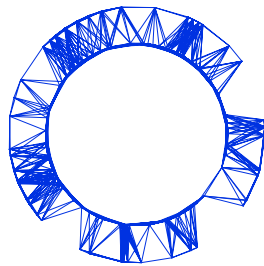


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Detailed Marking Scheme Experimental Problem 2

## Viscoelasticity of a polymer thread

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v1.1

Confidential

## Viscoelasticity of a polymer thread (10 points)

### Part A: Stress-relaxation measurements (1.9 points)

#### A.1

$\ell_0 \in [40, 50] \text{ cm}$	0.1
$\sigma_{\ell_0} \in [0.1, 0.5] \text{ cm}$	0.2
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

#### A.2

$P_0 \in [75, 85] \text{ gf}$	0.1
$\sigma_{P_0} \in [0.01, 0.1] \text{ gf}$	0.2
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

*Note: The scale must be in the gram units setting (g); any other setting is considered wrong units and values.*

#### A.3

Table with times and weight	1.0
Total	1.0

[Wrong or missing units in the first two columns of the table,  $-0.2\text{pt}$ ]

[Non-decimal time scale in column  $t$  (e.g. min:sec), necessary for the graphic in question D.2,  $-0.2\text{pt}$ ]

[less than 20 points,  $-0.3\text{pt}$ ]

[number of points  $\in [20, 30]$ ,  $-0.2\text{pt}$ ]

*Note: time units in min is acceptable; P units in gram is acceptable.*

#### A.4

$\ell \in [45, 55] \text{ cm}$	0.1
$\sigma_{\ell} \in [0.1, 0.5] \text{ cm}$	0.2
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

## Part B: Measurement of the stretched thread diameter (1.5 points)

### B.1

Reasonable sketch	0.6
Total	0.6

[no optimization of optical path (using mirrors),  $-0.6\text{pt}$ ]

*Note: Using one mirror for reflection of the diffracted beam is acceptable.*

### B.2

$D \in [1, 4] \text{ m}$	0.2
$\sigma_D \in [0.1, 3] \text{ cm}$	0.1
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

*Note: acceptable interval for  $\sigma_D$  enlarged to :  $\sigma_D \in [0.1, 4] \text{ cm}$*

### B.3

$\bar{x}$	0.1
$\sigma_{\bar{x}} \in [0.001\bar{x}, 0.1\bar{x}]$	0.2
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

### B.4

$d \in [0.40, 0.55] \text{ mm}$ , correctly calculated from B.3 and B.2	0.2
$\sigma_d \in [0.001, 0.05] \text{ mm}$ , correctly calculated from B.3 and B.2	0.1
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

## Part C: Changing to a new thread (0.3 points)

### C.1

$\ell'_0 \in [30, 35] \text{ cm}$	0.1
$\sigma_{\ell'_0} \in [0.1, 0.5] \text{ cm}$	0.2
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Wrong or missing units,  $-0.1\text{pt}$ ]

## Part D: Data analysis (5.7 points)

### D.1

Fill $F$ in Table 1, using of the correct algorithm $F = P_0 - P(t)$ for all the calculations	0.3
Total	0.3

[Errors in the calculation for some points (less than 50% of the points),  $-0.1\text{pt}$ ]

[Errors in the calculation for some points (more than 50% of the points),  $-0.3\text{pt}$ ]

### D.2

Correct and complete representation of axis quantities, units and labels	0.1
Complete representation of all data points	0.2
Optimization of the axis span in order to maximize the use of the provided space (more than half of the area)	0.1
Total	0.4

#### Correct and complete representation of axis quantities, units and labels

[Missing labels in the axis,  $-0.1\text{pt}$ ]

[Label values unequally spaced,  $-0.05 \text{ pt}$ ]

[Missing identification of the quantities in the axis,  $-0.05 \text{ pt}$ ]

[Missing or wrong units in the axis,  $-0.05 \text{ pt}$ ]

*Note: either in on one or in both axis.*

#### Complete representation of all data points

[Errors in the representation for some points (less than 50% of the points),  $-0.1 \text{ pt}$ ]

[Errors in the calculation for a significant number of points (more than 50% of the points),  $-0.2 \text{ pt}$ ]

## D.3

$\epsilon$ , correctly calculated from A.1 and A.4	0.2
$\sigma_{\epsilon}$ , correctly calculated from A.1 and B.4	0.1
Total	0.3

[Incoherent use of significant digits,  $-0.1\text{pt}$ ]

[Indication of units for  $\epsilon$ ,  $-0.1\text{pt}$ ]

## D.4

$\beta$ , correctly calculated from D.3 and B.4	0.3
Total	0.3

[Wrong or missing units,  $-0.1\text{pt}$ ]

*Note: any number of significant digits is acceptable.*

## D.5

Representation of a positive constant function $F(t)$	0.4
Total	0.4

## D.6

Fill $\frac{dF}{dt}$ in Table 1	0.5
Total	0.5

[Wrong determination of  $dF/dt$  values from either method,  $-0.5\text{ pt}$ ]

[Use of points at  $t < 1000\text{ s}$ ,  $-0.1\text{ pt}$ ]

[Exclusively use of points at  $t < 1000\text{ s}$ ,  $-0.5\text{ pt}$ ]

*Note: The "use of points" refers to the fit in the graph of D.8.*

## D.7

Expression for expected $dF(t)/dt$	0.3
Total	0.3

## D.8

Correct and complete graphical representation of axis quantities, units and labels	0.1
Complete representation of all data points and linear fit	0.2
Optimization of the axis span in order to maximize the use of the provided space (more than half of the area)	0.1
Reasonable value of $\tau_1$	0.3
Reasonable value of $E_1$	0.3
Total	1.0

[No linearisation of  $dF/dt$  function,  $-0.4$  pt]

[Absence of a fitted straight line to extract the parameters,  $-0.8$  pt]

[Bad fit of the straight line to the plotted points,  $-0.3$  pt]

### Correct and complete graphical representation of axis quantities, units and labels

[Missing labels in the axis,  $-0.1$  pt]

[Label values unequally spaced,  $-0.05$  pt]

[Missing identification of the quantities in the axis,  $-0.05$  pt]

[Missing or wrong units in the axis,  $-0.05$  pt]

*Note: either in on one or in both axis.*

### Writing reasonable value of $\tau_1$

[Unreasonable value of  $\tau_1$ , expected to be in the order of  $10^3$  s,  $-0.2$  pt]

[Wrong or missing units in  $\tau_1$ ,  $-0.1$  pt]

*Note: acceptable within  $[800, 1700]$  s; acceptable outside this range if the fit is good for the plotted points.*

### Writing reasonable value of $E_1$

[Unreasonable value of  $E_1$ , expected to be in the order of  $10^5$  N m $^{-2}$ ,  $-0.2$  pt]

[Wrong or missing units in  $E_1$ ,  $-0.1$  pt]

*Note: acceptable within  $[5 \times 10^4, 5 \times 10^6]$  N m $^{-2}$ ; acceptable outside this range if the fit is good for the plotted points.*

## D.9

Reasonable value of $E_0$ , expected to be in the order of $1.3 \times 10^7$ N m $^{-2}$	0.3
Total	0.3

[Wrong or missing units,  $-0.1$  pt]

*Note: acceptable within  $[5 \times 10^6, 5 \times 10^8]$  N m $^{-2}$ ; acceptable outside this range if calculations are correct.*

## D.10

Fill $y(t)$ in Table 1 with correct values	0.3
Total	0.3

[Errors in the calculation for some points (less than 50% of the points),  $-0.2$  pt]

[Errors in the calculation for a significant number of points (more than 50% of the points),  $-0.3$  pt]

[Calculations for points at  $t > 1000$  s,  $-0.1$  pt]

## D.11

Correct and complete graphical representation of axis quantities, units and labels	0.1
Complete representation of all data points and linear fit	0.2
Optimization of the axis span in order to maximize the use of the provided space (more than half of the area)	0.1
Reasonable value of $\tau_2$	0.3
Reasonable value of $E_2$	0.3
Total	1.0

[No linearisation of  $y$  function,  $-0.4$  pt]

[Absence of a fitted straight line to extract the parameters,  $-0.8$  pt]

[Bad fit of the straight line to the plotted points,  $-0.3$  pt]

### Correct and complete graphical representation of axis quantities, units and labels

[Missing labels in the axis,  $-0.1$  pt]

[Label values unequally spaced,  $-0.05$  pt]

[Missing identification of the quantities in the axis,  $-0.05$  pt]

[Missing or wrong units in the axis,  $-0.05$  pt]

*Note: either in on one or in both axis.*

### Writing reasonable value of $\tau_2$

[Unreasonable value of  $\tau_2$ , expected to be in the order of  $10^2$  s,  $-0.2$  pt]

[Wrong or missing units in  $\tau_2$ ,  $-0.1$  pt]

### Writing reasonable value of $E_2$

[Unreasonable value of  $E_2$ , expected to be in the order of  $10^5$  N m<sup>-2</sup>,  $-0.2$  pt]

[Wrong or missing units in  $E_2$ ,  $-0.1$  pt]

*Note: acceptable within  $[10^4, 10^6]$  N m<sup>-2</sup>; acceptable outside this range if the fit is good for the plotted points.*

## D.12

reasonable $t_i$	0.1
Reasonable $t_f$	0.2
Total	0.3

$[t_f > \text{initial time in the fit of the second component, } -0.2 \text{ pt}]$

[Wrong or missing units,  $-0.1 \text{ pt}$ ]

## D.13

Draw a line fit within $[t_i, t_f]$	0.2
$\tau_3$ with an order of magnitude of $10^0 - 10^1 \text{ s } (< 100 \text{ s})$	0.1
Total	0.3

[Wrong or missing units,  $-0.1 \text{ pt}$ ]

## Part E: Measuring $E$ in constant stress conditions (0.6 points)

### E.1

$E$ with the same order of magnitude of that in question D.9	0.4
Relative difference	0.2
Total	0.6

[Wrong or missing units,  $-0.2 \text{ pt}$ ]

*Note: acceptable if calculations are correct with available values.*