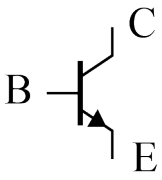
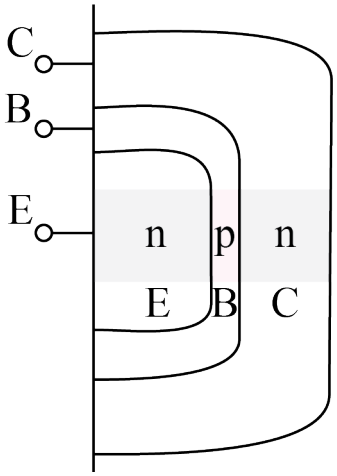
DEVICE: A Bipolar Junction Transistor (BJT) has a heavily-doped Emitter (E), lightly-doped, very thin Base (B), and a regularly doped Collector (C). The terms E, B, and C refer to electrons, which flow *opposite* conventional current.

SYMBOL:



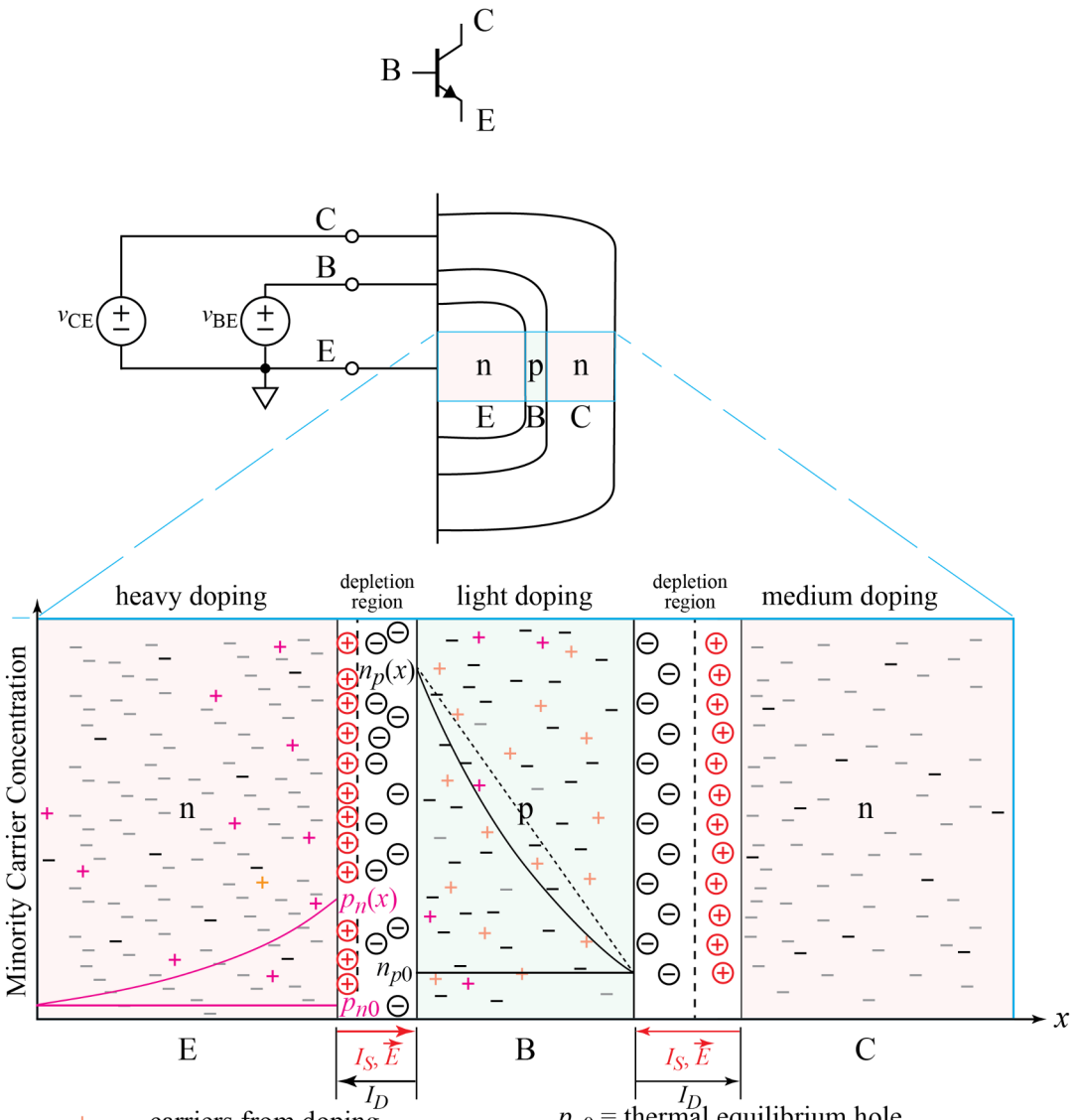
DEVICE:



DESCRIP: The Base (B) and Emitter (E) form a conventional diode. A forward voltage is applied to the Base Emitter terminals, and current flows according to the diode equation. The voltage drop for the diode is about 0.7 V, as usual.

The Collector (C) is at a higher voltage than either the Base or Emitter. The diode in the Base-Emitter junction is seemingly reverse-biased. However, the injection of holes into the Base causes the Emitter to send many more electrons toward the Base than can be taken out at the Base. Because the base is thin and the Collector voltage is quite positive, the extra Emitter electrons continue on to the Collector where they are swept out.

PHYSICS:



+ − carriers from doping

+ − injected carriers (from *v*-sources)

⊕ ⊖ bound, charged atoms

minority carriers (holes) in n-type region, $p_n(x)$

minority carriers (electrons) in p-type region, $n_p(x)$

minority carriers (electrons) in p-type region without recombination

p_{n0} = thermal equilibrium hole concentration in emitter

n_{p0} = thermal equilibrium electron concentration in base

diffusion current caused by flow of majority carriers away from high concentration

drift current caused by resulting *E*-field acting on *minority* carriers

PHYSICS: The key to the operation of the npn BJT is that an electron injected into the depletion region of a *reverse* biased diode sees an electric field that accelerates it out the *n*-side of the diode where the + side of the externally applied voltage is connected. The emitter of an npn transistor provides a way of injecting electrons into the depletion region of the reverse-biased Collector-Emitter diode.

The Base (B) and Emitter (E) form a conventional diode. A forward voltage is applied to the Base Emitter terminals, and conventional current flows from base to emitter according to the diode equation. The voltage drop for the diode is about 0.7 V, as usual.

The Collector (C) is at a higher voltage than either the Base or Emitter. The diode in the Base-Collector junction is seemingly reverse-biased. However, the injection of holes into the Base causes the Emitter to send many more electrons toward the Base than can be immediately taken out at the Base. Thus, excess electrons are injected into the base, and most of them even get past the front edge of the depletion region of the Base-Collector junction. (It is as though the many electrons from the heavily doped Emitter rush like dancers toward the too few partners in the lightly-doped Base, and they find themselves just inside the depletion region on the Collector side.) Once they get even a little ways into the depletion region of the Collector-Base junction, the electric field there pulls them into the Collector. Thus, the electrons are swept off the dance floor and out the door (the Collector terminal).

REF: [1] Behzad Razavi, *Fundamentals of Microelectronics with Robotics and Bioengineering Applications, 3rd Ed., Enhanced eText,* New York, NY: Wiley, 2021. ISBN: 9781119694397

[2] Adel S. Sedra and Kenneth C. Smith, *Microelectronic Circuits, 5th Ed.,* New York, NY: Oxford University Press, 2004.