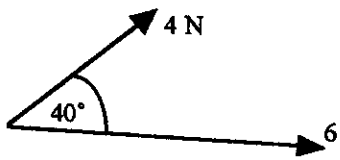
Take $g = 9{\cdot}8$ ms^{-2} and give all answers correct to 3 significant figures where necessary.

1. A plank of wood AB, of mass 8 kg and length 6 m, rests on a support at P, where $AP = 4$ m. When particles of mass 1 kg and k kg are suspended from A and B respectively, the plank rests horizontally in equilibrium.
   Modelling the plank as a uniform rod, find
   (a) the value of k, **(3 marks)**
   (b) the magnitude of the force exerted by the support on the plank at P. **(2 marks)**

2. Forces of magnitude 4 N and 6 N act in directions which make an angle of 40° with each other, as shown.



   Calculate
   (a) the magnitude of the resultant of the two forces, **(4 marks)**
   (b) the angle, in degrees, between the resultant and the 4 N force. **(2 marks)**

3. A stone is dropped from rest at a height of 7 m above horizontal ground. It falls vertically, hits the ground and rebounds vertically upwards with half the speed with which it hit the ground. Calculate
   (a) the time taken for the stone to fall to the ground, **(2 marks)**
   (b) the speed with which the stone hits the ground, **(2 marks)**
   (c) the height to which the stone rises before it comes to instantaneous rest. **(3 marks)**
   State **two** modelling assumptions that you have made. **(2 marks)**

4. A boy starts at the corner O of a rectangular playing field and runs across the field with constant velocity vector $(\mathbf{i} + 2\mathbf{j})$ ms^{-1}, where $\mathbf{i}$ and $\mathbf{j}$ are unit vectors in the directions of two perpendicular sides of the field. After 40 seconds, at the point P in the field, he changes speed and direction so that his new velocity vector is $(2{\cdot}4\mathbf{i} - 1{\cdot}8\mathbf{j})$ ms^{-1} and maintains this velocity until he reaches the point Q, where $PQ = 75$ m.
   Calculate (a) the distance OP, **(3 marks)**
   (b) the time taken to travel from P to Q, **(2 marks)**
   (c) the position vector of Q relative to O. **(3 marks)**

   Another boy travels directly from O to Q with constant velocity $(a\mathbf{i} + b\mathbf{j})$ ms^{-1}, leaving O and reaching Q at the same times as the first boy.
   (d) Find the values of the constants a and b. **(4 marks)**

5. Two railway trucks A and B, of masses 10 000 kg and 7 000 kg respectively, are moving towards each other along a horizontal straight track. The trucks collide, and in the collision A exerts an impulse on B of magnitude 84 000 Ns. Immediately after the collision, the trucks move together with speed 10 ms^{-1}. Modelling the trucks as particles,

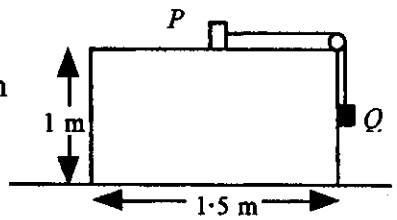
(a) find the speed of each truck immediately before the collision. **(6 marks)**

When the trucks are moving together along the track, the coefficient of friction between them and the track is 0·15. Assuming that no other resisting forces act on the trucks, calculate

(b) the magnitude of the resisting force on the trucks, **(3 marks)**

(c) the time taken after the collision for the trucks to come to rest. **(3 marks)**

6. A small package P, of mass 1 kg, is initially at rest on the rough horizontal top surface of a wooden packing case which is 1·5 m long and 1 m high and stands on a horizontal floor.



The coefficient of friction between P and the case is 0·2.

P is attached by a light inextensible string, which passes over a smooth fixed pulley, to a weight Q of mass M kg which rests against the smooth vertical side of the case.

The system is released from rest with P 0·75 m from the pulley and Q 0·5 m from the pulley. P and Q start to move with acceleration 0·4 ms^{-2}. Calculate

(a) the tension in the string, in N, **(3 marks)**

(b) the value of M, **(3 marks)**

(c) the time taken for Q to hit the floor. **(3 marks)**

Given that Q does not rebound from the floor,

(d) calculate the distance of P from the pulley when it comes to rest. **(6 marks)**

7. A car starts from rest at time $t = 0$ and moves along a straight road with constant acceleration 4 ms^{-2} for 10 seconds. It then travels at a constant speed for 50 seconds before decelerating to rest over a further distance of 240 m.

(a) Sketch a graph of velocity against time for the total period of the car's motion. **(3 marks)**

(b) Find the car's average speed for the whole journey. **(6 marks)**

In reality the car's acceleration a ms^{-2} in the first 10 seconds is not constant, but increases from 0 to 4 ms^{-2} in the first 5 seconds and then decreases to 0 again. A refined model designed to take account of this uses the formula $a = k(mt - t^2)$ for $0 \leq t \leq 10$.

(c) Calculate the values of the constants k and m. **(5 marks)**

(d) Find the acceleration of the car when $t = 2$ according to this model. **(2 marks)**

