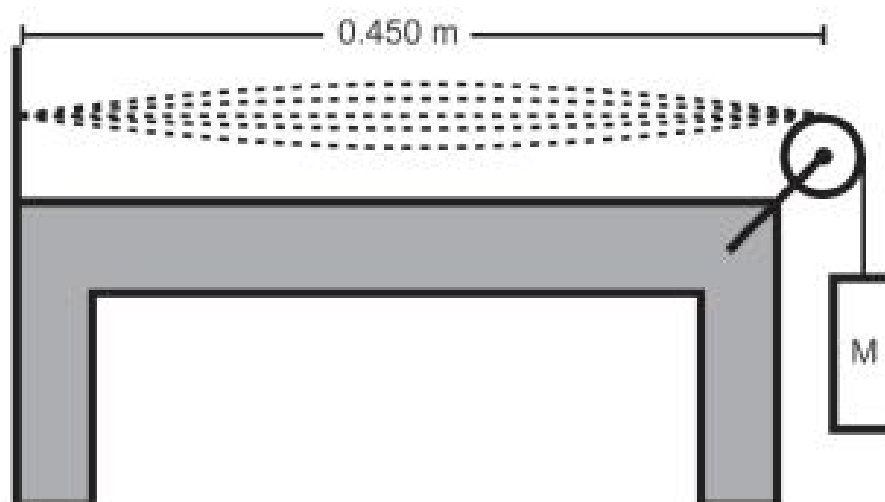**Question 16** (18 marks)

A group of students set up the apparatus shown in the diagram above to measure the mass per unit length of a thin and strong steel wire. On each successive trial, they increased the mass of the counterweight M, further stretching the wire. They then plucked the steel wire and measured the frequency of the vibrating wire using a strobe light. The length L of the vibrating portion of the wire, shown in the diagram above, was 0.450 m. Their results are given in the table below.

Mass (kg)	1.50	2.00	2.50	3.00	3.50	4.00
Frequency (Hz)	105	120	135	150	160	170

The students observed the wire vibrating in its fundamental mode, where wavelength $\lambda = 2L$, and substituted this into the wave equation $v = \lambda f$. They also used the following equation for the speed v of a wave along a wire under tension:

$$v = \sqrt{\frac{T}{\mu}}$$ where T is the tension in the wire (in N) and μ is the mass per unit length (in kg m^{-1}).

Using these equations they derived the relationship below.

$$T = (4L^2 \mu) f^2$$

(a)   Show how the students derived this relationship. (4 marks)

The students then manipulated their data so as to graph this relationship and produce a straight line.

(b) Make the adjustments to the data and place the results in the table below. Give your answers to **three** significant figures and express f^2 in scientific notation. (4 marks)

Mass (kg)	1.50	2.00	2.50	3.00	3.50	4.00
Tension (N)						
f^2 (Hz^2)						

(c) Graph your data on the grid below. Include a line of best fit. (3 marks)
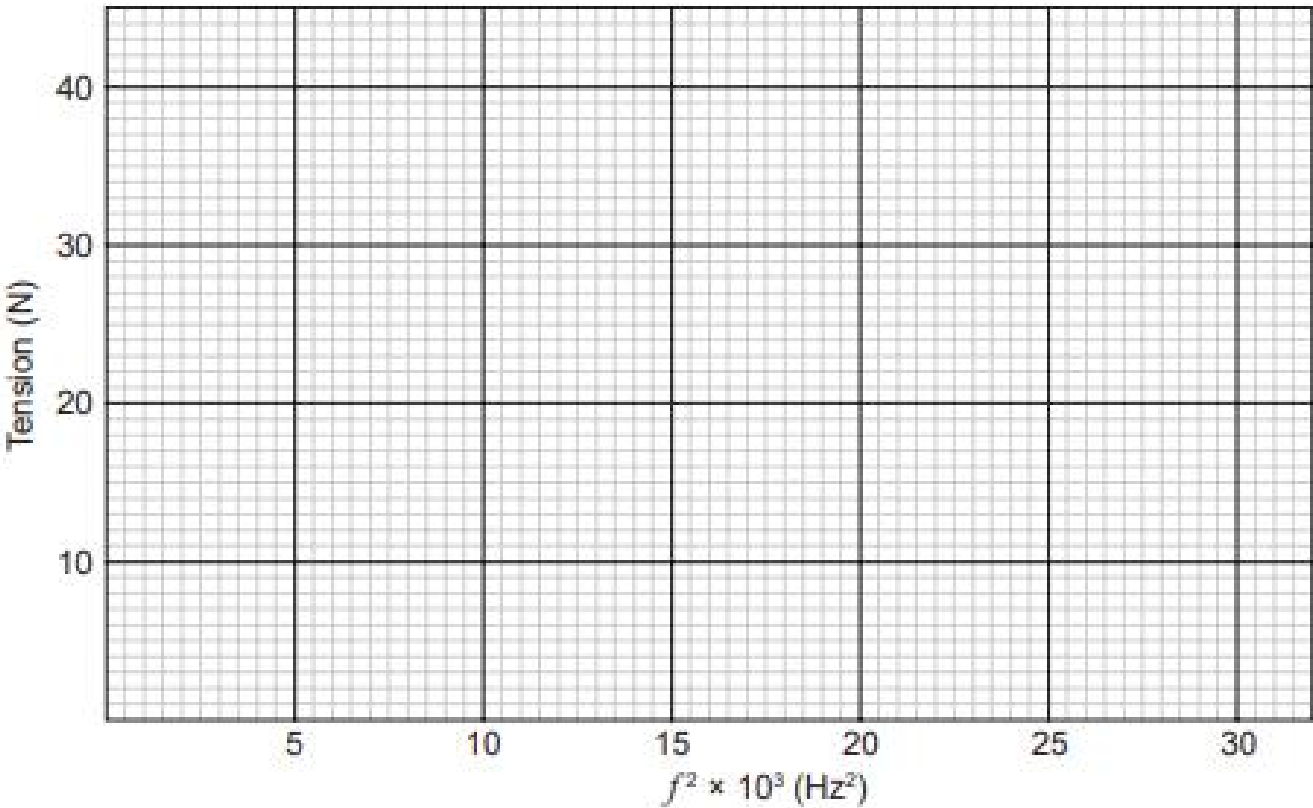
A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

(d) Use the gradient of your line of best fit to calculate the mass per unit length in kg m^{-1} of the steel wire. Indicate clearly the two points used and express your answer to the appropriate number of significant figures. (5 marks)

Answer: _____ kg m^{-1}

(e) In the summary of their report, the students had to identify any variables that could affect the accuracy of their value. They identified correctly an important assumption they had made, which may have caused their value to be slightly different from the theoretical value. This had nothing to do with human error, inaccurate equipment, atmospheric conditions or calibration of instruments. Describe their assumption. (2 marks)

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