Access Tuition

A-Level Physics

The Young Modulus

Mark Scheme

Time available: 66 minutes
Marks available: 46 marks

Mark schemes

1. (a) place mirror behind ruler $_1$✓

adjust position (of eye / head) until pin hides its own reflection $_2$✓

for $_1$✓ do not insist on contact between mirror and ruler; accept sketch if mirror is parallel to ruler

for $_2$✓ accept 'pin lines up with reflection / image'

allow $_{12}$✓ = 1 MAX

for convincing explanation of set-square placed against vertical ruler then aligned with pin

OR

move (clamped) ruler closer to pin

2

(b) strategy:

y (as the dependent variable) <u>measured</u> for different values of one independent variable $_1$✓

identifies <u>one</u> correct control variable $_2$✓

for $_1$✓ accept y read OR <u>recorded</u>;

for $_2$✓ control variables m OR L only;

m = independent variable and L = control variable OR

m = control variable and L = independent variable $_{12}$✓✓

if L is being varied and m = 250 g is stated, this can be taken as m = control variable and therefore known;

take a similar approach if m is being varied but in this case L must be <u>less than</u> 30 cm

idea that w and/or t are control variables is neutral

for more than one independent variable, eg variation of both m and L $_{12}$✗✗ but allow ecf for $_4$✓ as long as plot is valid, eg y against mL^3

2

suitable measuring instruments for L, *w* and *t* $_3$✓

use of ruler to measure L AND use of micrometer screw gauge OR

<u>digital</u> / electronic callipers to obtain w <u>and</u> d

procedures to reduce random / systematic error are neutral

1

analysis:

suggests valid plot $_4$✓

identifies correctly how E can be found $_5$✓

for $_4$✓ expect y [by itself or combined with another factor] on the vertical axis and their independent variable / some <u>valid manipulation</u> of their independent variable on the horizontal axis

for $_5$✓ E must be the subject of the expression given

examples:

plot y against m 4✓ $E = \dfrac{4 \times L^3 \times g}{w \times t^3 \times \text{gradient}}$ 5✓

plot y against L^3 4✓ $E = \dfrac{4 \times m \times g}{w \times d^3 \times \text{gradient}}$ 5✓

plot y against $\dfrac{4 \times L^3}{w \times t^3}$ 4✓ $E = \dfrac{m \times g}{\text{gradient}}$ 5✓

log y against log m 4✓ $E = \dfrac{4 \times g \times L^3}{w \times t^3 \times 10^{\text{intercept}}}$ 5✓

log y against log L 4✓ $E = \dfrac{4 \times m \times g}{w \times t^3 \times 10^{\text{intercept}}}$ 5✓

2

[7]

2. (a) correctly deduces extension is 2.6 or 2.7 mm ✓

Should see $AC^2 = 1.50^2 + (6.34 \times 10^{-2})^2$;

(new) AC = 1.50134;

Extension of AC = (1.50134 − 1.50 =) 0.00134 m or 1.34 mm; and then doubles this

Final value must be to at least 2 sf

1

(b) evidence of correct working: ✓

sin $\theta = \dfrac{6.34 \times 10^{-2}}{\text{their new AC}}$ or θ = 2.42° seen

OR

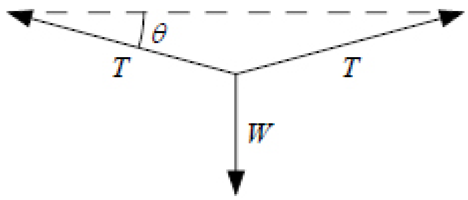
$W = 2T \sin\theta$ seen

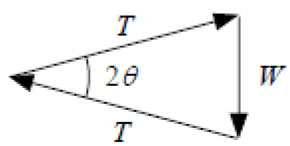
OR

suitable vector diagram with θ labelled

tension correctly calculated from $\dfrac{1.0}{2 \times \text{their } \sin\theta}$ ✓

For $_1$✓ acceptable diagrams are shown below





Correct final answer of 11.8 N or 12 N earns both marks

2

(c) ruled best-fit line between first and sixth points;

line must pass above 2nd point

and

must pass below 4th point $_1$✓

for $_1$✓ withhold mark if line is thick, faint or discontinuous

gradient calculated from $\frac{\Delta(W/y)}{\Delta y^2}$ with $\Delta y^2 \geq 0.004$ $_2$✓

(gradient ~ 3850)

for $_2$✓ condone read off errors of ± 1 division

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

for $_4$✓ reject 2 sf 1.2×10^{11}

evidence of using E = $\frac{\text{their gradient} \times 1.50^3}{1.11 \times 10^{-7}}$ $_3$✓

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

E in range 1.10×10^{11} to 1.24×10^{11} (Pa) $_4$✓

for $_4$✓ reject 2 sf 1.2×10^{11}

4

(d) kg s^{-2} ✓

no credit for N m^{-1}

correct answer only

1

[8]

3. (a) Attempt to resolve **A** or **B** eg 430 × cos35° or T_B × cos12° ✓

360 (N) ✓

If no other mark given, allow 430 × sin35° = T_B × sin12° to give 1190 N for 1 mark.

2

(b) Substitution of *F* and *A* into Young modulus or stress equation ✓

4.4×10^{-2} (m) ✓

Condone POT error for Young modulus

2

(c) Angle of **A** decreases or angle of **B** increases ✓

Accept references to 35º or 12º

Any correct application of trig or geometry to the situation

(eg $T_B/T_A = \cos\theta_A/\cos\theta_B$ so as θ_A decreases, $\cos\theta_A$ increases, $\cos\theta_B$ decreases, so T_B/T_A increases)

OR

eventually θ_B will equal 35º, θ_A = 12º so forces will be reversed (as system is symmetrical)

OR

sum of vertical components remains unchanged and vertical component of tension becomes less as angle **A** decreases ✓

Allow idea that more of the weight is supported by ***B***

T_A decreases, following some relevant discussion ✓

3

(d) Greater rate occurs when pulses are shorter (in time)/less modal dispersion ✓

Allow reverse arguments

Smaller diameter (leads to less modal dispersion) means smaller range of path lengths ✓

Accept idea of fewer reflections

X is more suitable because narrower core leads to lower modal dispersion or reduced pulse broadening ✓

3

[10]

4. (a) 37.8 ✓

CAO

1

(b) <u>random</u> (error)

condone 'statistical' ✓

the following are neutral:

'parallax' / 'human (error)' / '(some) results are anomalous'

1

(c) advantage (of using thinner beam):

(same load produces) larger (values of) s or wtte 1✓

so

the <u>percentage</u> uncertainty / error (in s) is reduced 2✓

for 1✓ accept 'beam bends / deflects more'

'beam extends more' / 'easier to bend' are neutral

for 2✓ the following are neutral:

'easier to make readings' / 'values (of s) are more accurate' / 'more precise' / 'less mass needed' / 'wider range of readings'

disadvantage (of beam bending more):

idea that beam may undergo plastic deformation 3✓

so

the graph will be non-linear / curve or wtte 4✓

or

beam 'may break' / 'slip off knife edges' **and** relevant comment about safety / health / hazard / 'cannot get unload data'

or

reduces range of m or wtte **and** relevant comment about the effect on the graph, eg increase scatter 34✓ = 1 MAX

for 3✓ accept / 'beam may become permanently deformed' or wtte / 'necking may occur' / 'hysteresis may occur' / 'beam can reach (go past) elastic limit'

the following are neutral:

'causes systematic error' / 'beam may go past limit of proportionality' / 'need to increase height of supports' / 'beam may bend under own weight'

MAX 3

(d) $E \approx 10^9$

or

1.14×10^9 seen 1✓

for 1✓ accept 10^9 seen in working

1

correct manipulation seen in **body of answer** of $s = \frac{\eta m}{E}$ 2✓

*for 2✓ **either***

*substitution of their E and data from **Figure 8***
leaving η as only unknown: allow POT in s but not in m

eg $\eta = \frac{\text{their } E \times 25.5 \left(\times 10^{-3}\right)}{0.25}$ **or**

substitution of their E and result of a gradient calculation: allow POT in Δs but not in Δm

*eg $\eta = 1.14 \times 10^{9} \times 1.02\ (\times 10^{-1})$ **or***

calculation involving orders of magnitude (expect 10^{-1} but allow 10^{2} for gradient)

eg $\eta \approx 10^{9} \times 10^{-1}$

2

correct raw result (allow POT in E) 3✓

for 3✓ expect 1.16×10^{8} but allow 1 sf gradient eg leading to 1.14×10^{8}

(on answer line) order of magnitude consistent with their raw result 4✓

for 4✓ $\eta = 10^{8}$ or 8 only; allow use of their E

award 34✓ = 1 MAX for use of gradient ≈ 100 leading to order of magnitude = 10^{11} or 11 only

1

(e) identifies that s and L are linked by a power law ✓

accept any correct expression (unless there is talk-out) with s or log s as the subject;

treat any quantities other than s and L as constant except E and η

possible answers are:

$s \propto L^n$

allow $s \propto L^m$ *if m identified as constant*

$s \propto L^3$

$s = kL^n$

log s = n log L *+ (log)* k

log s = 3 log L *+ (log)* k

log s = log L^3 *+ (log)* k

reject

$s = L^n$

log s = n log L

log s $\propto$ *n log* L

$10^s \propto 10^L$

'*s and* L *are linked logarithmically*'

'*s is directly proportional to* L'

1

(f) (log L =) −0.097 seen

for 1✓ accept any log L *rounding to −0.097;*

1

or

working on **Figure 5** confirming a value of log L between −0.095 and −0.100 1✓

uses **Figure 5** to obtain s in range 2.9 to 3.1 × 10^{-2} (m) 2✓

working can be suitable ruled line or mark on the best-fit line / on graph axes

for 2✓ accept 29, 30 or 31 mm etc

reject 1sf 3 × 10^{-2} *(m)*

1

use of wrong base

ln L = −0.22(3);

uses **Figure 5** to obtain s in range 1.49 to 1.51 × 10^{-1} or 1.5 × 10^{-1} (m) 12✓

accept 15 cm etc

(g) use of **Figure 4** to determine M ✓

*their (final answer to) (f) × gradient of **Figure 4** (9.8 ± 2.5%)*
minimum 2sf

condone use of 1sf s

1

[13]

5. (a) Sum of / total clockwise moments = sum of / total anticlockwise moments✓

For a body in equilibrium✓

2

(b) Clockwise moments = 2.0 × 9.81 × 0.25 + 0.65 × 9.81 × 0.45

= 7.77 (N m)✓

Anticlockwise moments = Tsin30 × 0.3✓

Tsin30 × 0.3 = 7.77 or T = 7.77/(sin30 × 0.3) ✓

T = 52.0 (N) ✓

First mark for clockwise moments, workings or correct answer.
Second mark for anticlockwise moments.
Third mark for equating clockwise and anticlockwise moments.
Fourth mark for correct answer.

4

(c) tensile stress = 52.0/(7.8×10^{-7}) = 6.6×10^{7} ✓

tensile strain = 6.6×10^{7}/(180×10^{9})= 3.7×10^{-4} ✓

2

[8]