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

1. A car accelerates from 0 to 108 km h^{-1} in 7·5 seconds. Find its acceleration in ms^{-2}. **(3 marks)**

2. A book rests on a rough desk-lid which is hinged at one end. When the lid is raised so that it makes an angle of 15° with the horizontal, the book is just on the point of sliding down a line of greatest slope. Modelling the book as a particle, find
   (a) the coefficient of friction between the book and the desk-lid, **(2 marks)**
   (b) the acceleration with which the book starts to move if it is released from rest when the lid is inclined at 20° to the horizontal. **(4 marks)**

3. A particle P is projected vertically upwards from ground level at time $t = 0$ with speed 20 ms^{-1}. Two seconds later another particle Q is projected vertically upwards with speed 30 ms^{-1} from a point on the same horizontal ground.
   (a) Taking the upward direction as positive, write down expressions in terms of g and t for the velocities of P and of Q at time t seconds after P is projected. **(3 marks)**
   (b) Find the value of t when both particles are moving with the same speed. **(4 marks)**

4. A jet of water issues from a cylindrical pipe with a circular cross-section of radius 2·75 cm. The water strikes a vertical wall at a speed of 9 ms^{-1}.
   Taking the density of water to be 1000 kg m^{-3}, calculate
   (a) the momentum destroyed each second by the impact with the wall, **(5 marks)**
   (b) the magnitude of the force exerted by the water on the wall. **(2 marks)**
   (c) State one modelling assumption that you have made. **(1 mark)**

5. Two particles A and B, of mass 1 kg and m kg respectively, where $m > 1$, are attached to the ends of a light inextensible string which passes over a small fixed smooth pulley.
   The particles are released from rest and move with the string taut and vertical.
   (a) Show that the acceleration of the system is equal to $\dfrac{(m-1)g}{m+1}$. **(6 marks)**
   (b) Find the tension in the string, in terms of m and g, expressing your answer as a single algebraic fraction in its simplest form. **(2 marks)**

   When the system is released from rest, both particles are 52·5 cm above ground level and 60 cm below the level of the pulley. B hits the ground after half a second.
   (c) Find the value of m. **(5 marks)**
   (d) Find the speed with which B hits the ground. **(3 marks)**

6. At noon, two boats P and Q have position vectors $(\mathbf{i} + 7\mathbf{j})$ km and $(3\mathbf{i} - 8\mathbf{j})$ km respectively relative to an origin O, where $\mathbf{i}$ and $\mathbf{j}$ are unit vectors in the directions due East and due North respectively. P is moving with constant velocity $(3\mathbf{i} - 4\mathbf{j})$ km h^{-1} and Q is moving with constant velocity $(6\mathbf{i} + 5\mathbf{j})$ km h^{-1}.

(a) Find the position vector of each boat at time t hours after noon, giving your answers in the form $f(t)\mathbf{i} + g(t)\mathbf{j}$, where $f(t)$ and $g(t)$ are linear functions of t to be found. **(6 marks)**

(b) Find, in terms of t, the distance between the boats t hours after noon. **(5 marks)**

(c) Calculate the time when the boats are closest together and find the distance between them at this time. **(6 marks)**

7. A particle starts from rest and accelerates at a uniform rate over a distance of 12 m. It then travels at a constant speed of u ms^{-1} for a further 30 seconds. Finally it decelerates uniformly to rest at $1{\cdot}6$ ms^{-2}.

(a) Sketch the velocity-time graph for this motion. **(2 marks)**

(b) Show that the total time for which the particle is in motion is

$$\frac{5u}{8} + 30 + \frac{24}{u} \text{ seconds.}$$ **(5 marks)**

(c) Find, in terms of u, the total distance travelled by the particle during the motion. **(3 marks)**

(d) Given that the total time for the motion is $39{\cdot}5$ seconds, show that $5u^2 - 76u + 192 = 0$. **(3 marks)**

(e) Find the two possible values of u and the total distance travelled in each case. **(5 marks)**

