

### Problem

Investigate what the polarity for collector voltage and base voltage must be for pnp and npn transistors in order for a collector current to flow.

### Equipment

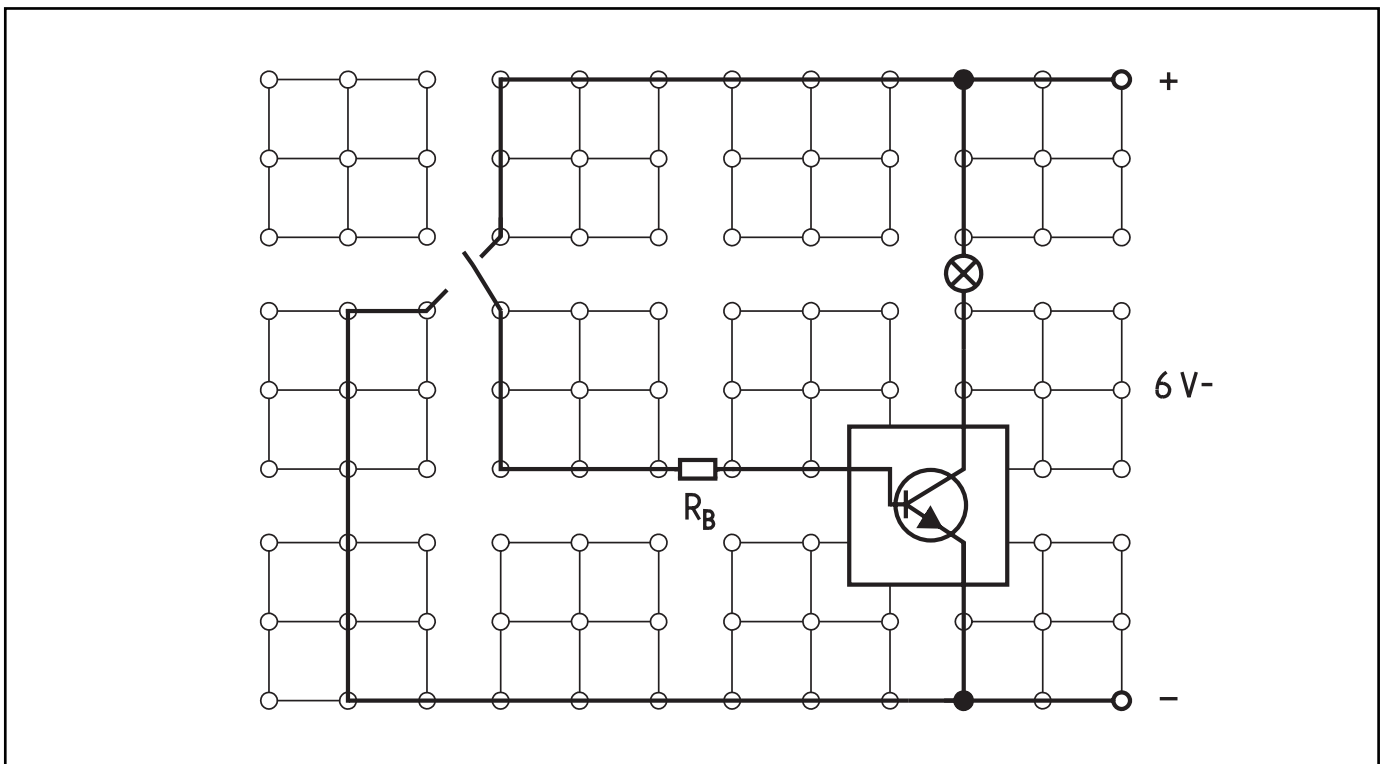
Plug-in board	06033.00	1
Changeover switch	39169.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
Resistor, 10 k $\Omega$	39104.30	1
Transistor BC337	39127.20	1
Transistor BC327	39127.21	1
Wire building block	39120.00	6
Connecting cables, 50 cm, red	07361.01	1
Connecting cables, 50 cm, blue	07361.04	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

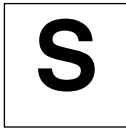
- Set direct voltage on power supply unit to 6 V. Switch on power supply unit. Observe filament lamp. Record observation by putting an 'X' in the appropriate box in Table 1.
- Switch connecting cables on power supply unit so the collector is now connected to the negative pole. Note observation.
- Plug in 10 k $\Omega$  base resistor. Toggle changeover switch back and forth several times. Note observations.
- Switch the connections on the power supply unit back again so the collector is connected to the positive pole. Toggle changeover switch and note observation.
- Switch power supply unit off. Replace npn transistor with pnp transistor. Remove base resistor.
- Switch on power supply unit. Repeat the same procedure with the pnp transistor and note observations in Table 2.

### Set-Up and Procedure

- Set up experiment as shown in Fig. 1 with the npn transistor and, initially, without the base resistor  $R_B = 10\text{ k}\Omega$ . (Collector should be connected with the positive pole.)

Fig. 1





# At what voltages are npn and/or pnp transistors operated?



### Observations

Table 1: npn transistor

	Does the filament lamp light up when the collector is connected to the			
	positive pole		negative pole	
	Yes	No	Yes	No
No base resistor in circuit				
Base resistor connected to positive pole				
Base resistor connected to negative pole				

Table 2: pnp transistor

	Does the filament lamp light up when the collector is connected to the			
	positive pole		negative pole	
	Yes	No	Yes	No
No base resistor in circuit				
Base resistor connected to positive pole				
Base resistor connected to negative pole				

### Evaluation

1. Indicate what pole of the voltage source the collector and base of a npn and/or pnp transistor must be connected to in order for collector current to flow.

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2. Estimate how high the base current is in your experiment set-up. Compare the base current with the collector current  
Note: You can estimate the base current with the connected operating voltage (6 V) and the base resistance used in the experiment. Disregard the base voltage (about 0.6 V). The collector current can be derived approximately from the nominal value of the current for the filament lamp.

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(At what voltages are npn and/or pnp transistors operated?)

This experiment should demonstrate that collector current only flows through a transistor when the collector voltage and base voltage are poled correctly. For an npn transistor, the collector and the base must be connected with the positive pole. For a pnp transistor, they must be connected with the negative pole. The emitter serves as the reference electrode in both cases.

Before carrying out the experiment, the students must know the designation of the transistor electrodes and the meaning of the terms npn and pnp transistor.

The comparison of base current, which can be estimated from the size of the base resistance and the connected voltage, with the collector current, which causes the lamp to light up, also leads to the conclusion that a minimal base current is sufficient to make the transistor conductive.

### Notes on Set-Up and Procedure

The breakdown voltage of the transistor barrier layers is considerably lower with inverse action. Therefore, the operating voltage should definitely not be set any higher than 6 V.

Make sure that the transistor is operated in either a totally blocked or totally conductive state since either the current or the collector voltage is very minimal in this case and, consequently, the dissipation power is only minimal. Otherwise, the transistor could be destroyed by overheating.

### Observations

See Table 1 and Table 2.

### Evaluation

1. Current only flows through an npn transistor when the collector and base are connected to the positive pole of the current source.

The opposite polarity must be used for a pnp transistor.

2. The base current is considerably smaller than the collector current. Disregarding the base-emitter voltage, which is about 0.6 V, the base current  $I_B$  is

$$U_B/R_B = 6 \text{ V}/10 \text{ k}\Omega = 0.6 \text{ mA}.$$

The collector current flows through the filament lamp. The lamp has a nominal current of about 40 mA.

### Notes

The model for transistors often found in reference works describing it as two diodes connected in opposition to one another does not sufficiently describe its behavior since it does not take the special property of the base-emitter barrier layer into account. This layer is actually responsible for the transistor effect, though. The base layer is considerably thinner and more weakly doped than the emitter and collector. The barrier layer created by diffusion of the

Table 1: npn-Transistor

	Does the filament lamp light up when the collector is connected to the			
	positive pole		negative pole	
	Yes	No	Yes	No
No base resistor in circuit		X		X
Base resistor connected to positive pole	X			X
Base resistor connected to negative pole		X		X

Table 2: pnp-Transistor

	Does the filament lamp light up when the collector is connected to the			
	positive pole		negative pole	
	Yes	No	Yes	No
No base resistor in circuit		X		X
Base resistor connected to positive pole		X		X
Base resistor connected to negative pole		X	X	

(At what voltages are npn and/or pnp transistors operated?)

charge carriers and consisting of donor and acceptor ions generates a diffusion voltage which prevents charge carriers from penetrating the base layer. The charge carriers can not flow from the emitter into the base until an external voltage with opposite polarity cancels the blocking effect of the diffusion voltage. Due to the minimal thickness

and doping of the base, however, there is only very little recombination, i.e. the greater part of the charge carriers diffuse through the base layer and are whisked away into the collector by the connected voltage since the collector-base junction is poled for these charge carriers (minority carriers) in the forward direction.