1 **In this question take $g = 10$.**

The directions of the unit vectors $\begin{pmatrix}1\\0\\0\end{pmatrix}$, $\begin{pmatrix}0\\1\\0\end{pmatrix}$ and $\begin{pmatrix}0\\0\\1\end{pmatrix}$ are east, north and vertically upwards.

Forces **p**, **q** and **r** are given by $\mathbf{p} = \begin{pmatrix}-1\\-1\\5\end{pmatrix}$ N, $\mathbf{q} = \begin{pmatrix}-1\\-4\\2\end{pmatrix}$ N and $\mathbf{r} = \begin{pmatrix}2\\5\\0\end{pmatrix}$ N.

(i) Find which of **p**, **q** and **r** has the greatest magnitude. **[2]**

(ii) A particle has mass 0.4 kg. The forces acting on it are **p**, **q**, **r** and its weight.

Find the magnitude of the particle's acceleration and describe the direction of this acceleration. **[4]**

2 The directions of the unit vectors **i** and **j** are east and north.

The velocity of a particle, $\mathbf{v}\,\text{m s}^{-1}$, at time t s is given by

$$\mathbf{v} = (16 - t^2)\mathbf{i} + (31 - 8t)\mathbf{j}.$$

Find the time at which the particle is travelling on a bearing of 045° and the speed of the particle at this time. **[6]**

3 A football is kicked with speed 31 m s^{-1} at an angle of 20° to the horizontal. It travels towards the goal which is 50 m away. The height of the crossbar of the goal is 2.44 m.

(i) Does the ball go over the top of the crossbar? Justify your answer. **[6]**

(ii) State one assumption that you made in answering part **(i)**. **[1]**

4 The three forces $\begin{pmatrix} -1 \\ 14 \\ -8 \end{pmatrix}$ N, $\begin{pmatrix} 3 \\ -9 \\ 10 \end{pmatrix}$ N and **F** N act on a body of mass 4 kg in deep space and give it an acceleration of $\begin{pmatrix} -1 \\ 2 \\ 4 \end{pmatrix}$ m s^{-2}.

(i) Calculate **F**. **[4]**

At one instant the velocity of the body is $\begin{pmatrix} -3 \\ 3 \\ 6 \end{pmatrix}$ m s^{-1}.

(ii) Calculate the velocity and also the speed of the body 3 seconds later. **[4]**

5 The position vector of a toy boat of mass 1.5 kg is modelled as $\mathbf{r} = (2 + t)\mathbf{i} + (3t - t^2)\mathbf{j}$ where lengths are in metres, t is the time in seconds, **i** and **j** are horizontal, perpendicular unit vectors and the origin is O.

(i) Find the velocity of the boat when $t = 4$. **[3]**

(ii) Find the acceleration of the boat and the horizontal force acting on the boat. **[3]**

(iii) Find the cartesian equation of the path of the boat referred to x- and y-axes in the directions of **i** and **j**, respectively, with origin O. You are not required to simplify your answer. **[2]**

6 An object of mass 5 kg has a constant acceleration of $\begin{pmatrix} -1 \\ 2 \end{pmatrix}$ m s^{-2} for $0 \leqslant t \leqslant 4$, where t is the time in seconds.

(i) Calculate the force acting on the object. [2]

When $t = 0$, the object has position vector $\begin{pmatrix} -2 \\ 3 \end{pmatrix}$ m and velocity $\begin{pmatrix} 4 \\ 5 \end{pmatrix}$ m s^{-1}.

(ii) Find the position vector of the object when $t = 4$. [3]

7 An object of mass 5 kg has a constant acceleration of $\begin{pmatrix} -1 \\ 2 \end{pmatrix}$ m s^{-2} for $0 \leqslant t \leqslant 4$, where t is the time in seconds.

(i) Calculate the force acting on the object. [2]

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(ii) Find the position vector of the object when $t = 4$. [3]