0 1

Thom is investigating how the extension of a spring is affected by the force applied to it. He obtains the below data.

Force (N)	Extension (cm)	Corrected extension (cm)
0	10	0
1	15	5
2	20	10
3	25	15
4	30	20
5	35	25
6	40	30
7	50	40
8	70	60

0 1 . 1

Thom has incorrectly measured the spring extension for each applied force. Suggest a mistake which he may have made during his experiment.

He may have measured the total length of the spring instead of its extension [1]. Extension, e = current length – initial length (when F = 0).

0 1 . 2

What is the name given to the type of error which his mistake introduced to the extension measurements?

Systematic error [1].

0 1 . 3

What was the independent variable in this investigation?

Force (applied to spring) [1].

0 1 . 4

By performing appropriate calculations, determine the correct extension for each force. Write your answers into the right-hand column of the above table.

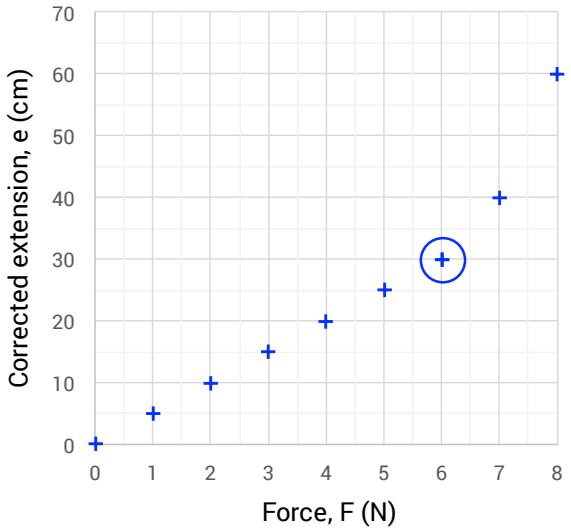
Subtract 10 from all measurements. All correct for 2 marks; 5 – 8 correct for 1 mark; 0 marks for less than 5 correct.

0 1 . 5

On the following page, plot a graph of corrected extension against force for the spring.

Do not penalise for wrong corrected extension values in above table. Allow full marks for graph if (uncorrected) extension values used.

0 1 . 5



0 1 . 6 Using the above graph (or otherwise), determine the spring constant of the spring which Thom used in his investigation.

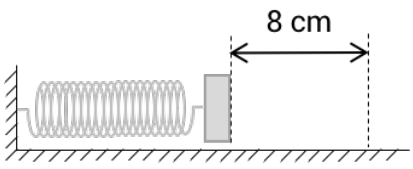
Take any point from straight section of graph (1 – 6 N) [1].
k = F ÷ e = 6 ÷ 0.3 = **20 N/m** [1]
Allow both marks if graph drawn incorrectly but calculation correct.

0 1 . 7 On the above graph, **circle** the point which marks the limit of proportionality of the spring.

0 1 . 8 Describe the relationship between force and extension when the spring has been extended beyond its limit of proportionality.

Beyond the limit of proportionality, the extension is no longer proportional to the applied force (the relationship becomes nonlinear) [1].

0 2 The spring of the launching mechanism inside a pinball machine can be pulled back by a maximum distance of 8 cm, as shown below. If its spring constant is 250 N/m, calculate the maximum amount of energy which the launching mechanism can transfer to a pinball.



e = 0.08 m
$E_e = ½ k e^2$
$E_e = ½ \times 250 \times 0.08^2$
E_e = **0.8 J**

Remember here that *e* can represent either the extension of a spring or the amount by which it has been compressed (its compression). Technically, we say that the extension of the spring is negative in this case, but since *e* is squared in the equation, we still end up with a positive value for E_e (the elastic potential energy stored in the compressed spring).