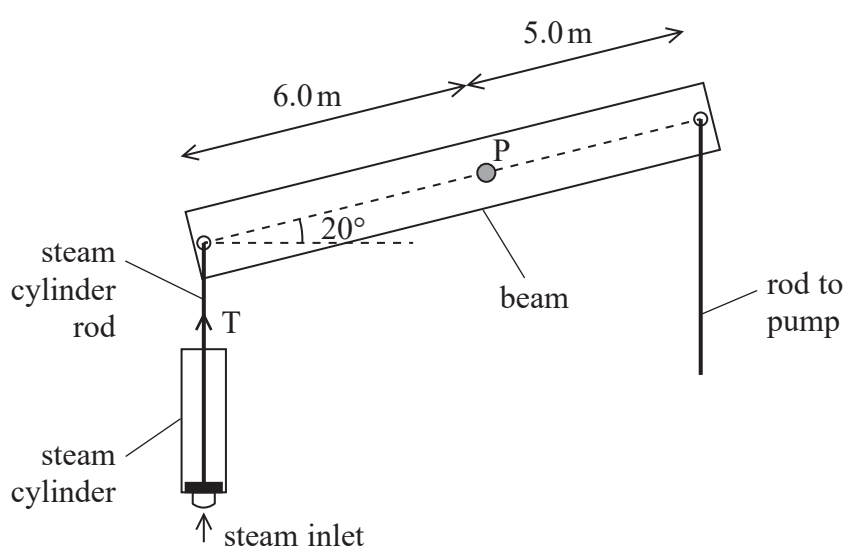


**13** Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.

The diagram below shows a simplified arrangement of a beam engine.



- (a) The beam has a constant thickness and a mass of  $3.05 \times 10^4 \text{ kg}$ . The length of the beam is 11.0 m. The pivot P is positioned 6.0 m from the steam cylinder end of the beam.

In its resting position the steam cylinder rod is supported by the base of the steam cylinder with the beam at an angle of  $20^\circ$  to the horizontal.

The steam cylinder rod exerts a force  $T$  on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force  $T$ .

(4)

$T =$  .....

- (b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.

The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy. The beam engine was said to have an efficiency of 10%.

Deduce whether this claim for efficiency was correct.

(5)