43.1 Measurement loading, amplifier gain and detector response

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS dead time • input impedance

Objective

Calculate measurement loading from finite meter and source impedances; Determine simple amplifier gain and first-order filter response; Interpret detector efficiency, resolution, dead time and calibration bias. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

A meter forms a divider with the source: reading = V_th · R_m/(R_m+R_th) ≤ V_th. Quote both resistances.

Non-inverting gain is 1+R2/R1. A first-order low-pass has f_c=1/(2πRC), amplitude 1/sqrt(1+(f/f_c)^2), and passes $1/\sqrt{2}$ at f_c.

Efficiency, FWHM/E resolution and dead time m=n/(1+nτ) are separate properties; invert to n=m/(1−mτ) with mτ<1.

Calibration removes constant offset or scale error, not noise or nonlinearity; report resolution and efficiency separately.

■ Worked method

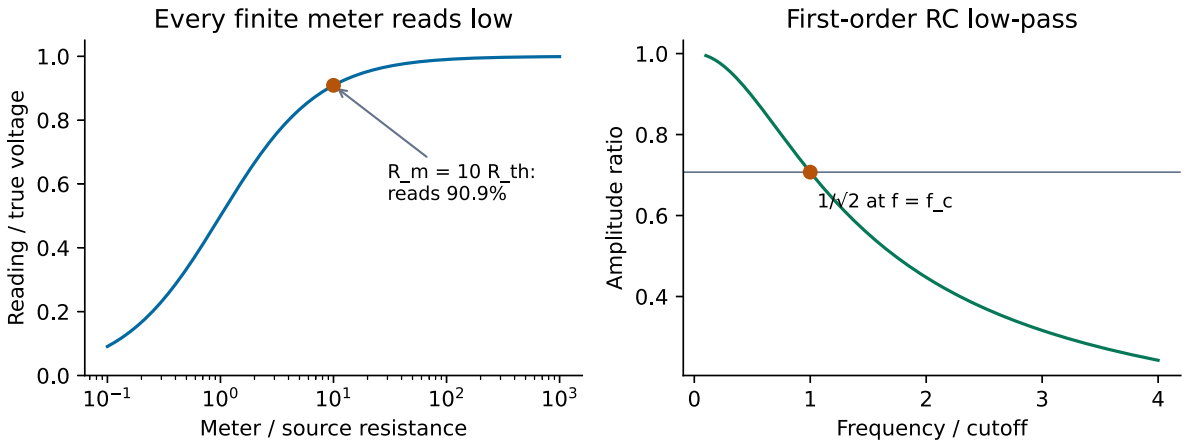
A voltmeter of finite input resistance forms a divider with the source resistance.

$$V_m = V_{th}\frac{R_m}{R_m + R_{th}} = (12\,\mathrm{V})\frac{1.0\,\mathrm{M\Omega}}{1.0\,\mathrm{M\Omega} + 0.20\,\mathrm{M\Omega}} = 10.0\,\mathrm{V}.$$

For a nonparalysable detector with observed rate m and dead time tau,

$$n = m/(1 - m\tau), \qquad m\tau < 1.$$

Efficiency, dead time and spectral resolution are different corrections; one cannot replace the others.



2 Practice

2.1 Choose one answer. A 12 V source with internal resistance 200 kΩ is measured by a voltmeter with input resistance 1 MΩ. The meter reads: [1]

- **A** 12.0 V
- **B** 10.0 V
- **C** 9.6 V
- **D** 2.0 V
- **E** 11.0 V

2.2 Choose one answer. A first-order RC low-pass driven exactly at its cutoff frequency passes an amplitude fraction of: [1]

- **A** $1/2$
- **B** $1/\sqrt{2}$
- **C** $1/e$
- **D** $9/10$
- **E** 1

2.3 An ideal non-inverting op-amp stage with R1=1 kΩ and R2=9 kΩ has gain _____. Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: Increasing a detector dead time increases the recorded count rate at fixed true rate. [2]

3 Exam-style questions

3.1 The same source is measured first with a 1 megohm meter, giving 6 V, then with a 3 megohm meter, giving 9 V. Find its Thevenin voltage and resistance. Assume stable linear behaviour. [4]