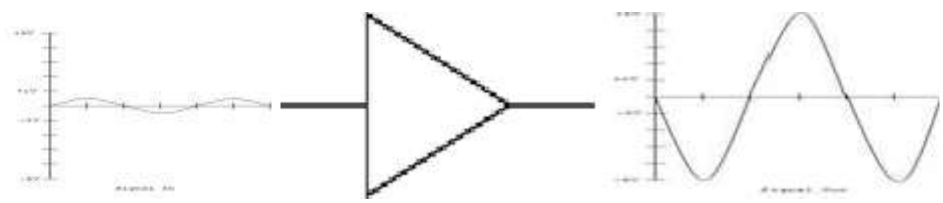
Circuit Components 004 Questions

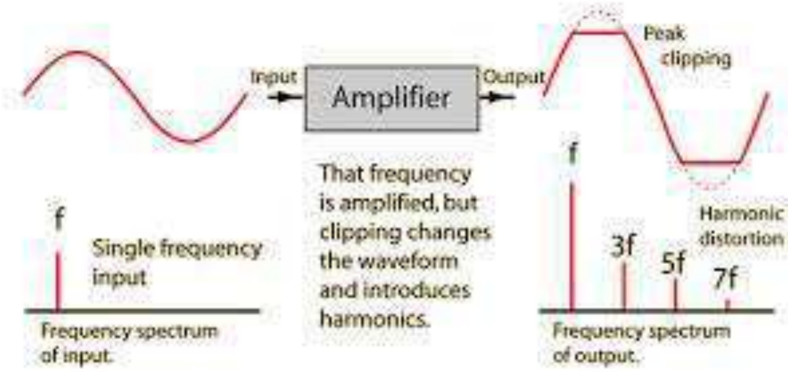
1. Amplifier fundamentals

- An amplifier is an electronic device or circuit for increasing the amplitude of electrical signals.
- An **amplifier** uses **active** components such as **transistors or vacuum tubes**.
- Electronic amplifiers make greater signals in terms of **power, voltage, and current**.
- The General symbol of an amplifier:

Small Input Signal **AMP** **Big Output Signal**



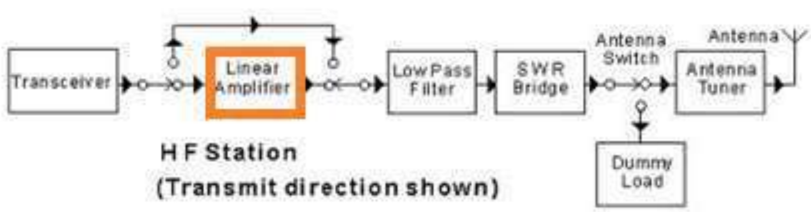
- An amplifier is said to be **Linear** if the **output** waveform **faithfully represents** the signal waveform of the **input** signal. (*at least in shape if not in phase*)
- However, the amplifier **output** is said to be **distorted** if the **output** waveform is **corrupted** in any way; this following diagram illustrates a distorted output waveform that usually results from over-driving the input on an amplifier:



- Most amplifiers have some small degree of distortion often given as performance figures such as Percentage of **Total Harmonic Distortion** (THD).

- Amplifiers have fixed or variable **"Gain"** usually given in **decibels (dB).**

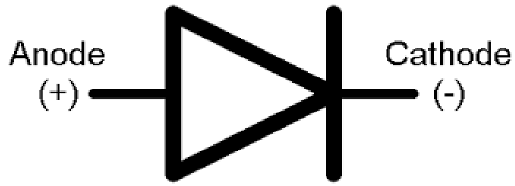
- A **"Linear" RF amplifier** may be used to boast the RF output of a modest power Amateur Radio Transceiver.



2. Diode fundamentals

- In electronics, a **diode is a two-terminal electronic component with asymmetric conductance**; it has **low (ideally zero) resistance to current in one direction** and **high (ideally very high) resistance in the other.**

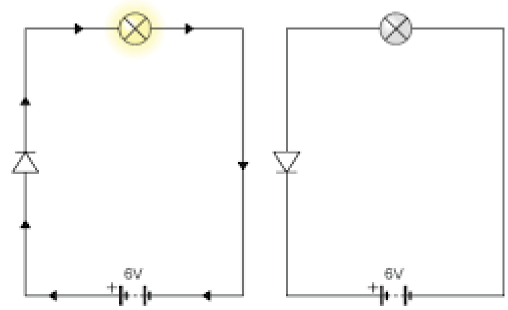
- **Electronic Symbol for a Diode**



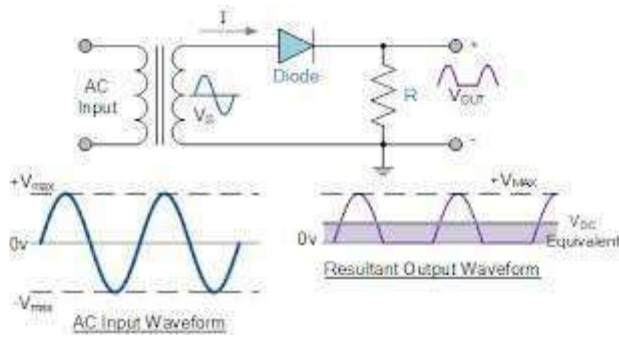
- As shown above, the **electrodes** of a diode device are the **Anode and the Cathode**. The current flow is from Anode to Cathode whereas, **the flow of electrons is from Cathode to Anode.**

- The **basic function of a diode** is to provide a **one way conduction path for electricity**. Under normal operation of a diode device, **current flow will happen** in the circuit if **Positive potential is applied to the Anode** relative to the Cathode. **If Positive potential is applied instead to the Cathode (relative to the anode), current will not flow in the circuit**.

- In the following circuit, when the **Positive of the battery is connected to the diode Anode, the lamp is ON**; **but reverse the diode** so that the Positive of the battery is connected to the cathode, **the light is OFF.**

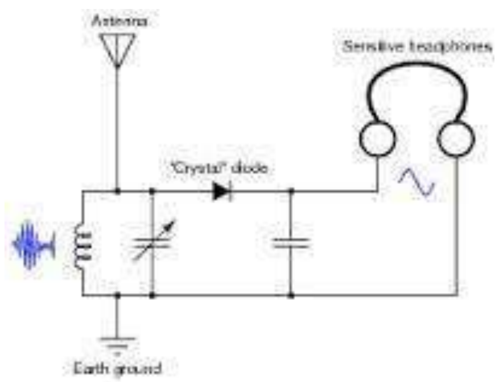


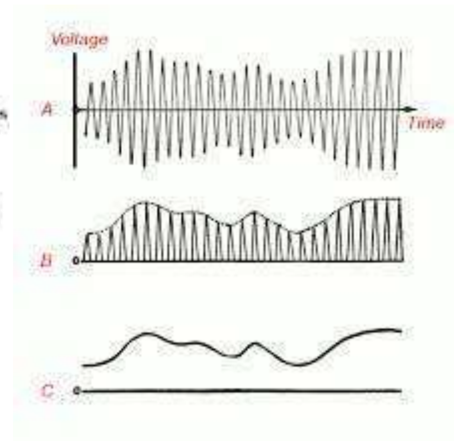
- Diodes are used for **"Rectification"** or converting **AC power into DC power** by allowing only one half of the AC waveform to be conducted through a Diode as illustrated below:



- In the above circuit, the **pulsating DC output** of the half wave diode rectifier circuit must be filtered with a large capacitor and then regulated. More on that when we study "Power Supplies".

- A diode is also used as the **demodulator or "detector"** for **amplitude modulation (AM)** in simple radio circuits for an AM Broadcast Band "crystal" diode receiver:





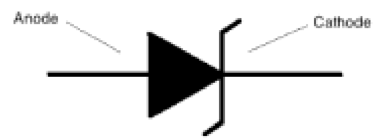
- In the above waveform diagrams, the top shows the RF carrier wave with an Amplitude Modulation (AM) audio envelop superimposed on it. The middle waveform shows the bottom half of the RF waveform is removed (rectified) by the diode detector leaving the **audio demodulated waveform.** The bottom waveform shows removal of RF component of detected audio waveform by the capacitor across headphones.

- There are many special types of diodes. Another type that relates to questions on the Basic exam is the **Zener diode**.

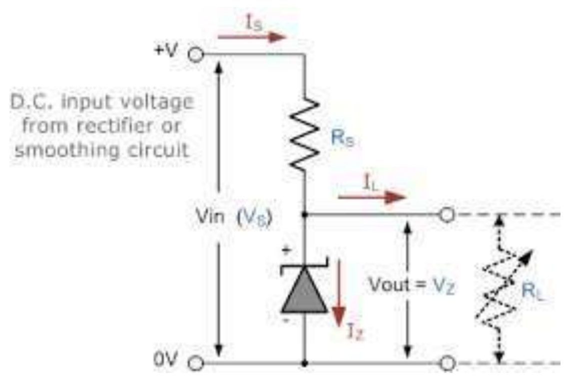
- A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits current to flow in the reverse direction above a **certain value of voltage across it based on the specified Zener voltage of a particular device.** Eg. the device may be specified as 5 or 7.5 or 12 or some other value of voltage that a circuit designer requires for desired circuit operation.

- Based on the way a Zener diode behaves, it is most often used as a **<u>Voltage Regulator</u>** device regulating at the specified **Zener voltage of the device.**

- The symbol of a Zener diode is:

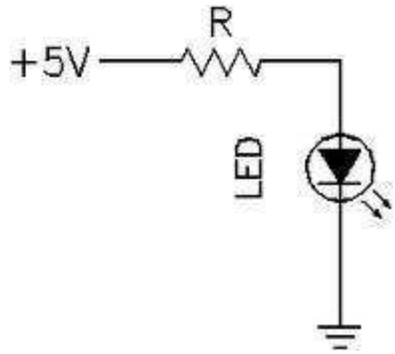


- A simple Zener diode regulating circuit:



- Another common type of diode is the **<u>LED (Light Emitting Diode</u>**) which now come in all sorts of sizes and illumination colours depending on their **<u>chemical composition</u>**.

- The circuit diagram and symbol for the LED is:

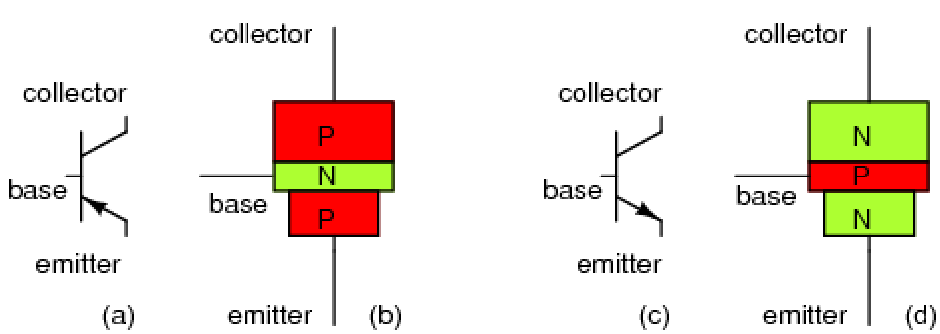


- LED devices typically require a current limiting series resistor to ensure the LED current does not exceed its specified maximum current for the device in question.

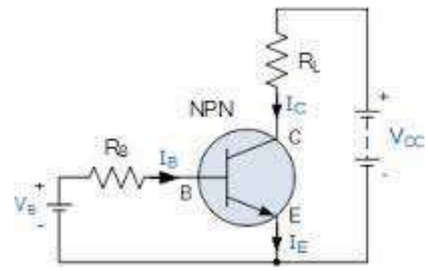
3. bipolar transistor fundamentals

- **Bipolar (junction) transistors are semiconductor "active" devices** that can be used as **amplifiers, switches and oscillators**. Transistors are found as either individual components or found in large numbers as parts of "integrated circuits".

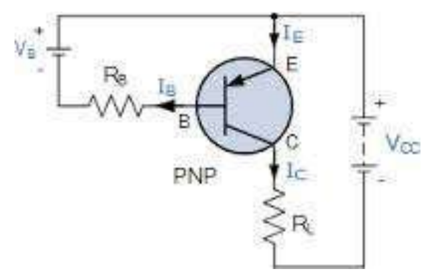
- **Bipolar transistors** are **3 lead devices** and manufactured as **either NPN or PNP** depending on the **desired polarity of operation.**



- An **NPN** Bipolar transistor is shown in the diagram below. The device **amplifies the Base input current** to produce a **larger output collector current.** The NPN transistor operates with a positive potential applied to the **Base (B)** lead and **Collector (C)** lead relative to the **Emitter (E)** lead.



- A **PNP** Bipolar transistor is shown in the diagram below. From an operational sense, this device works in a similar fashion to the NPN device except the polarity of operation is reversed. Note the symbol for the **PNP device has the Emitter arrow pointing inwards**. The Base and the Collector of the PNP device are at negative polarity relative to the Emitter.



- Below is the picture of a common small signal Bipolar PNP transistor. An equivalent NPN transistor is the 2N3904.

4. **field-effect transistor fundamentals**

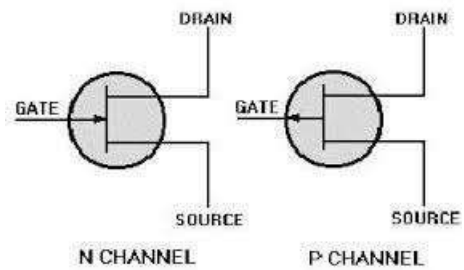
- A Field effect transistor **(FET)** is constructed and operates differently than the bipolar transistor but is used similarly to amplify signals.

- The **FET,** like the Bipolar transistor, is also a **3 terminal device**; the terminals are the **Source (S)**, the **Gate (G)** and the **Drain (D).**

- Whereas the Bipolar Transistor is a current controlled device with a low input (Base to Emitter) resistance, the **FET is a voltage controlled device with a very high input (Gate to Source) resistance.**

- Like Bipolar transistors, a FET can be designed for operating in one polarity or the other. For **negative** referenced circuits, a **"N" channel** device is used, or **positive** referenced circuits, a **"P" channel** device is used**. Note the way the arrow points for the Gate terminal for the N and P channel devices.**

- Some FET devices are known as **MOSFET**s; these have an insulated gate that can be **very susceptible to damage from stray static charges**; this is why such components (or the circuit boards using such components) **are shipped in "anti static bags".**



5. **triode vacuum tubes fundamentals**

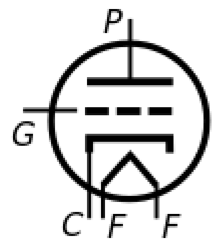
- The use of **vacuum tubes** as active devices has largely been replaced by semi conductor (solid state) devices in low power electronic circuitry.

- For some applications such as high power Radio Frequency (RF) transmitter amplifiers, vacuum tubes still remain a viable and relatively inexpensive technology to use.

- Vacuum tubes operate at high voltage compared to their solid state counterparts.

- Some **high power radio tube amplifiers** that are in amateur radio service have **operating voltages exceeding 3000 volts**. **Such voltages to touch are lethal !**

- A **triode tube** is **essentially a three terminal device** having a **Cathode** (C), **Grid** (G), and a **Plate**.



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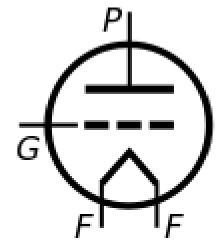
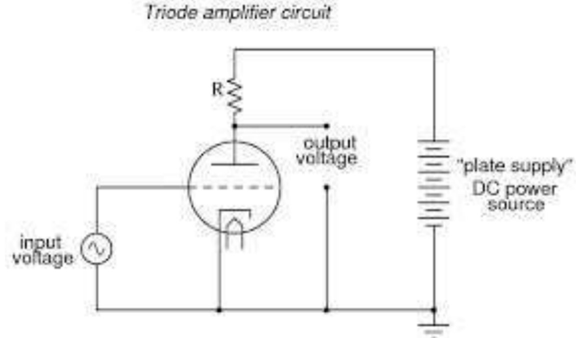
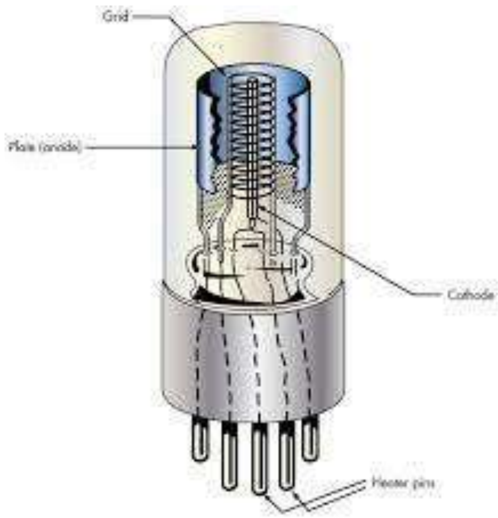


6. The "**F**s" in the above triode diagrams denote the "**Filament**" or the heater of the tube. Tubes have filaments like incandescent light bulbs. The filament either heats up the cathode (red hot) or serves as the cathode of the tube directly depending on tube design. **The hot cathode releases electrons in a process called thermionic emission.** These **free electrons travel** in the **vacuum** of the tube attracted to the **positively charged Plate**. The **electron flow in the tube must pass through** the **Grid** and depending on the grid's relative charge, **controls the electrons** flowing through to the Plate electrode. A **small voltage change applied to Grid** will create a **large voltage change at the Plate** thus amplifying the signal.

Triode amplifier circuit

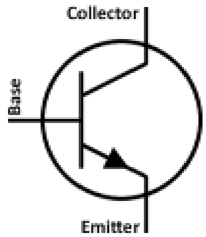


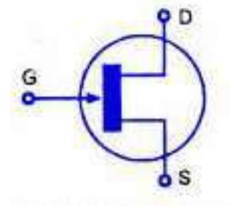


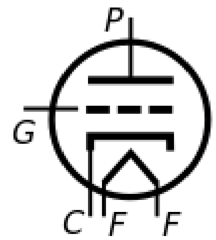
Exploded view of triode

Large transmitting tube

Comparisons of a Triode Tube, Bipolar Transistor and Field Effect Transistor				
Device Type	**Small Signal Input Terminal**	**Amplified Output Terminal**	**Electron Source Terminal**	**Remarks**
Triode Tube	**Grid**	**Plate**	**Cathode**	**Plate operates at very high voltage**
NPN Bipolar Transistor	**Base**	**Collector**	**Emitter**	
Field Effect Transistor	**Gate**	**Drain**	**Source**	





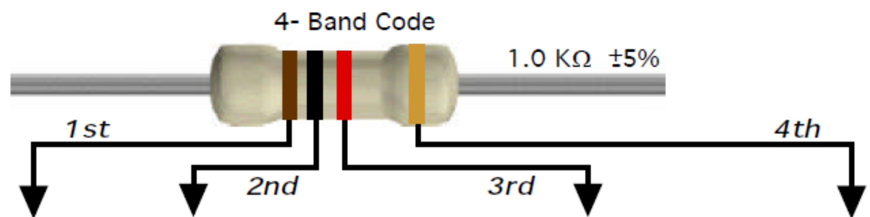


- For most types of active devices, the static current flow through the device may be governed by adjusting the **"Bias"** voltage (or current) applied to **controlling element such as the Gate or Grid or Base. Forward Bias increases the current flow through the device, and Reverse Bias decreases the current flow.**

7. <u>resistor colour codes, tolerances, temperature coefficient</u>

- Most conventional component resistors have 4 colour bands that denote their resistance value and the precision tolerance

RESISTOR COLOR CODE GUIDE



Color	1st Band	2nd Band	3rd Band	Decimal Multiplier		Tolerance
Black	0	0	0	1	1	
Brown	1	1	1	10	10	± 1 %
Red	2	2	2	100	100	± 2 %
Orange	3	3	3	1K	1,000	
Yellow	4	4	4	10K	10,000	
Green	5	5	5	100K	100,000	
Blue	6	6	6	1M	1,000,000	
Violet	7	7	7	10M	10,000,000	
Gray	8	8	8		100,000,000	
White	9	9	9		1,000,000,000	
Gold					0.1	± 5 %
Silver					0.01	± 10 %
None						± 20 %

- For the Basic exam, **you do <u>not</u> have to know the colour coding in detail** but the questions will require an understanding that:
  - ➢ The first 3 colour bands denote the resistance.
  - ➢ The fourth colour band denotes the so-called "tolerance" of the resistor, that is for any given resistor, it will be within +/- a percentage indicated by the colour of the 4^{th} band of the value indicated on the first 3 colour bands.

- Note that on a given resistor, if the fourth colour band is missing, the resistance is within +/- 20% of the resistance indicated on the first three colour bands.

- As an example, one Exam question asks *"What is the possible values of a 100 ohm resistor with a 10% tolerance?"* (as indicated by a silver 4th band). The answer is: *90 to 110 ohms.* or +/- 10% of 100 ohms.

- Some circuits require precision resistors with +/- 1% or better; this, for example, will be used in precision test equipment to ensure the accuracy of the instrument. Another possible question on the exam may be: "*a resistive voltage divider requires a very accurate and predictable ratio.* The question asks what resistor tolerance would be selected for the circuit from a choice of 20% to 0.1 % and of course, the right answer for this example is 0.1 %.

- **Temperature Coefficient of resistance.**

- There may be a question on the exam about a **resistor's temperature coefficient**. Like most conductive materials, their resistance will change dependent of temperature. The amount of ohmic change vs temperature change is the **temperature coefficient of resistance**. For pure metals, this coefficient is a **positive number** meaning that **resistance increased** with **increasing temperature**. For some **elements**

such as carbon from which many common resistor components are fabricated; these have a **negative temperature** coefficient meaning the **resistance decreases** with **increasing temperature**. In some circuits which require high stability, different components, such as resistors or otherwise, will be selected based on their Temperature Coefficient, some with a positive effect and others with a negative effect, one to counter the other.

8. crystals for RF oscillators

- Quartz Crystal devices are the fundamental stable frequency component(s) used in most radio receivers and transmitters. These devices are also used as time base oscillators in time keeping circuits for watches, and computers, etc.

- A Quartz Crystal device works on the "Piezoelectric" effect which is the ability of certain materials (such as quartz crystals cut in certain ways) to generate an AC voltage when subjected to electrical (or mechanical) stimulation between two plates that are the electrodes of connection of the device. The frequency at which the crystal oscillation takes place is basically determined by thickness and angle of the crystal cut. The Quartz Crystal when placed into an oscillator circuit behaves similar to LC (inductance and Capacitance) resonant circuit. There is much more that goes into precision manufacture of Quartz Crystal which is beyond the scope of this discussion. Quartz Crystal devices are also used in highly selective circuits in radio equipment.

- Picture of a Quartz Crystal used in early radio transmitters that determine the frequency of operation. These were "plug-in" and would be physically changed to provide another frequency of operation.

- Electronic Symbol for a Quartz Crystal and "LC" circuit equivalent.