The slope is \( a = \frac{40}{400} = 0.1 \).
Therefore the law of the machine is:

\[
F_E = 0.1F_L + 5
\]

For a load of 700 N, the effort required is:

\[
F_E = 0.1 \times 700 + 5 = 0.1 \times 700 + 5 = 75 \text{ N}
\]

### 22.5 LIMITING EFFICIENCY

If we calculate and plot efficiency for the experimental results under different load conditions, we will find that the efficiency increases with the load. However, the increase is not proportional to the load.

There is a limiting value to the efficiency of a particular machine, which is always less than 100 per cent. The value of the limiting efficiency can be found by combining the law of a machine with the definition of efficiency, as follows:

\[
\eta = \frac{MA}{VR} = \frac{F_E}{F_E \times VR}
\]

Also:

\[
F_E = aF_L + b
\]

Substitute:

\[
\eta = \frac{\frac{F_E}{F_L}}{aF_L + b} = \frac{1}{\left( a + \frac{b}{F_L} \right) VR} = \frac{1}{a VR + \frac{b VR}{F_L}}
\]

As the load \( F_L \) increases, the term \( \frac{b VR}{F_L} \) becomes smaller, tending towards zero at very large loads, when the limiting efficiency becomes:

\[
\eta = \frac{1}{a VR}
\]

### Example 22.5

For each of the test results in the previous example, calculate efficiency and show that it tends towards a limiting value at large loads.

**Solution**

**Efficiency:**

\[
\eta_1 = \frac{F_L}{F_E VR} = \frac{0}{5 \times 12} = 0\%
\]

\[
\eta_2 = \frac{200}{25 \times 12} = 66.7\%
\]

\[
\eta_3 = \frac{400}{45 \times 12} = 74.1\%
\]

\[
\eta_4 = \frac{600}{65 \times 12} = 76.9\%
\]

\[
\eta_5 = \frac{800}{85 \times 12} = 78.4\%
\]

\[
\eta_6 = \frac{1000}{105 \times 12} = 79.4\%
\]

**Limiting efficiency:**

\[
\eta = \frac{1}{a VR} = \frac{1}{0.1 \times 12} = 83.3\%
\]

This relationship can best be illustrated by a graph as shown in Figure 22.3.