine efficiency and temperature rise.

Working relation :-

$$\boxed{\eta = \text{output}/(\text{output}+\text{total losses})}$$

Solve in this order :

→ draw the circuit, waveform or reference axes

→ write known values with units and polarity

→ solve symbolically before inserting numbers

→ check sign, dimensions and extreme cases

Common mistake :-

Do not use eta=output/(output+total losses) before fixing reference directions, operating conditions and units.

One-line decision :-

The result must preserve this physical rule: Copper, core, mechanical and stray losses determine efficiency and temperature rise.

→ Mini application: Machine losses and eff...

→ Correction cue: Do not use eta=output/(o...

RECALL : SYNCHRONOUS MACHINES AND ELECTROMECHANICAL ENERGY CON

→ Energy conversion pr... : T=partial coenergy/partial theta at...

→ Synchronous speed an... : Ns=120 f/P

→ Alternator emf equation : Ephase=4.44 Kw f Phi T

→ Cylindrical rotor po... : P=3 V E sin(delta)/Xs

→ Salient pole machine : P=3VE sin(delta)/Xd+3V 2(Xd-Xq)sin(...

→ Alternator regulation : percent VR=(E0-V)100/V

→ Parallel operation : synchronizing conditions: V f seque...

→ Synchronous motor : P=3VE sin(delta)/Xs

→ V curves : underexcited draws lagging vars; ov...

→ Machine losses and e... : eta=output/(output+total losses)

Recall drill :-

Cover each relation, rebuild it from the physical idea, then say its units and one limiting case aloud.

→ state the model and reference direction

→ write the relation without looking

→ name the most likely exam mistake

Final recall pair :-

Energy conversion principles and Machine losses and efficiency: connect both to their assumptions.

Self-test :-

Explain Salient pole machine in two lines, then state its unit check.

→ Final recall pair: Energy conversion pri...

GATE MISTAKES & FINAL CHECK

Synchronous Machines and Electromechanical Energy Conversion :-

→ Energy conversi... : Do not use T=partial coe...

→ Synchronous spe... : Do not use Ns=120 f/P be...

→ Alternator emf... : Do not use Ephase=4.44 k...

→ Cylindrical rot... : Do not use P=3 V E sin(d...

→ Salient pole ma... : Do not use P=3VE sin(del...

→ Alternator regu... : Do not use percent VR=(E...

→ Parallel operation : Do not use synchronizing...

→ Synchronous motor : Do not use P=3VE sin(del...

→ V curves : Do not use underexcited...

→ Machine losses... : Do not use eta=output/(o...

Before selecting the answer :-

→ confirm passive sign convention and polarity

→ separate RMS, peak, line and phase values

→ check units, per-unit base and frequency

→ test zero, infinity and steady-state limits

Final habit :-

Use the quickest decisive law first. Calculate only after the circuit model, reference direction and assumptions are fixed.

Last comparison :-

V curves versus Machine losses and efficiency: identify the governing model first.

→ Repair drill: Do not use P=3VE sin(delta...