

Problem 1.44

[Difficulty: 2]

1.44 The mass flow rate in a water flow system determined by collecting the discharge over a timed interval is 0.2 kg/s. The scales used can be read to the nearest 0.05 kg and the stopwatch is accurate to 0.2 s. Estimate the precision with which the flow rate can be calculated for time intervals of (a) 10 s and (b) 1 min.

Given: Mass flow rate of water determine by collecting discharge over a timed interval is 0.2 kg/s.

Scales can be read to nearest 0.05 kg.

Stopwatch can be read to nearest 0.2 s.

Find: Estimate precision of flow rate calculation for time intervals of (a) 10 s, and (b) 1 min.

Solution: Apply methodology of uncertainty analysis, Appendix F:

$$\dot{m} = \frac{\Delta m}{\Delta t}$$

Computing equations:

$$u_{\dot{m}} = \pm \left[\left(\frac{\Delta m}{\dot{m}} \frac{\partial \dot{m}}{\partial \Delta m} u_{\Delta m} \right)^2 + \left(\frac{\Delta t}{\dot{m}} \frac{\partial \dot{m}}{\partial \Delta t} u_{\Delta t} \right)^2 \right]^{\frac{1}{2}}$$

Thus
$$\frac{\Delta m}{\dot{m}} \frac{\partial \dot{m}}{\partial \Delta m} = \Delta t \frac{1}{\Delta t} = 1 \quad \text{and} \quad \frac{\Delta t}{\dot{m}} \frac{\partial \dot{m}}{\partial \Delta t} = \frac{\Delta t^2}{\Delta m} \cdot -\frac{\Delta m}{\Delta t^2} = -1$$

The uncertainties are expected to be \pm half the least counts of the measuring instruments.

Tabulating results:

Time Interval, Δt (s)	Error in Δt (s)	Uncertainty in Δt (%)	Water Collected, Δm (kg)	Error in Δm (kg)	Uncertainty in Δm (%)	Uncertainty in \dot{m} (%)
10	± 0.10	± 1.0	2.0	± 0.025	± 1.25	± 1.60
60	± 0.10	± 0.167	12.0	± 0.025	± 0.208	± 0.267

A time interval of about 15 seconds should be chosen to reduce the uncertainty in results to ± 1 percent.