# EE 4BD4 Lecture 22

## Electrical Safety I

# Electrical Safety

## Medical Instrumentation Application and Design, 4th Edition

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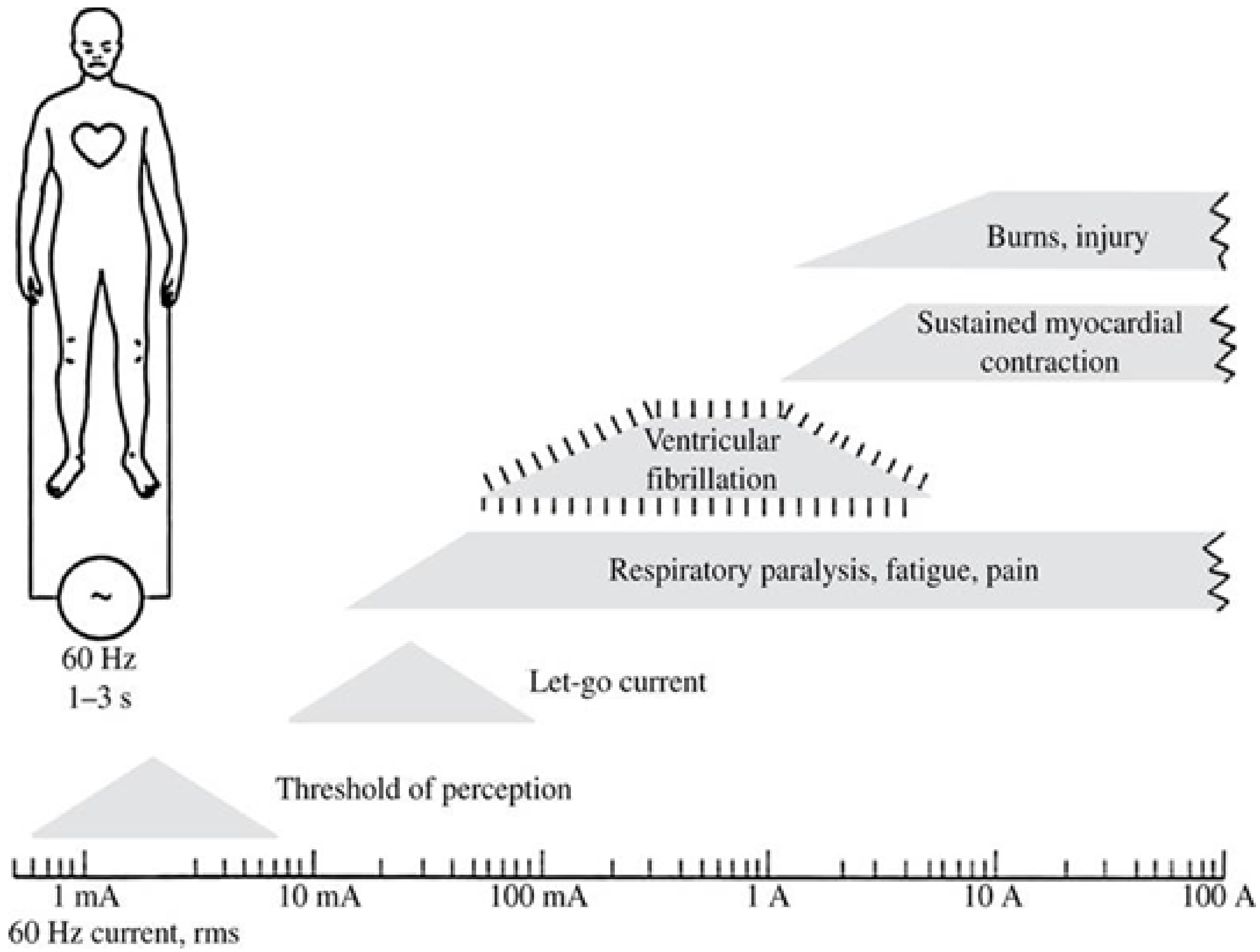



**Figure 14.1 Physiological effects of electricity Threshold or estimated mean values are given for each effect in a 70 kg human for a 1 to 3 s exposure to 60 Hz current applied via copper wires grasped by the hands.**

# Electrode on Skin

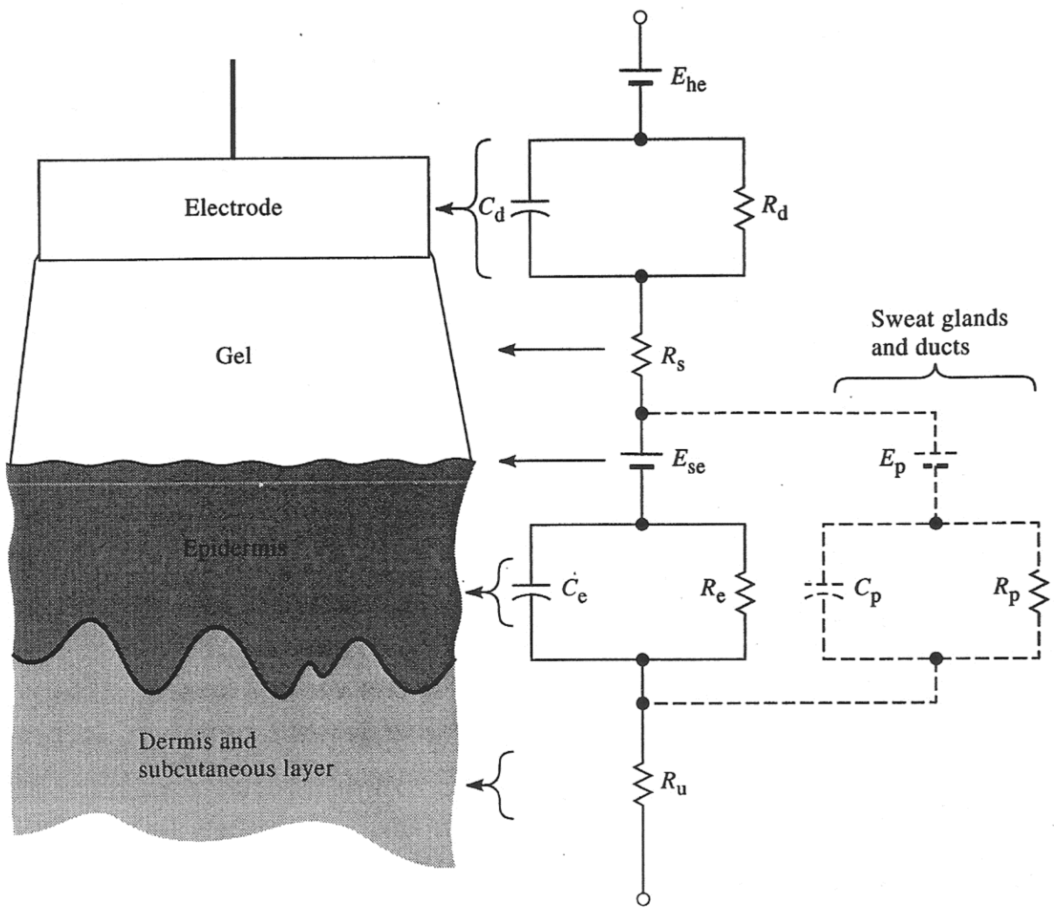



**Figure 5.8** A body-surface electrode is placed against skin, showing the total electrical equivalent circuit obtained in this situation. Each circuit element on the right is at approximately the same level at which the physical process that it represents would be in the left-hand diagram.

# PopulationVariability of Threshold of Perception and Let-go Current (60 Hz)

Straight line fit shows Gaussian Distribution

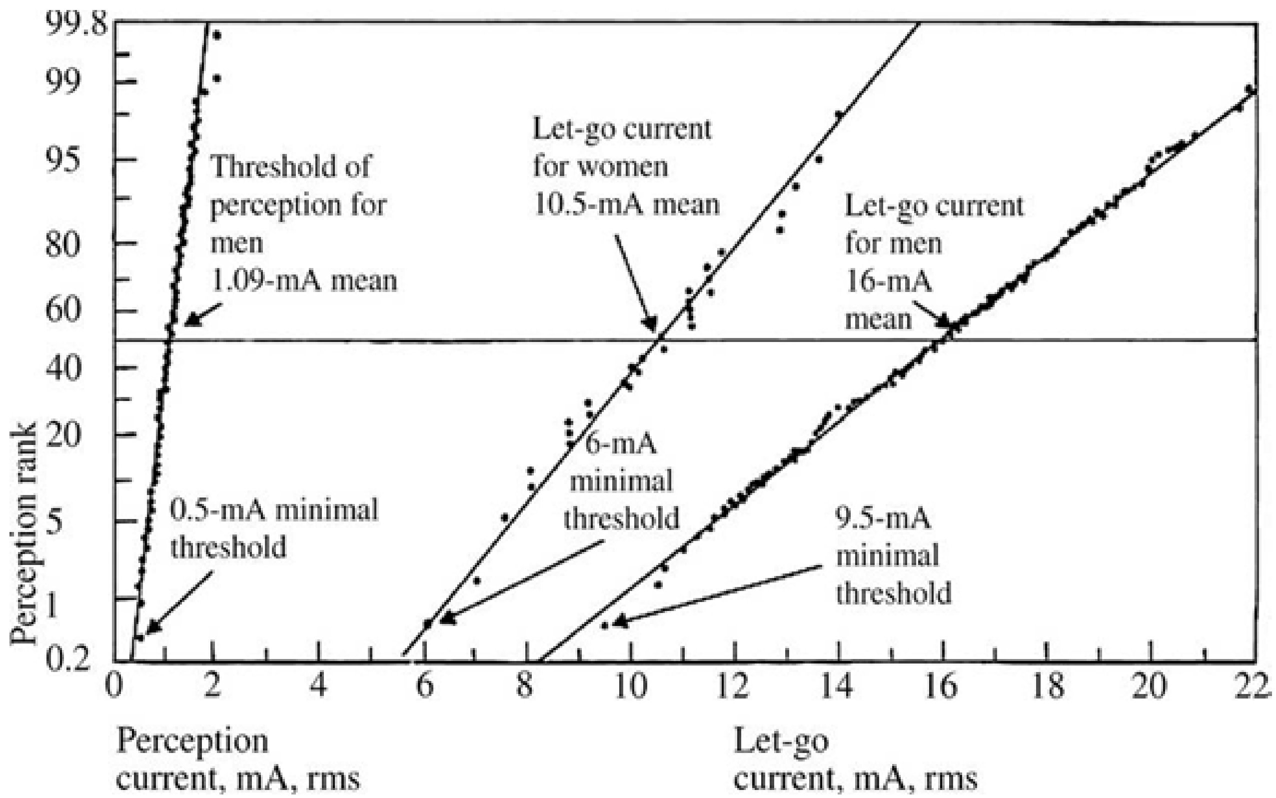
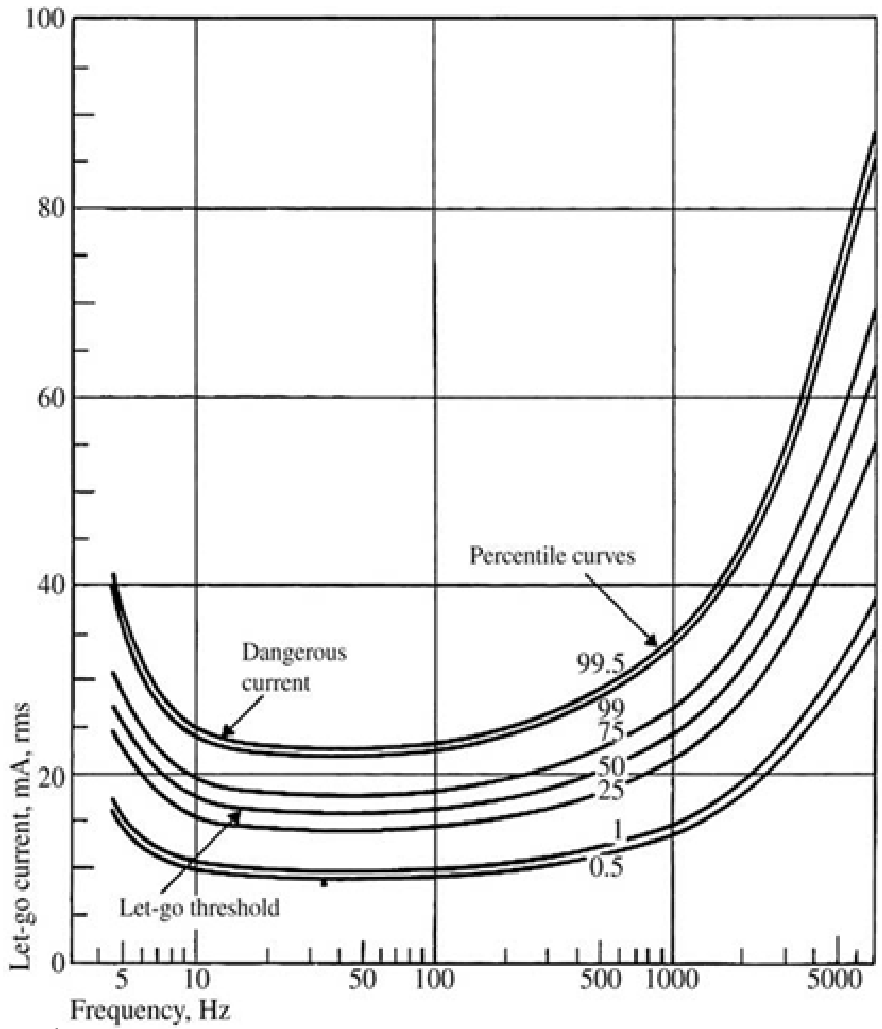



**Figure 14.2 Distributions of perception thresholds and let-go currents** These data depend on surface area of contact (moistened hand grasping AWG No. 8 copper wire). (Replotted from C. F. Dalziel, "Electric Shock," *Advances in Biomedical Engineering,* edited by J. H. U. Brown and J. F. Dickson III, 1973 3, 223-248.)

# Frequency Effect on Let-go Current

**Figure 14.3 Let-go current versus frequency Percentile values indicate variability of let-go current among individuals. Let-go currents for women are about two-thirds the values for men. (Reproduced, with permission, from C. F. Dalziel, "Electric Shock," *Advances in Biomedical Engineering,* edited by J. H. U. Brown and J. F. Dickson III, 1973, 3, 223–248.)**



# Stimulation Strength Duration Curve
## Rectangular Current Pulses Duration *d*

- $I_r$ is the rheobase current (for very long pulses)
- *τ is the membrane time constant = RC = 2 ms*

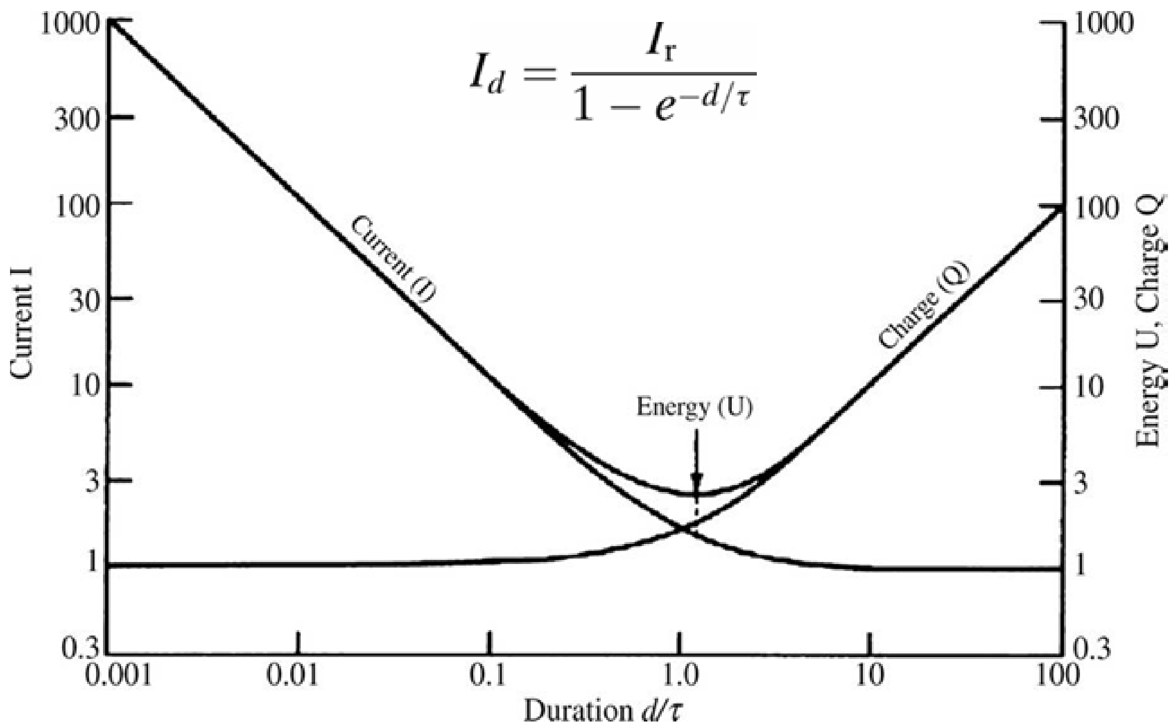


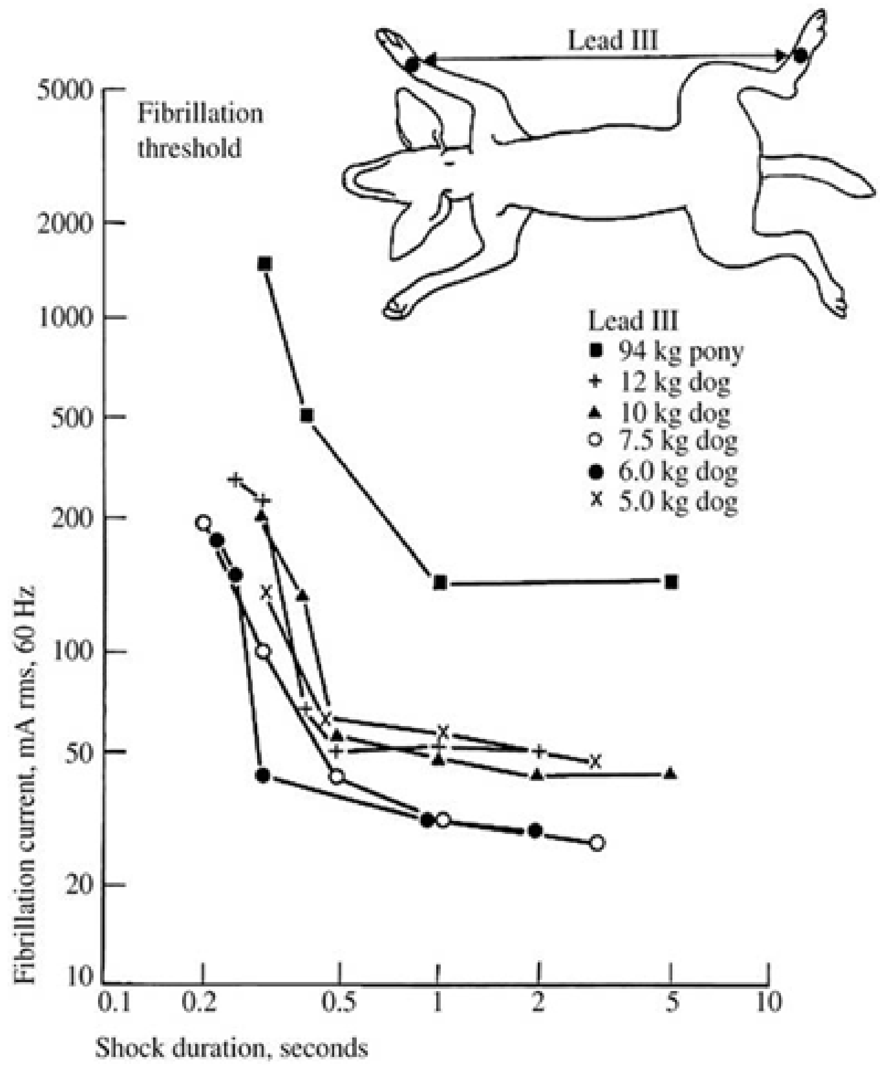

**Figure 14.4 Normalized analytical strength–duration curve for current *I*, charge *Q*, and energy *U*. The *x* axis shows the normalized duration of *d/τ* (From Geddes, L. A., and L. E. Baker, *Principles of Applied Biomedical Instrumentation*, 3rd ed. New York: John Wiley & Sons, 1989).**

# Danger of a Single Stimulation Pulse Causing Fibrillation

- Delivered during T wave
- For large electrical transients < 100 μs dur’n applied directly to heart, stimulation threshold →3.5 μC $cm^{-2}$
- For normal hearts fibrillation stim. threshold to single-beat stimulation threshold above is 20:1 to 30:1 for electrodes on heart, 10:1 to 15:1 for chest electrodes
- Electric fences  and Tasers have 100 μs pulses (IEC 2006) so very safe normally.

# Shock Duration vs Body Weight

**Figure 14.5 Fibrillation current versus shock duration. Thresholds for ventricular fibrillation in animals for 60 Hz ac current. Duration of current (0.2 to *5* s) and weight of animal body were varied. (From L. A. Geddes, *IEEE Trans. Biomed. Eng.*, 1973, 20, 465–468. Copyright 1973 by the Institute of Electrical and Electronics Engineers. Reproduced with permission.)**



# Current Pathway

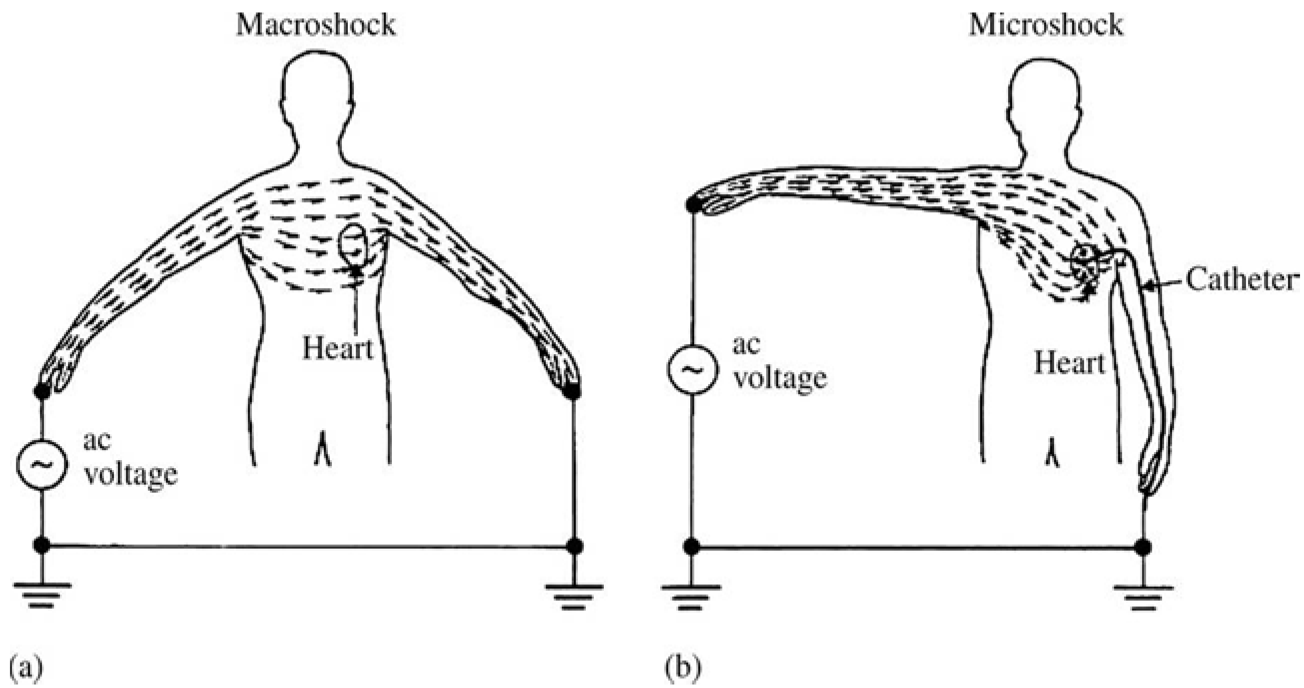
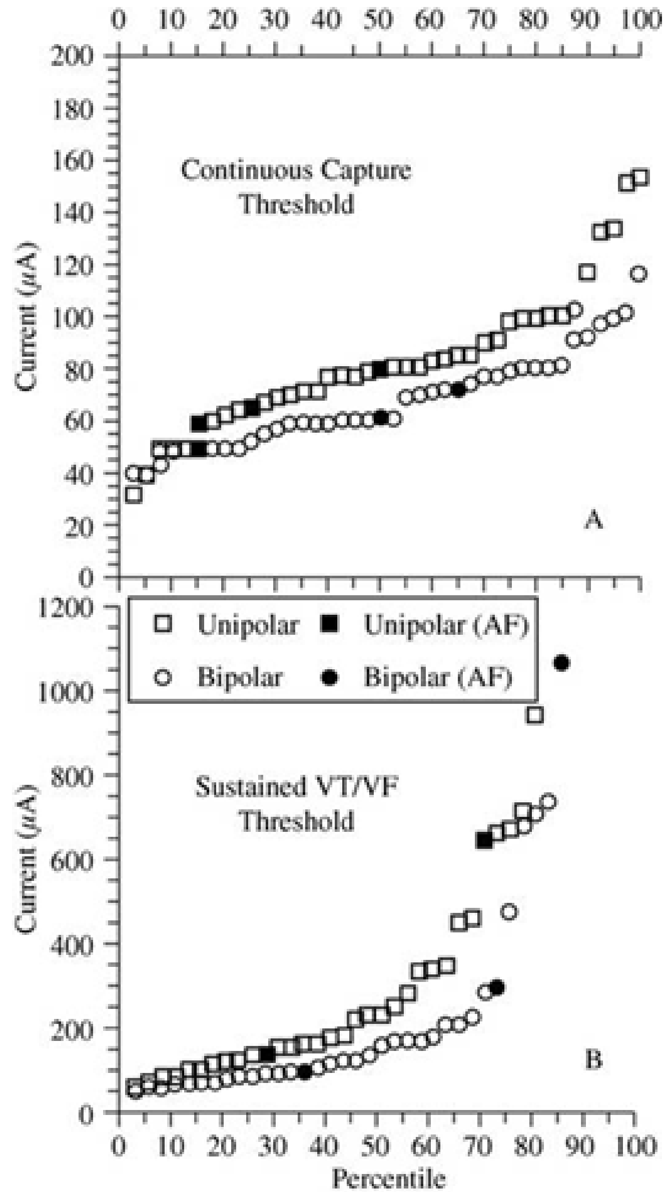



**Figure 14.6 Effect of entry points on current distribution (a) *Macroshock,* externally applied current spreads throughout the body, (b) *Microshock,* all the current applied through an intracardiac catheter flows through the heart. (From F. J. Weibell, "Electrical Safety in the Hospital," *Annals of Biomedical Engineering,* 1974, 2, 126–148.)**

# What is the Current Threshold for Cardiac Dysfunction?

- 60 Hz ac applied for 5 sec to a ventricular pacing catheter during implantable defibrillator testing in 40 patients
- Intermittent capture (i.e. induced ventricular fibrillation (VF) or tachycardia (VT) as low as 20 μA (dogs)
- Continuous capture with a minimum of 32 μA
- Sustained VF even after ac removed for 49 μA

**Figure 14.7. Percentile plot of thresholds for continuous capture and VF (or sustained VT). Cumulative percent of patients is shown on abscissa and root-mean-square AC current (in μA) on ordinate. Squares denote unipolar data; circles, bipolar data. Solid symbols identify data from patients in whom the only clinical arrhythmia was atrial fibrillation (AF). Top, Thresholds for continuous capture. Current strength of 50 μA caused continuous capture in 5 patients (12%) with unipolar AC and in 9 (22%) with bipolar AC (*P*=0.49). Bottom, Thresholds for sustained VT/VF. These plots do not reach 100% because sustained-VT/VF thresholds exceeded maximum output of stimulator in 6 patients (15%) with bipolar AC and 8 (20%) with unipolar AC. From Swerdlow, C. D., W. H. Olson, M. E. O'Connor, D. M. Gallik, R. A. Malkin, M. Laks, "Cardiovascular collapse caused by electrocardiographically silent 60-Hz intracardiac leakage current – Implications for electrical safety." *Circulation.*, 1999, 99, 2559–2564.**



# Distribution of Electrical Power

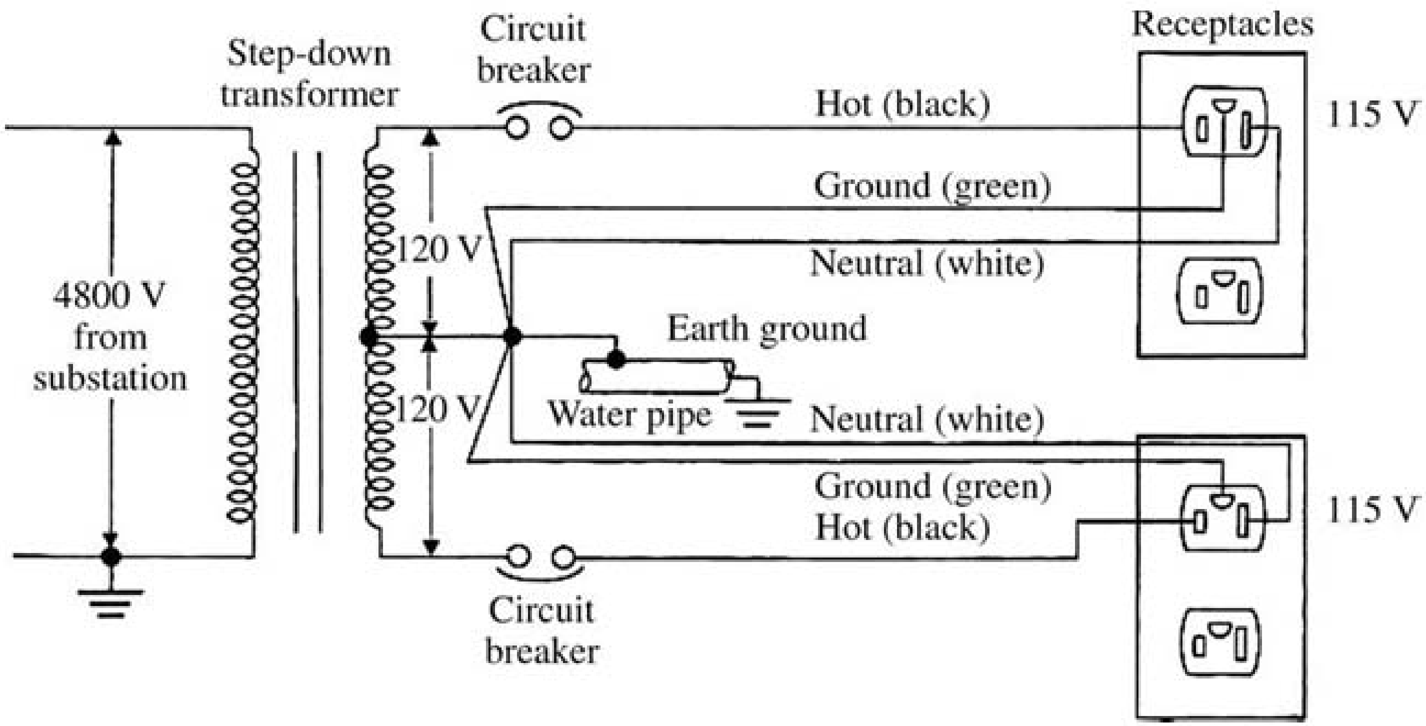



**Figure 14.8 Simplifed electric-power distribution for 115 V circuits. Power frequency is 60 Hz.**

# Patient's Electrical Environment

- Any two conductive surfaces near a patient cannot have more than 500 mV potential difference for general care areas in a hospital, 40 mV in a critical care area (NEC 2006)
- In general care areas patients have only incidental contact with electrical devices
- In critical care areas all exposed conductive surfaces must be grounded at a single point
- Other regulations exist for numbers and connections of outlets in each patient care area

# Isolated Power for Critical Care Areas to Avoid Ground Pathways

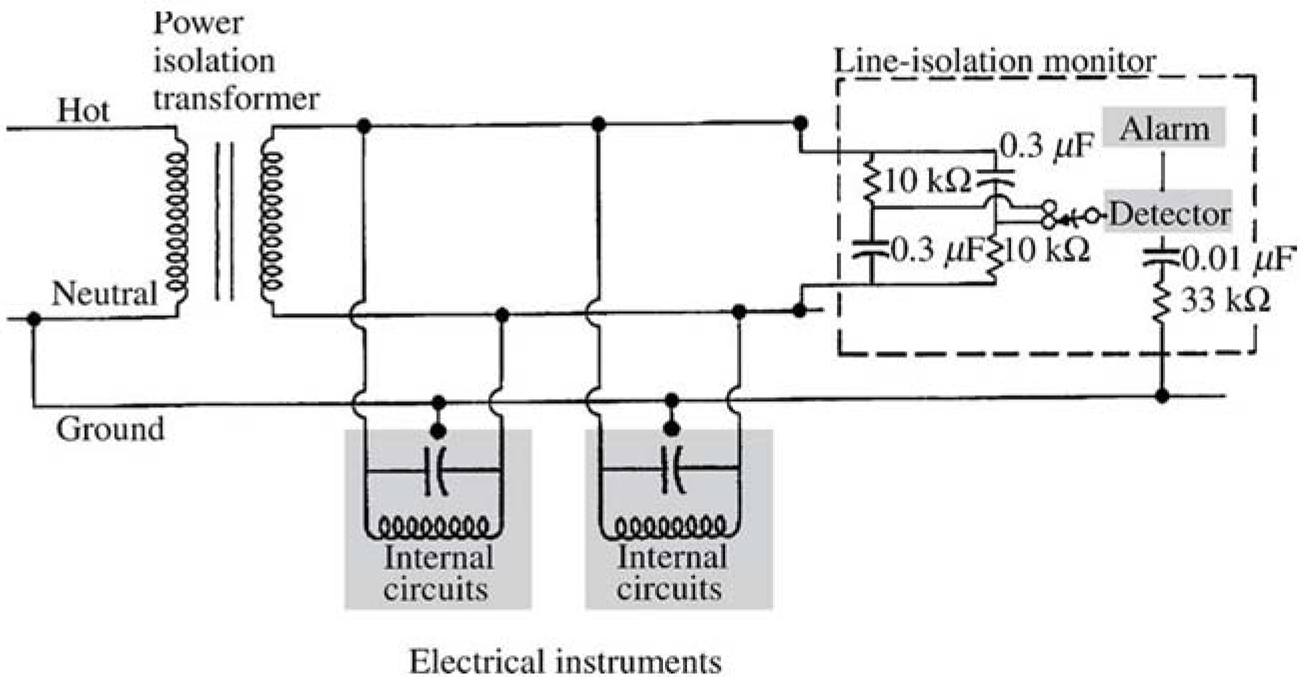



**Figure 14.9 Power-isolation-transformer system with a line-isolation monitor to detect ground faults.**