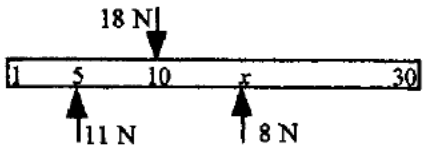
Take $g = 9{\cdot}8$ ms^{-2} and give all answers correct to 3 significant figures where necessary.

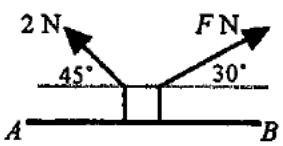
1. A boy holds a 30 cm metal ruler between three fingers of one hand, pushing down with the middle finger and up with the other two, at the points marked 5 cm, 10 cm and x cm and exerting forces of magnitude 11 N, 18 N and 8 N respectively. The ruler is in equilibrium in this position. Modelling the ruler as a uniform rod, find



(a) the mass of the ruler, in grams, **(3 marks)**

(b) the value of x. **(3 marks)**

(c) State how you have used the modelling assumption that the ruler is a uniform rod. **(1 mark)**

2. 

A small packet of mass 0·3 kg rests on a rough horizontal surface. The coefficient of friction between the packet and the surface is $\frac{1}{4}$. Two strings are attached to the packet, making angles of 45° and 30° with the horizontal, and when forces of magnitude 2 N and F N are exerted through the strings as shown, the packet is on the point of moving in the direction $\overrightarrow{AB}$.

Find the value of F. **(7 marks)**

3. A body moves in a straight line with constant acceleration. Its speed increases from 17 ms^{-1} to 33 ms^{-1} while it travels a distance of 250 m. Find

(a) the time taken to travel the 250 m, **(3 marks)**

(b) the acceleration of the body. **(2 marks)**

The body now decelerates at a constant rate from 33 ms^{-1} to rest in 6 seconds.

(c) Find the distance travelled in these 6 seconds. **(2 marks)**

4. A particle P of mass m kg, at rest on a smooth horizontal table, is connected to particles Q and R, of mass 0·1 kg and 0·5 kg respectively, by strings which pass over fixed pulleys at the edges of the table. The system is released from rest with Q and R hanging freely and it is found that the tension in the section of the string between P and R is 2 N.

(a) Show that the acceleration of the particles has magnitude 5·8 ms^{-2}. **(3 marks)**

(b) Find the value of m. **(5 marks)**

Modelling assumptions have been made about the pulley and the strings.

(c) Briefly describe these two assumptions. For each one, state how the mathematical model would be altered if the assumption were not made. **(4 marks)**

5. Two trucks P and Q, of masses 18 000 kg and 16 000 kg respectively, collide while moving towards each other in a straight line. Immediately before the collision, both trucks are travelling at the same speed, u ms^{-1}. Immediately after the collision, P is moving at half its original speed, its direction of motion having been reversed.

(a) Find, in terms of u, the speed of Q immediately after the collision. **(5 marks)**

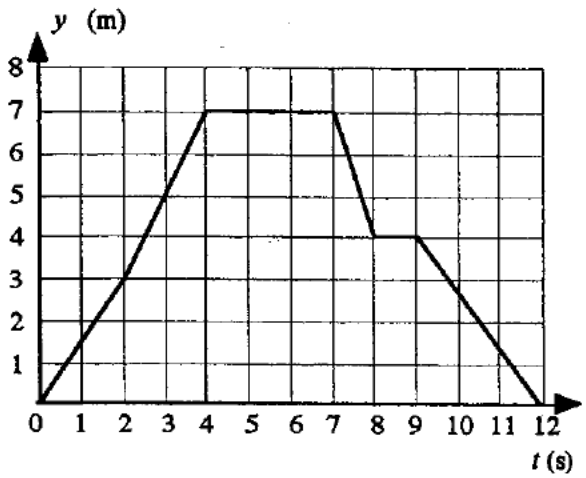
(b) State, with a reason, whether the direction of Q's motion has been reversed. **(1 mark)**

(c) Find, in terms of u, the magnitude of the impulse exerted by P on Q in the collision, stating the units of your answer. **(3 marks)**

The force exerted by each truck on the other in the impact has magnitude $108\,000u$ N.

(d) Find the time for which the trucks are in contact. **(3 marks)**

6. A particle P moves in a straight line such that its displacement from a fixed point O at time t s is y metres. The graph of y against t is as shown.



(a) Write down the velocity of P when

(i) $t = 1$, (ii) $t = 10$. **(2 marks)**

(b) State the total distance travelled by P. **(2 marks)**

(c) Write down a formula for y in terms of t when $2 \leq t < 4$. **(3 marks)**

(d) Sketch a velocity-time graph for the motion of P during the twelve seconds. **(3 marks)**

(e) Find the maximum speed of P during the motion. **(3 marks)**

7. Two trains S and T are moving with constant speeds on straight tracks which intersect at the point O. At 9.00 a.m. S has position vector $(-10\mathbf{i} + 24\mathbf{j})$ km and T has position vector $25\,\mathbf{j}$ km relative to O, where $\mathbf{i}$ and $\mathbf{j}$ are unit vectors in the directions due east and due north respectively. S is moving with speed 52 km h^{-1} and T is moving with speed 50 km h^{-1}, both towards O.

(a) Show that the velocity vector of S is $(20\mathbf{i} - 48\mathbf{j})$ km h^{-1} and find the velocity vector of T. **(5 marks)**

(b) Find expressions for the position vectors of S and T at time t **minutes** after 9.00 a.m. **(5 marks)**

(c) Show that the bearing of T from S remains constant during the motion, and find this bearing. **(5 marks)**

(d) Show that if the trains continue at the given speeds they will collide. **(2 marks)**

