Fundamentals of Electronics (4311102) - Summer 2024 Solution

Milav Dabgar

June 21, 2024

Question Question 1 [14 marks]

Answer any seven out of ten.

Question 1(1): Define resistor and give its unit.

Solution

A **resistor** is an electronic component that opposes the flow of electric current. Its unit is **Ohm** (Ω).

Table 1. Resistor Properties

Property	Description
Symbol	———
Unit	Ohm (Ω)
Function	Limits current flow

Mnemonic

"Resistors Oppose Current (ROC)"

Question 1(2): Give two examples of active and passive components each.

Solution

Table 2. Electronic Components Classification

Active Components	Passive Components
1. Transistors 2. Diodes	1. Resistors 2. Capacitors

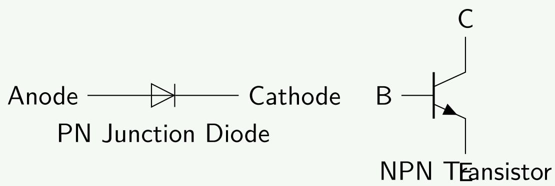
Mnemonic

"TARD - Transistors And Resistors Differ"

Question 1(3): Draw symbols of any two semiconductor devices.

Solution

Figure 1. Semiconductor Device Symbols



Mnemonic

"Diodes Direct, Transistors Transfer"

Question 1(4): Differentiate between intrinsic and extrinsic semiconductor.

Solution

Table 3. Intrinsic vs Extrinsic Semiconductors

Intrinsic	**Extrinsic**
Pure semiconductor without impurities	Semiconductor with added impurities
Equal number of holes and electrons	Unequal holes and electrons
Examples: Pure Silicon, Germanium	Examples: Silicon doped with Phosphorus

Mnemonic

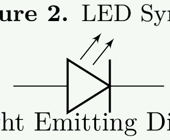
"Pure In, Doped Ex"

Question 1(5): LED stands for ____________________________.

Solution

LED stands for **Light Emitting Diode**.

Figure 2. LED Symbol



Mnemonic

"Light Emitters Dazzle"

Question 1(6): State any two applications of Photo-diode.

Solution

Table 4. Photo-diode Applications

Application	**How it works**
Light sensors	Converts light to electrical current
Optical communication	Detects optical signals in fiber optics

Mnemonic

"Light Sensing Communication (LSC)"

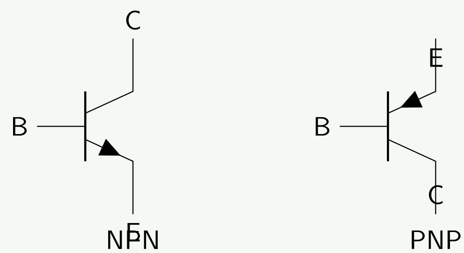
Question 1(7): List the types of transistor and draw their symbols.

Solution

Types of Transistors:

1. NPN Transistor
2. PNP Transistor

Figure 3. Transistor Symbols



Mnemonic

"Not Pointing iN, Pointing outP"

Question 1(8): Give the value of forward voltage drop of Germanium and Silicon diode.

Solution

Table 5. Forward Voltage Drop Values

Diode Type	Forward Voltage Drop
Germanium	0.3V
Silicon	0.7V

Mnemonic

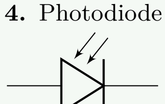
"Germanium's Three, Silicon's Seven (0.3V, 0.7V)"

Question 1(9): The ____________________________ diode can be used as a light detector.

Solution

The **Photodiode** can be used as a light detector.

Figure 4. Photodiode Symbol



Photodiode

Mnemonic

"Photo Detects Light (PDL)"

Question 1(10): Define Q-factor of a coil.

Solution

Q-factor (Quality factor) of a coil is the ratio of its inductive reactance to its resistance, indicating how efficiently it stores energy.

Table 6. Q-Factor

Parameter	Description
Formula	$Q = \frac{X_L}{R}$
Higher Q	Better quality, less energy loss
Lower Q	Poor quality, more energy loss

Mnemonic

"Quality equals Reactance over Resistance (QRR)"

Question Question 2(a) [3 marks]

Question 2(a): Explain colour coding method of resistor.

Solution

Resistor color coding uses colored bands to indicate resistance value and tolerance.

Table 7. Resistor Color Code

Color	Digit	Multiplier
Black	0	10^0
Brown	1	10^1
Red	2	10^2
Orange	3	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
Violet	7	10^7
Grey	8	10^8
White	9	10^9

For a 4-band resistor:

- First band: First digit
- Second band: Second digit
- Third band: Multiplier
- Fourth band: Tolerance

Mnemonic

"Bad Boys Race Our Young Girls But Violet Generally Wins (Black, Brown, Red, Orange, Yellow, Green, Blue, Violet, Grey, White)"

Question 2(a) OR: Explain Light Dependent Resistor with its characteristics.

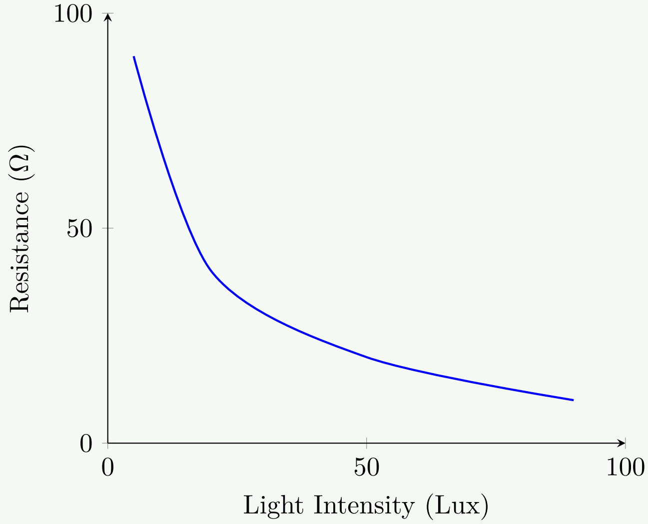
Solution

LDR is a resistor whose resistance decreases when light intensity increases.
Characteristics:

Table 8. LDR Properties

Parameter	**Behavior**
Dark condition	High resistance ($M\Omega$)
Bright condition	Low resistance ($k\Omega$)
Response time	Few milliseconds

Figure 5. LDR Characteristics



Mnemonic

"Light Up, Resistance Down (LURD)"

Question Question 2(b) [3 marks]

Question 2(b): Explain classification of capacitors in detail.

Solution

Capacitors are classified based on dielectric material and construction.

Figure 6. Classification of Capacitors

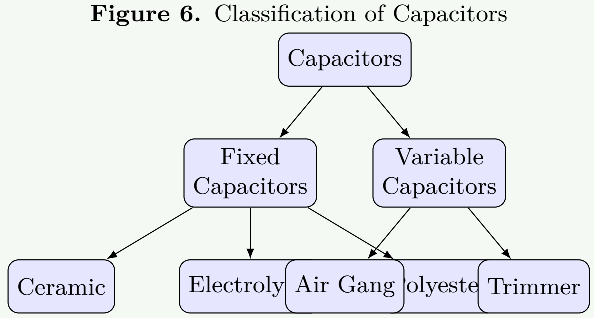


Table 9. Capacitor Classifications

Type	Dielectric	Applications
Ceramic	Ceramic	High frequency
Electrolytic	Aluminum oxide	Power supplies
Polyester	Plastic film	General purpose
Tantalum	Tantalum oxide	Small, high capacity

Mnemonic

"CEPT (Ceramic, Electrolytic, Polyester, Tantalum)"

Question 2(b) OR: Explain classification of inductor in detail.

Solution

Inductors are classified based on core material and construction.

Figure 7. Classification of Inductors

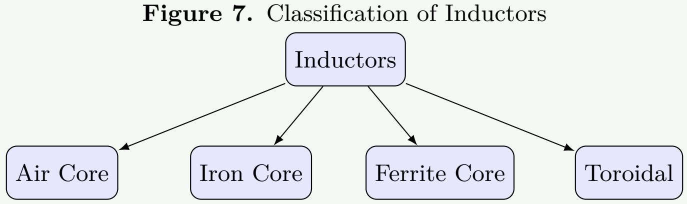


Table 10. Inductor Classifications

Type	Core	Characteristics
Air core	Air	Low inductance, low losses
Iron core	Iron	High inductance, high losses
Ferrite core	Ferrite	Medium inductance, low losses
Toroidal	Ring shaped	High efficiency, low EMI

Mnemonic

"Air Iron Ferrite Toroid (AIFT)"

Question Question 2(c) [4 marks]

Question 2(c): State and explain Faraday's laws of Electromagnetic Induction.

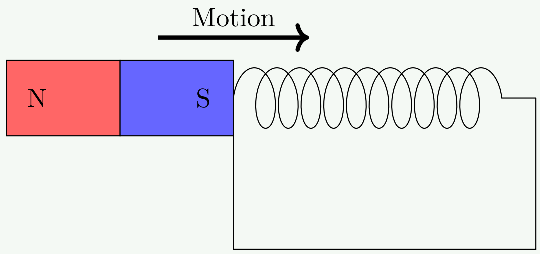
Solution

Faraday's laws explain how electromagnetic induction works.
Faraday's First Law: When a magnetic field linked with a conductor changes, an EMF is induced in the conductor.
Faraday's Second Law: The magnitude of induced EMF is proportional to the rate of change of magnetic flux.

Table 11. Faraday's Laws Summary

Law	Statement	Formula
First Law	Change in magnetic field induces EMF	-
Second Law	EMF $\propto$ rate of change of flux	$E = -N\frac{d\Phi}{dt}$

Figure 8. Faraday's Law



Mnemonic

"Change Magnetic Field, Create Electric Current (CMFCEC)"

Question 2(c) OR: Enlist specifications of capacitors and explain two in detail.

Solution

Specifications of Capacitors:

1. Capacitance value
2. Voltage rating
3. Tolerance
4. Leakage current
5. Temperature coefficient

Detailed Explanation:

1. Capacitance Value: The amount of charge a capacitor can store per volt, measured in Farads (F).

2. Voltage Rating: The maximum voltage that can be applied without damaging the capacitor.

Table 12. Capacitor Specifications

Specification	**Description**	**Typical Values**
Capacitance	Charge storage capacity	pF to mF
Voltage Rating	Maximum safe voltage	16V, 25V, 50V

Mnemonic

"Capacitors Very Tolerant of Low Temperatures (CVTLT)"

Question Question 2(d) [4 marks]

Question 2(d): Write colour band of 47Ω±5% resistance.

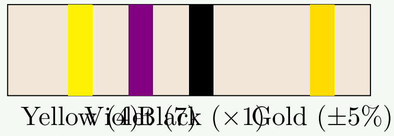
Solution

For $47\Omega \pm 5\%$ resistor, the color bands are:

Table 13. Color Bands for 47Ω±5%

Band	**Color**	**Represents**
1st band	Yellow	4
2nd band	Violet	7
3rd band	Black	$\times 10^0$
4th band	Gold	$\pm 5\%$

Figure 9. Resistor Color Code: 47 ± 5%



Mnemonic

"Yellow Violets Bring Gold"

Question 2(d) OR: Calculate value of resistor and tolerance for a given colour code: Brown, Black, yellow.

Solution

Table 14. Interpretation of Brown, Black, Yellow

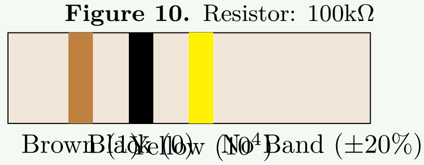
Band	Color	Value	Meaning
1st	Brown	1	First digit
2nd	Black	0	Second digit
3rd	Yellow	10^4	Multiplier

Calculation:

- 1st digit: 1
- 2nd digit: 0
- Multiplier: 10^4

Value $= 10 \times 10^4 = 100,000\Omega = 100k\Omega$
No 4th band means ±20% tolerance.

Figure 10. Resistor: 100kΩ



Mnemonic

"Big Black Yield (Brown-Black-Yellow)"

Question Question 3(a) [3 marks]

Question 3(a): Define doping. Give the name of semiconductor materials fabricated by doping with an example of each.

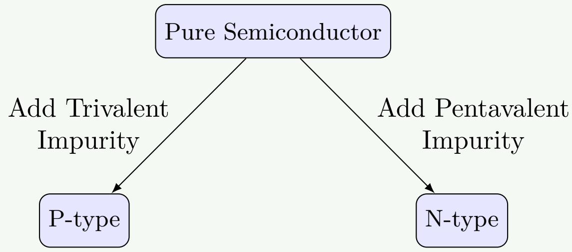
Solution

Doping is the process of adding impurities to a pure semiconductor to modify its electrical properties.

Table 15. Doped Semiconductors

Type	Dopant Added	Example	Majority Carriers
P-type	Trivalent (Boron, Gallium)	Silicon + Boron	Holes
N-type	Pentavalent (Phosphorus, Arsenic)	Silicon + Phosphorus	Electrons

Figure 11. Doping Process



Mnemonic

"Positive has Plus Holes, Negative has Numerous Electrons (PHNE)"

Question 3(a) OR: Define Ripple factor, Peak Inverse Voltage (PIV), Rectification efficiency.

Solution

Table 16. Rectifier Terms

Term	**Definition**	**Formula**
Ripple Factor	Measure of AC component in DC output	$r = \frac{V_{rms(AC)}}{V_{dc}}$
Peak Inverse Voltage	Max reverse voltage diode can withstand	-
Rectification Efficiency	Ratio of DC output to AC input power	$\eta = \frac{P_{dc}}{P_{ac}} \times 100\%$

Mnemonic

"Ripples Peak Efficiently (RPE)"

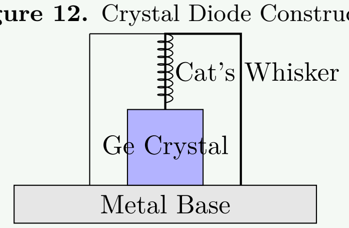
Question Question 3(b) [3 marks]

Question 3(b): Explain working of Crystal diode.

Solution

A **Crystal Diode** is a point-contact diode used for detecting RF signals.
Construction: It consists of a semiconductor crystal (Germanium/Silicon) and a thin tungsten wire (cat's whisker) pressing against it.
Function: It rectifies high-frequency radio signals (demodulation).

Figure 12. Crystal Diode Construction



Mnemonic

"Crystal Detects Radio Frequencies (CDRF)"

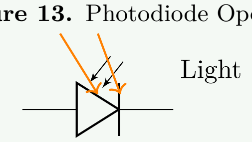
Question 3(b) OR: Explain working of photodiode.

Solution

Photodiode converts light energy into electrical current when operated in reverse bias.
Working:

1. Light strikes the PN junction.
2. Photons generate electron-hole pairs.
3. Reverse bias field sweeps carriers across junction, creating a current.

Figure 13. Photodiode Operation



Mnemonic

"Light In, Current Out (LICO)"

Question Question 3(c) [4 marks]

Question 3(c): Explain half-wave rectifier with circuit diagram and waveforms.

Solution

Half-wave rectifier converts AC to pulsating DC by conducting only during positive half cycles.

Figure 14. Half-Wave Rectifier Circuit

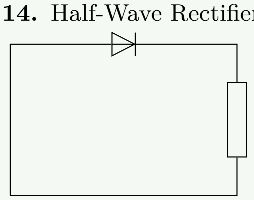
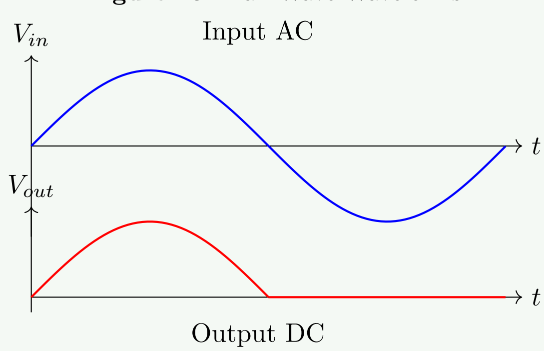


Figure 15. Half-Wave Waveforms



Mnemonic

"Half Wave Passes Half (HWPH)"

Question 3(c) OR: Explain full-wave rectifier with circuit diagram and waveforms.

Solution

Full-wave rectifier (Bridge Type) converts both halves of AC input to DC.

Figure 16. Bridge Rectifier Circuit

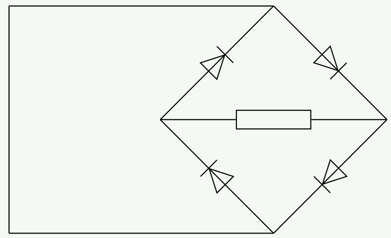
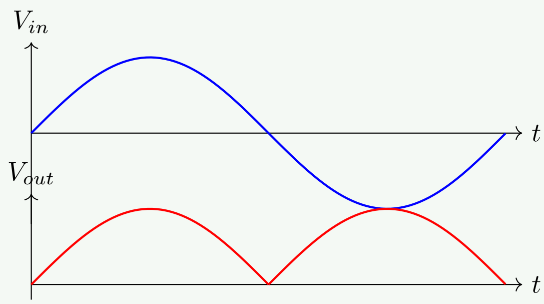


Figure 17. Full-Wave Waveforms



Mnemonic

"Full Wave Makes Full Use (FWMFU)"

Question Question 3(d) [4 marks]

Question 3(d): Draw and explain VI characteristics of PN junction diode.

Solution

Figure 18. VI Characteristics of PN Diode

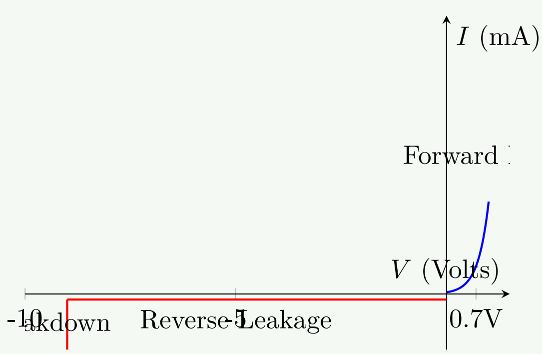


Table: Characteristics

Region	Behavior
Forward Bias	Current rises exponentially after 0.7V (V_k)
Reverse Bias	Negligible leakage current
Breakdown	Sharp current increase at high reverse voltage

Mnemonic

"Forward Flows, Reverse Restricts"

Question 3(d) OR: Write difference between P-type and N-type semiconductor.

Solution

Table 17. P-type vs N-type

Property	**P-type**	**N-type**
Dopant	Trivalent (Boron)	Pentavalent (Phosphorus)
Majority Carriers	Holes	Electrons
Minority Carriers	Electrons	Holes

Mnemonic

"Positive has Plus Holes, Negative has Numerous Electrons"

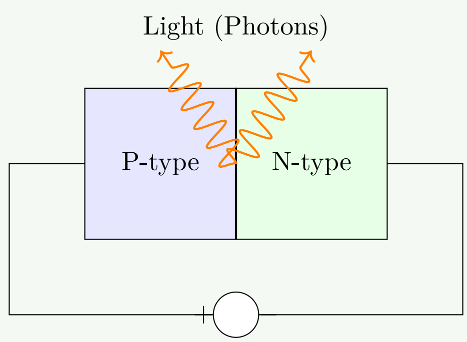
Question Question 4(a) [3 marks]

Question 4(a): Explain the principle of operation of LED.

Solution

LED works on the principle of **Electroluminescence**.
Operation: When forward biased, electrons from N-region recombine with holes in P-region at the junction. This recombination releases energy in the form of photons (light).

Figure 19. LED Operation



Mnemonic

"Forward Current Emits Light (FCEL)"

Question 4(a) OR: State applications of LED.

Solution

Table 18. LED Applications

Application	Advantage
Display indicators	Low power
Digital displays (7-segment)	Varied colors
Lighting (Bulbs)	Energy efficient
Remote controls	Infrared communication
Traffic signals	High visibility

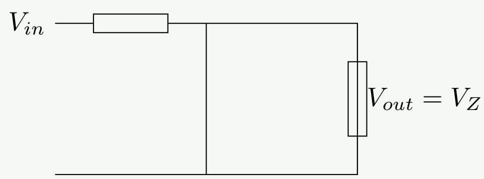
Question Question 4(b) [4 marks]

Question 4(b): Explain Zener diode as voltage regulator.

Solution

A **Zener Diode** maintains a constant output voltage across the load when operated in the reverse breakdown region.

Figure 20. Zener Voltage Regulator



Working:
- The series resistor R_S absorbs voltage fluctuations.
- The Zener diode conducts variable current to keep voltage across it constant (V_Z).

Mnemonic

"Zeners Break to Regulate"

Question 4(b) OR: Give limitations of zener voltage regulator.

Solution

Table 19. Limitations

Limitation	Effect
Power Dissipation	Limited by Zener wattage rating
Current Capacity	Suitable only for low load currents
Efficiency	Poor due to power loss in R_S

Question Question 4(c) [7 marks]

Question 4(c): Discuss the necessity of filter circuit in rectifier. List various types of filter circuits used in rectifier and explain any one with neat diagram.

Solution

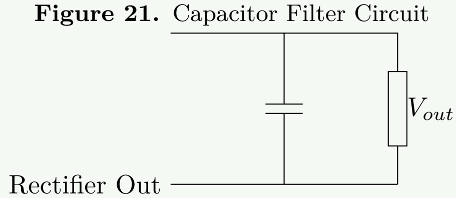
Necessity: Rectifier output is pulsating DC (contains AC ripples). Filter circuits remove these ripples to provide a steady DC voltage required by electronic circuits.

Types of Filters:

1. Capacitor Filter (Shunt)
2. Inductor Filter (Series)
3. LC Filter (L-Section)
4. π-Filter (C-L-C)

Capacitor Filter Explanation: A capacitor is connected in parallel with the load.

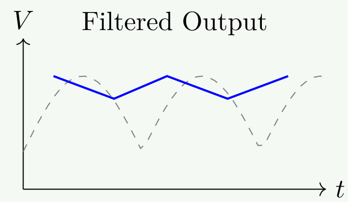
Figure 21. Capacitor Filter Circuit



Operation:

- During voltage peak, capacitor charges to V_{peak}.
- During voltage drop, capacitor discharges through load, maintaining voltage.
- Result: Reduced ripple, smoother DC.

Figure 22. Filter Waveform



Mnemonic

"Capacitors Hold Voltage During Drops"

Question Question 5(a) [3 marks]

Question 5(a): Define e-waste. List common e-waste items.

Solution

E-waste (Electronic Waste) refers to discarded electrical or electronic devices that are near the end of their useful life.

Table 20. Common E-waste

Category	Examples
Computing	Laptops, PCs, Tablets
Communication	Mobile phones, Landlines
Home Appliances	TVs, Fridges, Washing Machines
Components	Batteries, PCBs, Cables

Mnemonic

"Computers, Communication, Components (CCC)"

Question 5(b): State and explain various strategies of e-waste management.

Solution

Table 21. Management Strategies

Strategy	**Description**
Reduce	Buy less, maintain devices longer
Reuse	Repair, donate, or sell old devices
Recycle	Extract valuable metals (Au, Ag, Cu)
Disposal	Safe disposal of hazardous materials

Mnemonic

"3 R's: Reduce, Reuse, Recycle"

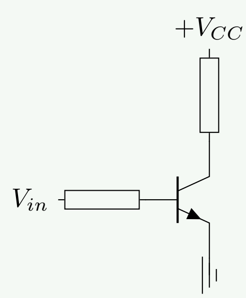
Question Question 5(c) [4 marks]

Question 5(c): Explain transistor as switch.

Solution

A transistor acts as a switch by operating in **Cutoff** (OFF) and **Saturation** (ON) regions.

Figure 23. Transistor Switch Circuit



States:

- **OFF (Open Switch)**: $V_{in} = 0V$. Base current $I_B = 0$, so Collector current $I_C = 0$. $V_{CE} = V_{CC}$.
- **ON (Closed Switch)**: $V_{in} = High$. I_B flows, transistor saturates. $V_{CE} \approx 0V$.

Mnemonic

"No Base No Current"

Question Question 5(d) [4 marks]

Question 5(d): Derive relation between α and β for CE configuration of transistor.

Solution

Definitions:

- $\alpha = \frac{I_C}{I_E}$ (Common Base Gain)
- $\beta = \frac{I_C}{I_B}$ (Common Emitter Gain)

Derivation: We know that emitter current is the sum of base and collector currents:

$$I_E = I_C + I_B \tag{1}$$

Divide equation (1) by I_C:

$$\frac{I_E}{I_C} = \frac{I_C}{I_C} + \frac{I_B}{I_C}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\frac{1}{\alpha} = \frac{\beta + 1}{\beta}$$

Inverting both sides:

$$\alpha = \frac{\beta}{1 + \beta}$$

Rearranging for β:

$$\beta = \frac{\alpha}{1 - \alpha}$$

Mnemonic

"Beta equals Alpha over One minus Alpha"