Note: the following is an example of the type of calculation you may be asked to perform in the TE1 narrative paper. Please note this is not the complete exam paper. Calculation questions typically make up 20 out of the 40 marks for the paper.

EXAMPLE CALCULATIONS ASSOCIATED WITH PARTICULATE MONITORING USING ISOKINETIC SAMPLING TECHNIQUES

The following calculations are used in conjunction with method BS EN 13284-1 and the associated Environment Agency Method Implementation Document (MID). Raw data from an assumed scenario are provided in the tables below:

General information

Daily average ELV	mg/m^3	20
Expected particulate concentration	mg/m^3	10
Uncertainty of weighing procedure	mg	0.35

Duct dimensions and velocity

Duct Diameter	m	1.2
Duct Area	m^2	1.13
Average stack velocity	m/s	14.3

Nozzle diameter and sample time

Nozzle diameter	mm	8
Total sample time	min	60

Duct and reference conditions for the duct

		Duct	**Reference**
Temperature	ºC	165	0
Pressure	kPa	101.3	101.3
Oxygen concentration	%	10	11
Moisture content	%	13	0

Gas meter volumes (dry)

Gas meter initial	m^3	1.3
Gas meter final	m^3	2.94
Gas Meter Temperature	°C	17

Particulate collection

Filter weight initial	g	4.0
Filter weight final	g	4.018
Mass of particulate in rinsing solution	mg	1.3

You may be asked to calculate the minimum mass to be collected

The expanded uncertainty of the weighing procedure is 0.35 mg
For a given ELV the particulate mass shall be at least 10 times the expanded uncertainty of the weighing

Minimum mass to be collected = 10 x uncertainty of weighing procedure
= 10 x 0.35 mg
= 3.5 mg

You may be asked to calculate the minimum sampling volume required

The minimum mass to be collected is 3.5 mg
Daily average ELV is 20 mg/m^3

$$\text{Minimum sampling volume required} = \frac{\text{minimum mass to be collected}}{\text{daily average ELV}}$$

$$= \frac{3.5\text{ mg}}{20\text{ mg/m}^3}$$

$$= 0.175\text{ m}^3$$

You may be asked to calculate the minimum sampling flow rate required

The minimum sampling volume required is 0.175 m^3
Sampling time is 60 minutes

$$\text{Minimum sampling flow rate required} = \frac{\text{minimum sampling volume required}}{\text{Sampling time}}$$

$$= \frac{0.175\text{ m}^3}{60}$$

$$= 0.0029\text{ m}^3\text{/min}$$

$$= 2.9\text{ l/min}$$

You may be asked to calculate the volumetric flow rate in the stack.

Duct diameter is 1.2m

Duct cross sectional area = πr^2
= 3.14×0.6^2
= 1.13 m^2

Duct cross sectional area (csa) is 1.13 m^2
Average velocity of stack gases is 14.3 m/s

Volumetric flow rate = duct csa x average velocity of stack gases
= 1.13 m^2 x 14.3 m/s
= 16.16 m^3/s

You may be asked to calculate the cross sectional area of the nozzle

Nozzle diameter is 8mm (radius = 4mm)

Nozzle cross sectional area = πr^2
= 3.14×4^2
= 50.29 mm^2 (0.0000503 m^2)

Convert from mm^2 to m^2 = 50.29 mm^2 / 1000000
= 0.0000503 m^2

You may be asked to calculate the volumetric flow rate through the nozzle

Cross sectional area (csa) of nozzle is 0.0000503 m^2
Average velocity of stack gases is 14.3 m/s

Volumetric flow rate through nozzle = csa of nozzle x average velocity of gases
= 0.0000503 m^2 x 14.3 m/s
= 0.0007192 m^3/s

You may be asked to calculate the predicted sample volume

Volumetric flow rate is 0.0007192 m^3/s
Sampling time is 60 minutes (3600 seconds)

Predicted sample volume = volumetric flow rate through nozzle x sampling time

= 0.0007192 m^3/s x 3600
= 2.589 m^3

You may be asked to calculate the predicted sample volume at reference conditions

Stack temperature is 165 ^{o}C	Reference temperature is 0 ^{o}C (273K)
Stack pressure is 101.3 kPa	Reference pressure is 101.3 kPa
Stack moisture is 13%	Reference moisture is dry
Stack oxygen is 10%	Reference oxygen is 11%

Temperature correction factor

$$= \frac{\text{reference temperature}}{\text{stack temperature}}$$

$$= \frac{273\ \text{K}}{273 + 165\ \text{K}}$$

$$= 0.623$$

Pressure correction factor

$$= \frac{\text{stack pressure}}{\text{reference pressure}}$$

$$= \frac{101.3\ \text{kPa}}{101.3\ \text{kPa}}$$

$$= 1$$

Moisture correction factor

$$= \frac{(100 - \text{stack moisture})}{100}$$

$$= \frac{(100 - 13)}{100}$$

$$= 0.87$$

Oxygen correction factor

$$= \frac{(21 - \text{stack oxygen})}{(21 - \text{reference oxygen})}$$

$$= \frac{(21 - 10)}{(21 - 11)}$$

$$= 1.1$$

Predicted sample volume at reference conditions = predicted volume at stack conditions x correction factors for temperature, pressure, moisture and oxygen

$$= 2.589\ \text{m}^3 \times 0.623 \times 1 \times 0.87 \times 1.1$$

$$= 1.544\ \text{m}^3$$

You may be asked to calculate the sample volume at the dry gas meter

Initial meter reading is 1.3 m^3
Final meter reading is 2.94 m^3

Sample volume at dry gas meter = Final reading – initial reading

= 2.94 m^3 – 1.3 m^3

= 1.64 m^3

You may be asked to calculate the actual sample volume at reference conditions

Sample volume at dry gas meter is 1.64 m^3
Gas meter temperature is 17°C
Reference temperature is 0 °C (273K)
Stack oxygen is 10%
Reference oxygen is 11%

Temperature correction factor $= \frac{\text{reference temperature}}{\text{dry gas meter temperature}}$

$= \frac{273 \text{ K}}{273 + 17 \text{ K}}$

= 0.94

Oxygen correction factor $= \frac{(21 - \text{dry gas meter oxygen})}{(21 - \text{reference oxygen})}$

$= \frac{(21 - 10)}{(21 - 11)}$

= 1.1

Actual sample volume at reference conditions = sample volume at dry gas meter x correction factors for temperature and oxygen

= 1.64 m^3 x 0.94 x 1.1

= 1.696 m^3

You may be asked to calculate the isokinetic rate

$$\text{Isokinetic rate} = \frac{\text{actual sample volume at reference conditions}}{\text{predicted sample volume at reference conditions}} \times 100$$

$$= \frac{1.696 \text{ m}^3}{1.544 \text{ m}^3} \times 100$$

$$= 109.8\%$$

You may be asked to calculate the mass of particulate collected on the filter

Initial filter weight is 4.0 g
Final filter weight is 4.018 g

Mass of particulate collected on filter = final filter weight – initial filter weight

= 4.018 g – 4.0 g

= 0.018 g (18 mg)

You may be asked to calculate the total mass of particulate collected

Mass collected on filter is 18 mg
Mass collected from rinsing solution is 1.3 mg

Total mass of particulate collected = mass collected on filter + mass collected from rinsing solution

= 18 mg + 1.3 mg

= 19.3 mg

You may be asked to calculate the particulate concentration at reference conditions

Sample volume at reference conditions is 1.696 m^3
Total mass of particulate collected is 19.3 mg

$$\text{Particulate concentration at reference conditions} = \frac{\text{mass of particulate collected}}{\text{sample volume at reference conditions}}$$

$$= \frac{19.3 \text{ mg}}{1.696 \text{ m}^3}$$

$$= 11.4 \text{ mg/m}^3$$

You may be asked to calculate the particulate blank concentration

Mass of particulate recovered from blank is 0.7 mg
Sample volume at reference conditions is 1.696 m^3

$$\text{Particulate blank concentration} = \frac{\text{mass of particulate recovered from blank}}{\text{sample volume at reference conditions}}$$

$$= \frac{0.7\ \text{mg}}{1.696\ \text{m}^3}$$

$$= 0.41\ \text{mg/m}^3$$