OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary General Certificate of Education
Advanced General Certificate of Education

MEI STRUCTURED MATHEMATICS 4761

Mechanics 1

Friday **14 JANUARY 2005** Morning 1 hour 30 minutes

Additional materials:
Answer booklet
Graph paper
MEI Examination Formulae and Tables (MF2)

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by g m s^{-2}. Unless otherwise instructed, when a numerical value is needed, use g = 9.8.
- The total number of marks for this paper is 72.

This question paper consists of 5 printed pages and 3 blank pages.

Section A (36 marks)

1 The position vector, $\mathbf{r}$, of a particle of mass 4 kg at time t is given by

$$\mathbf{r} = t^2\mathbf{i} + (5t - 2t^2)\mathbf{j},$$

where $\mathbf{i}$ and $\mathbf{j}$ are the standard unit vectors, lengths are in metres and time is in seconds.

(i) Find an expression for the acceleration of the particle. [4]

The particle is subject to a force $\mathbf{F}$ and a force $12\mathbf{j}$ N.

(ii) Find $\mathbf{F}$. [3]

2 Particles of mass 2 kg and 4 kg are attached to the ends X and Y of a light, inextensible string. The string passes round fixed, smooth pulleys at P, Q and R, as shown in Fig. 2. The system is released from rest with the string taut.

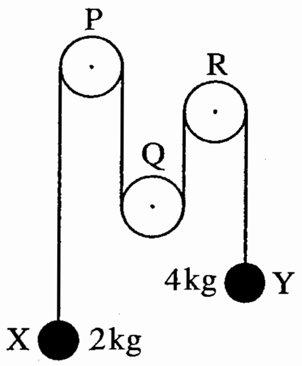

Fig. 2

(i) State what information in the question tells you that

(*A*) the tension is the same throughout the string,

(*B*) the magnitudes of the accelerations of the particles at X and Y are the same. [2]

The tension in the string is T N and the magnitude of the acceleration of the particles is a m s^{-2}.

(ii) Draw a diagram showing the forces acting at X and a diagram showing the forces acting at Y. [1]

(iii) Write down equations of motion for the particles at X and at Y. Hence calculate the values of T and a. [5]

3 A particle is in equilibrium when acted on by the forces $\begin{pmatrix} x \\ -7 \\ z \end{pmatrix}$, $\begin{pmatrix} 4 \\ y \\ -5 \end{pmatrix}$ and $\begin{pmatrix} 5 \\ 4 \\ -7 \end{pmatrix}$, where the units are newtons.

(i) Find the values of x, y and z. [4]

(ii) Calculate the magnitude of $\begin{pmatrix} 5 \\ 4 \\ -7 \end{pmatrix}$. [2]

4 A particle is projected vertically upwards from a point O at $21\,\text{m s}^{-1}$.

(i) Calculate the greatest height reached by the particle. [2]

When this particle is at its highest point, a second particle is projected vertically upwards from O at $15\,\text{m s}^{-1}$.

(ii) Show that the particles collide 1.5 seconds later and determine the height above O at which the collision takes place. [6]

5 A small box B of weight 400 N is held in equilibrium by two light strings AB and BC. The string BC is fixed at C. The end A of string AB is fixed so that AB is at an angle α to the vertical where $\alpha < 60°$. String BC is at 60° to the vertical. This information is shown in Fig. 5.

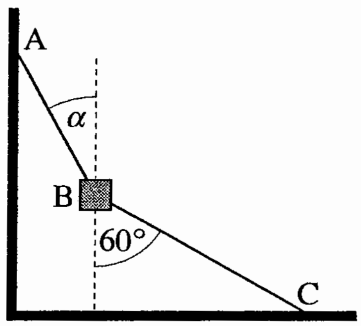

Fig. 5

(i) Draw a labelled diagram showing all the forces acting on the box. [1]

(ii) In one situation string AB is fixed so that $\alpha = 30°$.

By drawing a triangle of forces, or otherwise, calculate the tension in the string BC and the tension in the string AB. [4]

(iii) Show carefully, but briefly, that the box cannot be in equilibrium if $\alpha = 60°$ and BC remains at 60° to the vertical. [2]

[Turn over

7 The trajectory ABCD of a small stone moving with negligible air resistance is shown in Fig. 7. AD is horizontal and BC is parallel to AD.

The stone is projected from A with speed $40\,\text{m}\,\text{s}^{-1}$ at 50° to the horizontal.

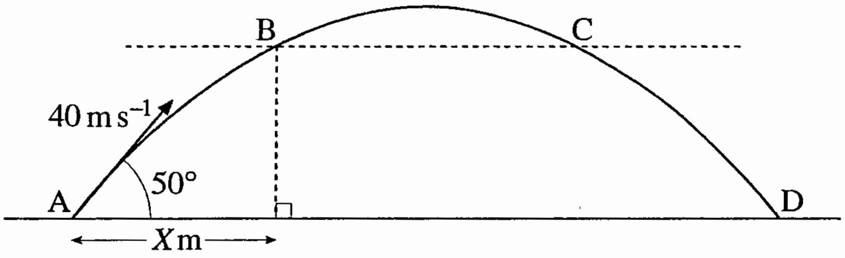

Fig. 7

(i) Write down an expression for the horizontal displacement from A of the stone t seconds after projection. Write down also an expression for the vertical displacement at time t. [3]

(ii) Show that the stone takes 6.253 seconds (to three decimal places) to travel from A to D. Calculate the range of the stone. [5]

You are given that $X = 30$.

(iii) Calculate the time it takes the stone to reach B. Hence determine the time for it to travel from A to C. [4]

(iv) Calculate the direction of the motion of the stone at C. [5]

Section B (36 marks)

6 In this question take g as $10\,\mathrm{m\,s^{-2}}$.

A small ball is released from rest. It falls for 2 seconds and is then brought to rest over the next 5 seconds. This motion is modelled in the speed-time graph Fig. 6.

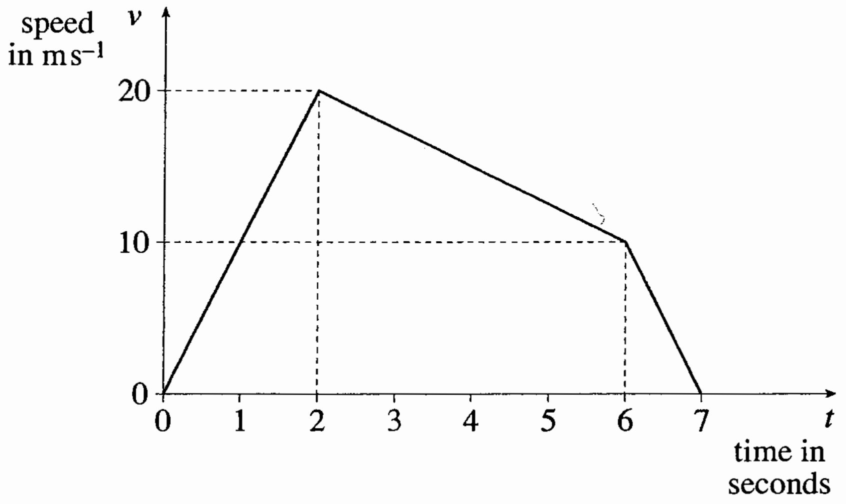

Fig. 6

For this model,

(i) calculate the distance fallen from $t = 0$ to $t = 7$, [3]

(ii) find the acceleration of the ball from $t = 2$ to $t = 6$, specifying the direction, [3]

(iii) obtain an expression in terms of t for the downward speed of the ball from $t = 2$ to $t = 6$, [3]

(iv) state the assumption that has been made about the resistance to motion from $t = 0$ to $t = 2$. [1]

The part of the motion from $t = 2$ to $t = 7$ is now modelled by $v = -\frac{3}{2}t^2 + \frac{19}{2}t + 7$.

(v) Verify that v agrees with the values given in Fig. 6 at $t = 2$, $t = 6$ and $t = 7$. [2]

(vi) Calculate the distance fallen from $t = 2$ to $t = 7$ according to this model. [7]

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

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MEI STRUCTURED MATHEMATICS 4761

Mechanics 1

Tuesday **7 JUNE 2005** Afternoon 1 hour 30 minutes

Additional materials:
Answer booklet
Graph paper
MEI Examination Formulae and Tables (MF2)

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
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- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by g m s^{-2}. Unless otherwise instructed, when a numerical value is needed, use g = 9.8.
- The total number of marks for this paper is 72.

This question paper consists of 5 printed pages and 3 blank pages.

Section A (36 marks)

1 A particle travels along a straight line. Its *acceleration* during the time interval $0 \leqslant t \leqslant 8$ is given by the acceleration–time graph in Fig. 1.

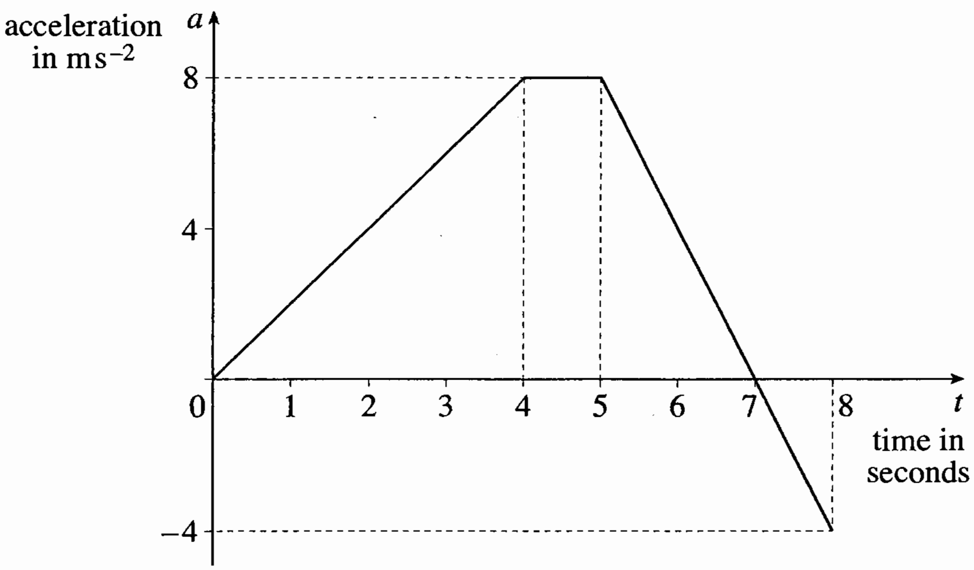

Fig. 1

(i) Write down the acceleration of the particle when $t = 4$. Given that the particle starts from rest, find its speed when $t = 4$. [2]

(ii) Write down an expression in terms of t for the acceleration, $a\,\mathrm{m\,s^{-2}}$, of the particle in the time interval $0 \leqslant t \leqslant 4$. [1]

(iii) Without calculation, state the time at which the *speed* of the particle is greatest. Give a reason for your answer. [2]

(iv) Calculate the change in speed of the particle from $t = 5$ to $t = 8$, indicating whether this is an increase or a decrease. [3]

2 A particle moves along the x-axis with velocity, $v\,\mathrm{m\,s^{-1}}$, at time t given by

$$v = 24t - 6t^2.$$

The positive direction is in the sense of x increasing.

(i) Find an expression for the acceleration of the particle at time t. [2]

(ii) Find the times, t_1 and t_2, at which the particle has zero speed. [2]

(iii) Find the distance travelled between the times t_1 and t_2. [4]

3 A particle rests on a smooth, horizontal plane. Horizontal unit vectors **i** and **j** lie in this plane. The particle is in equilibrium under the action of the three forces $(-3\mathbf{i} + 4\mathbf{j})$ N and $(21\mathbf{i} - 7\mathbf{j})$ N and **R** N.

(i) Write down an expression for **R** in terms of **i** and **j**. [2]

(ii) Find the magnitude of **R** and the angle between **R** and the **i** direction. [4]

4 A block of mass 4 kg is in equilibrium on a rough plane inclined at 60° to the horizontal, as shown in Fig. 4. A frictional force of 10 N acts up the plane and a vertical string AB attached to the block is in tension.

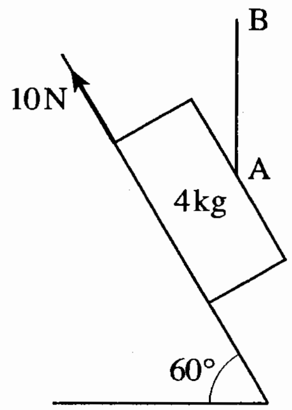

Fig. 4

(i) Draw a diagram showing the four forces acting on the block. [1]

(ii) By considering the components of the forces parallel to the slope, calculate the tension in the string. [3]

(iii) Calculate the normal reaction of the plane on the block. [3]

5 The position vector of a particle at time t is given by

$$\mathbf{r} = \tfrac{1}{2}t\mathbf{i} + (t^2 - 1)\mathbf{j},$$

referred to an origin O where **i** and **j** are the standard unit vectors in the directions of the cartesian axes Ox and Oy respectively.

(i) Write down the value of t for which the x-coordinate of the position of the particle is 2. Find the y-coordinate at this time. [2]

(ii) Show that the cartesian equation of the path of the particle is $y = 4x^2 - 1$. [2]

(iii) Find the coordinates of the point where the particle is moving at 45° to both Ox and Oy. [3]

Section B (36 marks)

6 A car of mass 1000 kg is travelling along a straight, level road.

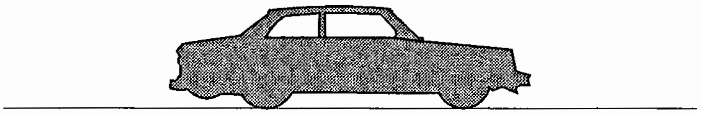

Fig. 6.1

(i) Calculate the acceleration of the car when a resultant force of 2000 N acts on it in the direction of its motion.

How long does it take the car to increase its speed from $5\,\mathrm{m\,s^{-1}}$ to $12.5\,\mathrm{m\,s^{-1}}$? [3]

The car has an acceleration of $1.4\,\mathrm{m\,s^{-2}}$ when there is a driving force of 2000 N.

(ii) Show that the resistance to motion of the car is 600 N. [2]

A trailer is now atached to the car, as shown in Fig. 6.2. The car still has a driving force of 2000 N and resistance to motion of 600 N. The trailer has a mass of 800 kg. The tow-bar connecting the car and the trailer is light and horizontal. The car and trailer are accelerating at $0.7\,\mathrm{m\,s^{-2}}$.

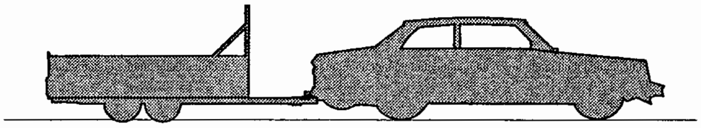

Fig. 6.2

(iii) Show that the resistance to the motion of the trailer is 140 N. [3]

(iv) Calculate the force in the tow-bar. [3]

The driving force is now removed and a braking force of 610 N is applied to the car. All the resistances to motion remain as before. The trailer has no brakes.

(v) Calculate the new acceleration. Calculate also the force in the tow-bar, stating whether it is a tension or a thrust (compression). [6]

7 In this question take the value of g to be $10\,\mathrm{m\,s^{-2}}$.

A particle A is projected over horizontal ground from a point P which is 9 m above a point O on the ground. The initial velocity has horizontal and vertical components of $10\,\mathrm{m\,s^{-1}}$ and $12\,\mathrm{m\,s^{-1}}$ respectively, as shown in Fig. 7. The trajectory of the particle meets the ground at X. Air resistance may be neglected.

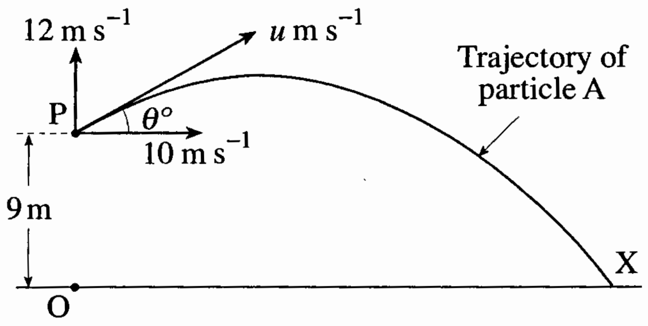

Fig. 7

(i) Calculate the speed of projection $u\,\mathrm{m\,s^{-1}}$ and the angle of projection $\theta°$. [3]

(ii) Show that, t seconds after projection, the height of particle A above the ground is $9 + 12t - 5t^2$. Write down an expression in terms of t for the horizontal distance of the particle from O at this time. [4]

(iii) Calculate the maximum height of particle A above the point of projection. [2]

(iv) Calculate the distance OX. [4]

A second particle, B, is projected from O with speed $20\,\mathrm{m\,s^{-1}}$ at 60° to the horizontal. The trajectories of A and B are in the same vertical plane. Particles A and B are projected at the same time.

(v) Show that the horizontal displacements of A and B are always equal. [2]

(vi) Show that, t seconds after projection, the height of particle B above the ground is $10\sqrt{3}t - 5t^2$. [1]

(vii) Show that the particles collide 1.7 seconds after projection (correct to two significant figures). [3]

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary General Certificate of Education
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MEI STRUCTURED MATHEMATICS 4761

Mechanics 1

Tuesday **10 JANUARY 2006** Afternoon 1 hour 30 minutes

Additional materials:
8 page answer booklet
Graph paper
MEI Examination Formulae and Tables (MF2)

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.

INFORMATION FOR CANDIDATES

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- The total number of marks for this paper is 72.

This question paper consists of 5 printed pages and 3 blank pages.

Section A (36 marks)

1 A particle travels in a straight line during the time interval $0 \leqslant t \leqslant 12$, where t is the time in seconds. Fig. 1 is the velocity-time graph for the motion.

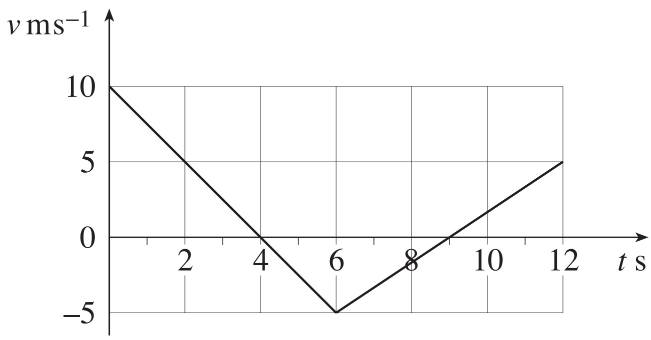

Fig. 1

(i) Calculate the acceleration of the particle in the interval $0 < t < 6$. [2]

(ii) Calculate the distance travelled by the particle from $t = 0$ to $t = 4$. [2]

(iii) When $t = 0$ the particle is at A. Calculate how close the particle gets to A during the interval $4 \leqslant t \leqslant 12$. [2]

2 Fig. 2 shows a light string with an object of mass 4 kg attached at end A. The string passes over a smooth pulley and its other end B is attached to two light strings BC and BD of the same length. The strings BC and BD are attached to horizontal ground and are each inclined at 20° to the vertical.

The system is in equilibrium.

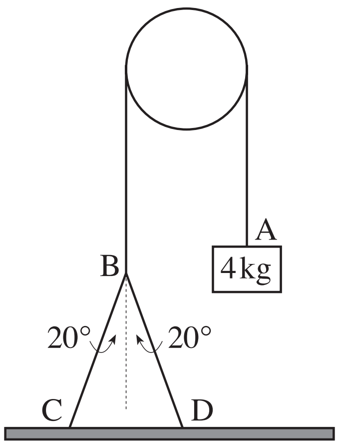

Fig. 2

(i) What information in the question tells you that the tension is the same throughout the string AB? [1]

(ii) What is the tension in the string AB? [1]

(iii) Calculate the tension in the strings BC and BD. [3]

3 A force $\mathbf{F}$ is given by $\mathbf{F} = (3.5\mathbf{i} + 12\mathbf{j})$ N, where $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors east and north respectively.

(i) Calculate the magnitude of $\mathbf{F}$ and also its direction as a bearing. [3]

(ii) $\mathbf{G}$ is the force $(7\mathbf{i} + 24\mathbf{j})$ N. Show that $\mathbf{G}$ and $\mathbf{F}$ are in the same direction and compare their magnitudes. [2]

(iii) Force $\mathbf{F}_1$ is $(9\mathbf{i} - 18\mathbf{j})$ N and force $\mathbf{F}_2$ is $(12\mathbf{i} + q\mathbf{j})$ N. Find q so that the sum $\mathbf{F}_1 + \mathbf{F}_2$ is in the direction of $\mathbf{F}$. [2]

4 A car and its trailer travel along a straight, horizontal road. The coupling between them is light and horizontal. The car has mass 900 kg and resistance to motion 100 N, the trailer has mass 700 kg and resistance to motion 300 N, as shown in Fig. 4. The car and trailer have an acceleration of $1.5\ \mathrm{m\,s^{-2}}$.

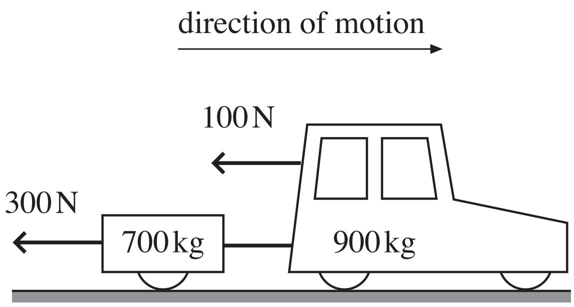

Fig. 4

(i) Calculate the driving force of the car. [3]

(ii) Calculate the force in the coupling. [2]

5 The acceleration of a particle of mass 4 kg is given by $\mathbf{a} = (9\mathbf{i} - 4t\mathbf{j})\ \mathrm{m\,s^{-2}}$, where $\mathbf{i}$ and $\mathbf{j}$ are unit vectors and t is the time in seconds.

(i) Find the acceleration of the particle when $t = 0$ and also when $t = 3$. [1]

(ii) Calculate the force acting on the particle when $t = 3$. [1]

The particle has velocity $(4\mathbf{i} + 2\mathbf{j})\ \mathrm{m\,s^{-1}}$ when $t = 1$.

(iii) Find an expression for the velocity of the particle at time t. [4]

6 A car is driven with constant acceleration, $a \text{ m s}^{-2}$, along a straight road. Its speed when it passes a road sign is $u \text{ m s}^{-1}$. The car travels 14 m in the 2 seconds after passing the sign; 5 seconds after passing the sign it has a speed of 19 m s^{-1}.

(i) Write down two equations connecting a and u. Hence find the values of a and u. [5]

(ii) What distance does the car travel in the 5 seconds after passing the road sign? [2]

Section B (36 marks)

7 Clive and Ken are trying to move a box of mass 50 kg on a rough, horizontal floor. As shown in Fig. 7, Clive always pushes horizontally and Ken always pulls at an angle of 30° to the horizontal. Each of them applies forces to the box in the same vertical plane as described below.

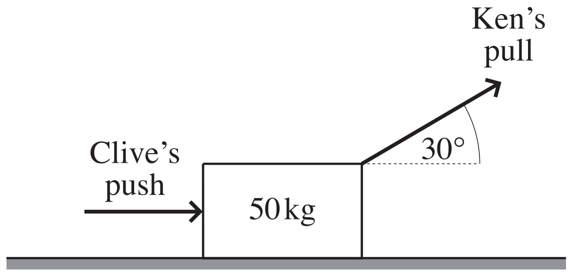

Fig. 7

Initially, the box is in equilibrium with Clive pushing with a force of 60 N and Ken not pulling at all.

(i) What is the resistance to motion of the box? [1]

Ken now adds a pull of 70 N to Clive's push of 60 N. The box remains in equilibrium.

(ii) What now is the resistance to motion of the box? [2]

(iii) Calculate the normal reaction of the floor on the box. [3]

The frictional resistance to sliding of the box is 125 N.

Clive now pushes with a force of 160 N but Ken does not pull at all.

(iv) Calculate the acceleration of the box. [2]

Clive stops pushing when the box has a speed of 1.5 m s^{-1}.

(v) How far does the box then slide before coming to rest? [4]

Ken and Clive now try again. Ken pulls with a force of Q N and Clive pushes with a force of 160 N. The frictional resistance to sliding of the box is now 115 N and the acceleration of the box is 3 m s^{-2}.

(vi) Calculate the value of Q. [4]

8 A girl throws a small stone with initial speed $14\,\mathrm{m\,s^{-1}}$ at an angle of 60° to the horizontal from a point 1 m above the ground. She throws the stone directly towards a vertical wall of height 6 m standing on horizontal ground. The point O is on the ground directly below the point of projection, as shown in Fig. 8. Air resistance is negligible.

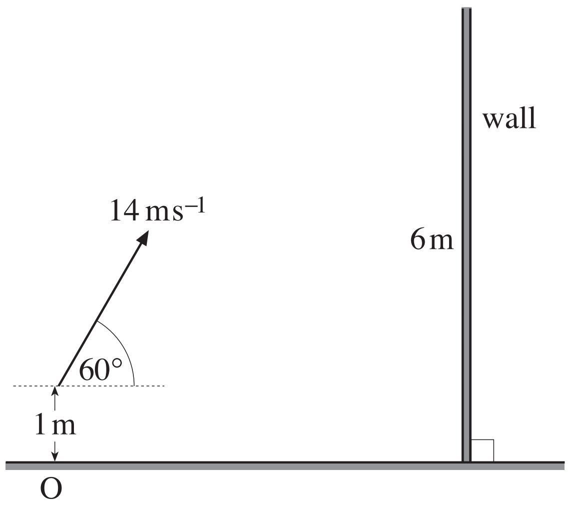

Fig. 8

(i) Write down an expression in terms of t for the horizontal displacement of the stone from O, t seconds after projection. Find also an expression for the height of the stone above O at this time. [5]

The stone is at the top of its trajectory when it passes over the wall.

(ii) (*A*) Find the time it takes for the stone to reach its highest point. [2]

(*B*) Calculate the distance of O from the base of the wall. [2]

(*C*) Show that the stone passes over the wall with 2.5 m clearance. [4]

(iii) Find the cartesian equation of the trajectory of the stone referred to the horizontal and vertical axes, Ox and Oy. There is no need to simplify your answer. [2]

The girl now moves away a further distance d m from the wall. She throws a stone as before and it just passes over the wall.

(iv) Calculate d. [5]

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary General Certificate of Education
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MEI STRUCTURED MATHEMATICS 4761

Mechanics 1

Monday **22 MAY 2006** Morning 1 hour 30 minutes

Additional materials:
8 page answer booklet
Graph paper
MEI Examination Formulae and Tables (MF2)

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
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INFORMATION FOR CANDIDATES

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- The total number of marks for this paper is 72.

This question paper consists of 6 printed pages and 2 blank pages.

Section A (36 marks)

1 A particle is thrown vertically upwards and returns to its point of projection after 6 seconds. Air resistance is negligible.

Calculate the speed of projection of the particle and also the maximum height it reaches. [4]

2 Force $\mathbf{F}_1$ is $\begin{pmatrix} -6 \\ 13 \end{pmatrix}$ N and force $\mathbf{F}_2$ is $\begin{pmatrix} -3 \\ 5 \end{pmatrix}$ N, where $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are vectors east and north respectively.

(i) Calculate the magnitude of $\mathbf{F}_1$, correct to three significant figures. [2]

(ii) Calculate the direction of the force $\mathbf{F}_1 - \mathbf{F}_2$ as a bearing. [3]

Force $\mathbf{F}_2$ is the resultant of all the forces acting on an object of mass 5 kg.

(iii) Calculate the acceleration of the object and the change in its velocity after 10 seconds. [3]

3 A train consists of an engine of mass 10 000 kg pulling one truck of mass 4000 kg. The coupling between the engine and the truck is light and parallel to the track.

The train is accelerating at $0.25\ \mathrm{m\,s^{-2}}$ along a straight, level track.

(i) What is the resultant force on the train in the direction of its motion? [2]

The driving force of the engine is 4000 N.

(ii) What is the resistance to the motion of the train? [1]

(iii) If the tension in the coupling is 1150 N, what is the resistance to the motion of the truck? [2]

With the same overall resistance to motion, the train now climbs a uniform slope inclined at 3° to the horizontal with the same acceleration of $0.25\ \mathrm{m\,s^{-2}}$.

(iv) What extra driving force is being applied? [3]

4 Fig. 4 shows the unit vectors **i** and **j** in the directions of the cartesian axes Ox and Oy, respectively. O is the origin of the axes and of position vectors.

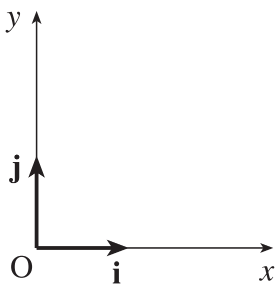

Fig. 4

The position vector of a particle is given by $\mathbf{r} = 3t\mathbf{i} + (18t^2 - 1)\mathbf{j}$ for $t \geqslant 0$, where t is time.

(i) Show that the path of the particle cuts the x-axis just once. [2]

(ii) Find an expression for the velocity of the particle at time t.

Deduce that the particle never travels in the **j** direction. [3]

(iii) Find the cartesian equation of the path of the particle, simplifying your answer. [3]

5 You should neglect air resistance in this question.

A small stone is projected from ground level. The maximum height of the stone above horizontal ground is 22.5 m.

(i) Show that the vertical component of the initial velocity of the stone is 21 m s^{-1}. [2]

The speed of projection is 28 m s^{-1}.

(ii) Find the angle of projection of the stone. [2]

(iii) Find the horizontal range of the stone. [4]

Section B (36 marks)

6 A toy car is travelling in a straight horizontal line.

One model of the motion for $0 \leqslant t \leqslant 8$, where t is the time in seconds, is shown in the velocity–time graph Fig. 6.

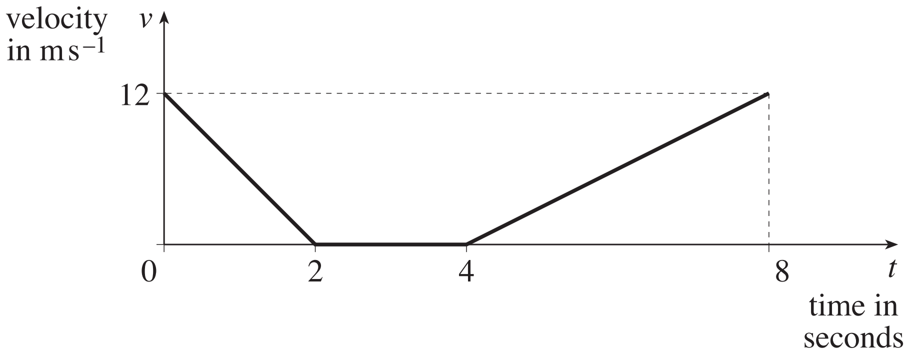

Fig. 6

(i) Calculate the distance travelled by the car from $t = 0$ to $t = 8$. [2]

(ii) How much less time would the car have taken to travel this distance if it had maintained its initial speed throughout? [1]

(iii) What is the acceleration of the car when $t = 1$? [2]

From $t = 8$ to $t = 14$, the car travels 58.5 m with a new constant acceleration, a m s^{-2}.

(iv) Find a. [2]

A second model for the velocity, v m s^{-1}, of the toy car is

$$v = 12 - 10t + \tfrac{9}{4}t^2 - \tfrac{1}{8}t^3, \text{ for } 0 \leqslant t \leqslant 8.$$

This model agrees with the values for v given in Fig. 6 for $t = 0, 2, 4$ and 6. [Note that you are not required to verify this.] Use this second model to answer the following questions.

(v) Calculate the acceleration of the car when $t = 1$. [3]

(vi) Initially the car is at A. Find an expression in terms of t for the displacement of the car from A after the first t seconds of its motion.

Hence find the displacement of the car from A when $t = 8$. [5]

(vii) Explain with a reason what this model predicts for the motion of the car between $t = 2$ and $t = 4$. [3]

[Turn over

7 A box of weight 147 N is held by light strings AB and BC. As shown in Fig. 7.1, AB is inclined at α to the horizontal and is fixed at A; BC is held at C. The box is in equilibrium with BC horizontal and α such that $\sin \alpha = 0.6$ and $\cos \alpha = 0.8$.

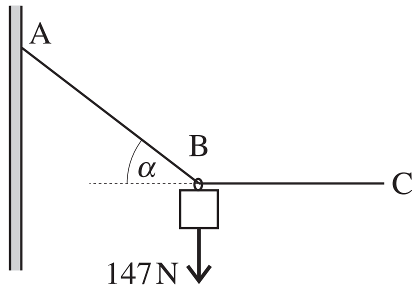

Fig. 7.1

(i) Calculate the tension in string AB. [3]

(ii) Show that the tension in string BC is 196 N. [2]

As shown in Fig. 7.2, a box of weight 90 N is now attached at C and another light string CD is held at D so that the system is in equilibrium with BC still horizontal. CD is inclined at β to the horizontal.

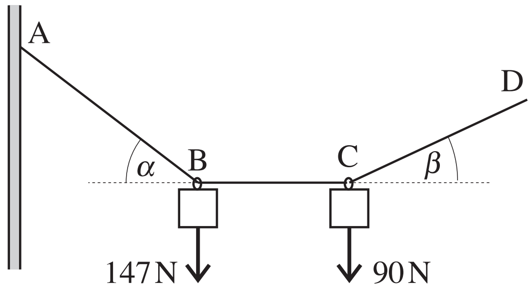

Fig. 7.2

(iii) Explain why the tension in the string BC is still 196 N. [2]

(iv) Draw a diagram showing the forces acting on the box at C.

Find the angle β and show that the tension in CD is 216 N, correct to three significant figures. [7]

The string section CD is now taken over a smooth pulley and attached to a block of mass M kg on a rough slope inclined at 40° to the horizontal. As shown in Fig. 7.3, the part of the string attached to the box is still at β to the horizontal and the part attached to the block is parallel to the slope. The system is in equilibrium with a frictional force of 20 N acting on the block **up** the slope.

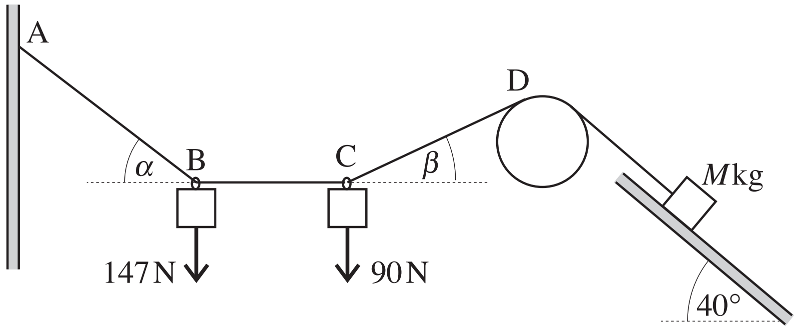

Fig. 7.3

(v) Calculate the value of M. [4]

RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE UNIT **4761/01**

MATHEMATICS (MEI)

Mechanics 1

WEDNESDAY 10 JANUARY 2007

Afternoon
Time: 1 hour 30 minutes

Additional materials:
Answer booklet (8 pages)
Graph paper
MEI Examination Formulae and Tables (MF2)

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
- You are permitted to use a graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by g m s^{-2}. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 72.

ADVICE TO CANDIDATES

- Read each question carefully and make sure you know what you have to do before starting your answer.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.

This document consists of **7** printed pages and **1** blank page.

Section A (36 marks)

1 Fig. 1 is the velocity-time graph for the motion of a body. The velocity of the body is $v\,\text{m}\,\text{s}^{-1}$ at time t seconds.

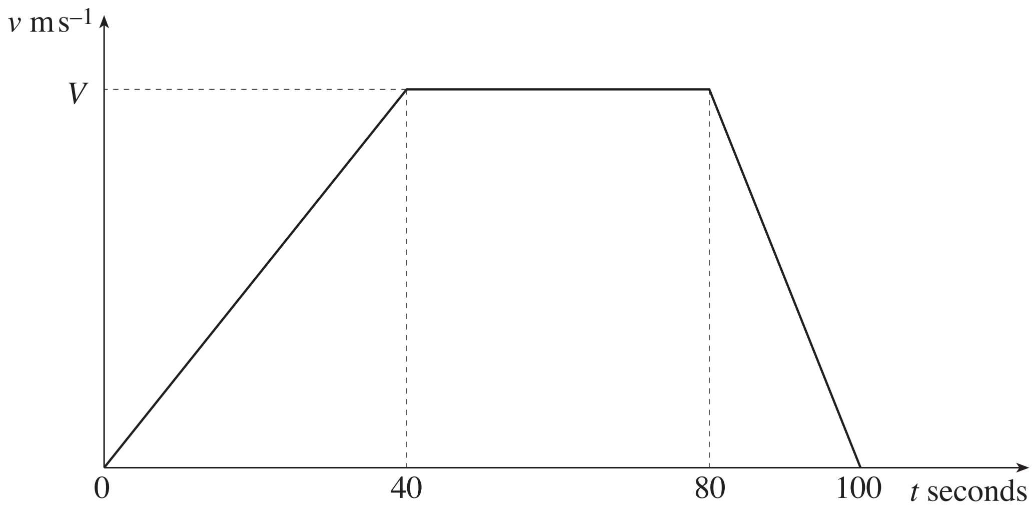

Fig. 1

The displacement of the body from $t = 0$ to $t = 100$ is 1400 m. Find the value of V. [4]

2 A particle moves along a straight line containing a point O. Its displacement, x m, from O at time t seconds is given by

$$x = 12t - t^3, \text{ where } -10 \leqslant t \leqslant 10.$$

Find the values of x for which the velocity of the particle is zero. [5]

3 A box of mass 5 kg is at rest on a rough horizontal floor.

(i) Find the value of the normal reaction of the floor on the box. [1]

The box remains at rest on the floor when a force of 10 N is applied to it at an angle of 40° to the upward vertical, as shown in Fig. 3.

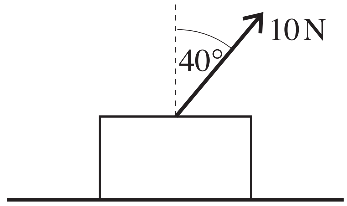

Fig. 3

(ii) Draw a diagram showing all the forces acting on the box. [2]

(iii) Calculate the new value of the normal reaction of the floor on the box and also the frictional force. [4]

4 Fig. 4 shows forces of magnitudes 20 N and 16 N inclined at 60°.

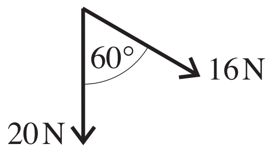

Fig. 4

(i) Calculate the component of the resultant of these two forces in the direction of the 20 N force. [1]

(ii) Calculate the magnitude of the resultant of these two forces. [3]

These are the only forces acting on a particle of mass 2 kg.

(iii) Find the magnitude of the acceleration of the particle and the angle the acceleration makes with the 20 N force. [3]

5 A block of mass 4 kg slides on a horizontal plane against a constant resistance of 14.8 N. A light, inextensible string is attached to the block and, after passing over a smooth pulley, is attached to a freely hanging sphere of mass 2 kg. The part of the string between the block and the pulley is horizontal. This situation is shown in Fig. 5.

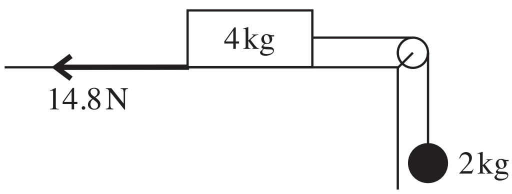

Fig. 5

The tension in the string is T N and the acceleration of the block and of the sphere is a m s^{-2}.

(i) Write down the equation of motion of the block and also the equation of motion of the sphere, each in terms of T and a. [3]

(ii) Find the values of T and a. [3]

6 The velocity of a model boat, $\mathbf{v}$ m s^{-1}, is given by

$$\mathbf{v} = \begin{pmatrix} -5 \\ 10 \end{pmatrix} + t \begin{pmatrix} 6 \\ -8 \end{pmatrix},$$

where t is the time in seconds and the vectors $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are east and north respectively.

(i) Show that when $t = 2.5$ the boat is travelling south-east (i.e. on a bearing of 135°). Calculate its speed at this time. [3]

The boat is at a point O when $t = 0$.

(ii) Calculate the bearing of the boat from O when $t = 2.5$. [4]

Section B (36 marks)

7 A horizontal force of 24 N acts on a block of mass 12 kg on a horizontal plane. The block is initially at rest.

This situation is first modelled assuming the plane is smooth.

(i) Write down the acceleration of the block according to this model. [1]

The situation is now modelled assuming a constant resistance to motion of 15 N.

(ii) Calculate the acceleration of the block according to this new model. How much less distance does the new model predict that the block will travel in the first 4 seconds? [5]

The 24 N force is removed and the block slides *down* a slope at 5° to the horizontal. The speed of the block at the top of the slope is $1.5\,\mathrm{m\,s^{-1}}$, as shown in Fig. 7. The answers to parts **(iii)** and **(iv)** should be found using the assumption that the resistance to the motion of the block is still a constant 15 N.

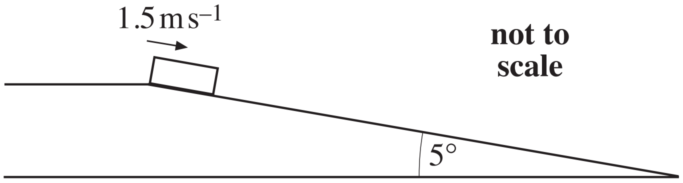

Fig. 7

(iii) Calculate the acceleration of the block in the direction of its motion. [4]

(iv) For how much time does the block slide down the slope before coming to rest and how far does it slide in that time? [4]

Measurements show that the block actually comes to rest in 3.5 seconds.

(v) Assuming that the error in the prediction is due only to the value of the resistance, calculate the true value of the resistance. [4]

[Question 8 is printed overleaf.]

8 In this question the value of g should be taken as $10\,\text{m}\,\text{s}^{-2}$.

As shown in Fig. 8, particles A and B are projected towards one another. Each particle has an initial speed of $10\,\text{m}\,\text{s}^{-1}$ vertically and $20\,\text{m}\,\text{s}^{-1}$ horizontally. Initially A and B are 70 m apart horizontally and B is 15 m higher than A. Both particles are projected over horizontal ground.

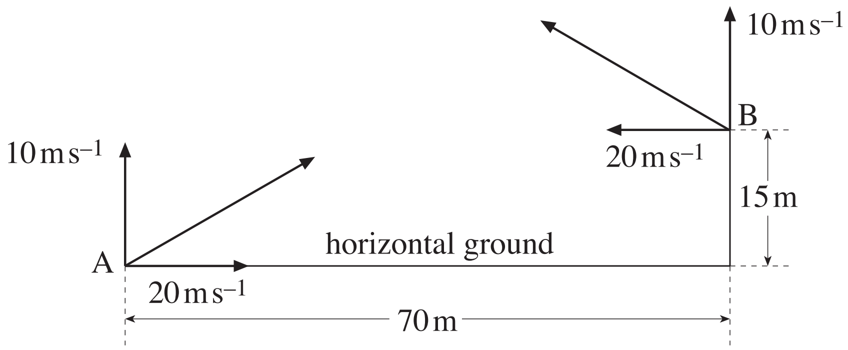

Fig. 8

(i) Show that, t seconds after projection, the height in metres of each particle above its point of projection is $10t - 5t^2$. [1]

(ii) Calculate the horizontal range of A. Deduce that A hits the horizontal ground between the initial positions of A and B. [5]

(iii) Calculate the horizontal distance travelled by B before reaching the ground. [5]

(iv) Show that the paths of the particles cross but that the particles do not collide if they are projected at the same time. [2]

In fact, particle A is projected 2 seconds after particle B.

(v) Verify that the particles collide 0.75 seconds after A is projected. [5]

RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE UNIT **4761/01**

MATHEMATICS (MEI)

Mechanics 1

MONDAY 21 MAY 2007

Morning
Time: 1 hour 30 minutes

Additional materials:
Answer booklet (8 pages)
Graph paper
MEI Examination Formulae and Tables (MF2)

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the spaces provided on the answer booklet.
- Answer **all** the questions.
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- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\ \mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

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- The total number of marks for this paper is 72.

ADVICE TO CANDIDATES

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- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.

This document consists of **7** printed pages and **1** blank page.

[Turn over

Section A (36 marks)

1 Fig. 1 shows four forces in equilibrium.

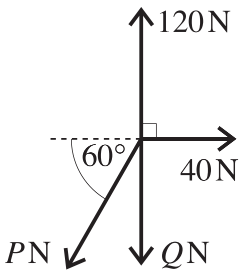

Fig. 1

(i) Find the value of P. [3]

(ii) Hence find the value of Q. [2]

2 A car passes a point A travelling at $10\,\mathrm{m\,s^{-1}}$. Its motion over the next 45 seconds is modelled as follows.

- The car's speed increases uniformly from $10\,\mathrm{m\,s^{-1}}$ to $30\,\mathrm{m\,s^{-1}}$ over the first 10 s.
- Its speed then increases uniformly to $40\,\mathrm{m\,s^{-1}}$ over the next 15 s.
- The car then maintains this speed for a further 20 s at which time it reaches the point B.

(i) Sketch a speed-time graph to represent this motion. [3]

(ii) Calculate the distance from A to B. [3]

(iii) When it reaches the point B, the car is brought uniformly to rest in T seconds. The total distance from A is now 1700 m. Calculate the value of T. [2]

3 Fig. 3 shows a system in equilibrium. The rod is firmly attached to the floor and also to an object, P. The light string is attached to P and passes over a smooth pulley with an object Q hanging freely from its other end.

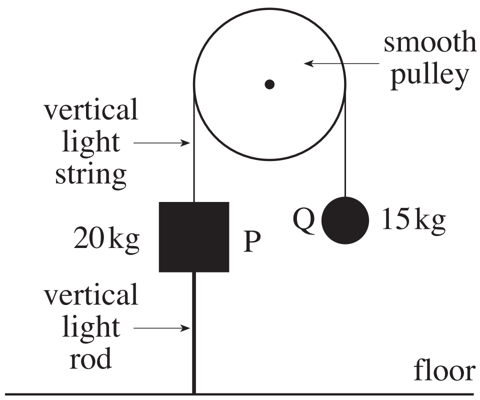

Fig. 3

(i) Why is the tension the same throughout the string? [1]

(ii) Calculate the force in the rod, stating whether it is a tension or a thrust. [3]

4 Two trucks, A and B, each of mass 10 000 kg, are pulled along a straight, horizontal track by a constant, horizontal force of P N. The coupling between the trucks is light and horizontal. This situation and the resistances to motion of the trucks are shown in Fig. 4.

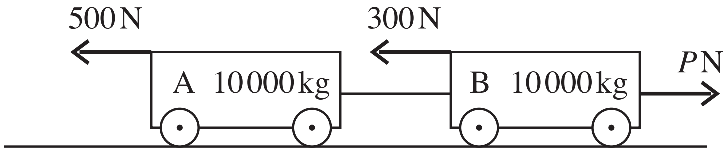

Fig. 4

The acceleration of the system is $0.2\,\text{m}\,\text{s}^{-2}$ in the direction of the pulling force of magnitude P.

(i) Calculate the value of P. [3]

Truck A is now subjected to an extra resistive force of 2000 N while P does not change.

(ii) Calculate the new acceleration of the trucks. [2]

(iii) Calculate the force in the coupling between the trucks. [2]

5 A block of weight 100 N is on a rough plane that is inclined at 35° to the horizontal. The block is in equilibrium with a horizontal force of 40 N acting on it, as shown in Fig. 5.

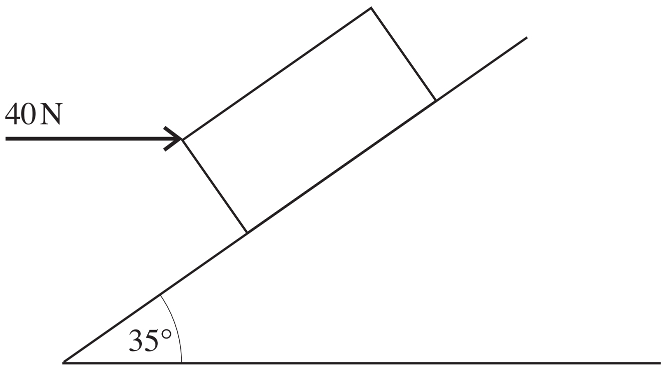

Fig. 5

Calculate the frictional force acting on the block. [4]

6 A rock of mass 8 kg is acted on by just the two forces $-80\mathbf{k}$ N and $(-\mathbf{i} + 16\mathbf{j} + 72\mathbf{k})$ N, where **i** and **j** are perpendicular unit vectors in a horizontal plane and **k** is a unit vector vertically upward.

(i) Show that the acceleration of the rock is $\left(-\frac{1}{8}\mathbf{i} + 2\mathbf{j} - \mathbf{k}\right)\text{m s}^{-2}$. [2]

The rock passes through the origin of position vectors, O, with velocity $(\mathbf{i} - 4\mathbf{j} + 3\mathbf{k})\text{ m s}^{-1}$ and 4 seconds later passes through the point A.

(ii) Find the position vector of A. [3]

(iii) Find the distance OA. [1]

(iv) Find the angle that OA makes with the horizontal. [2]

Section B (36 marks)

7 Fig. 7 is a sketch of part of the velocity-time graph for the motion of an insect walking in a straight line. Its velocity, v m s^{-1}, at time t seconds for the time interval $-3 \leqslant t \leqslant 5$ is given by

$$v = t^2 - 2t - 8.$$

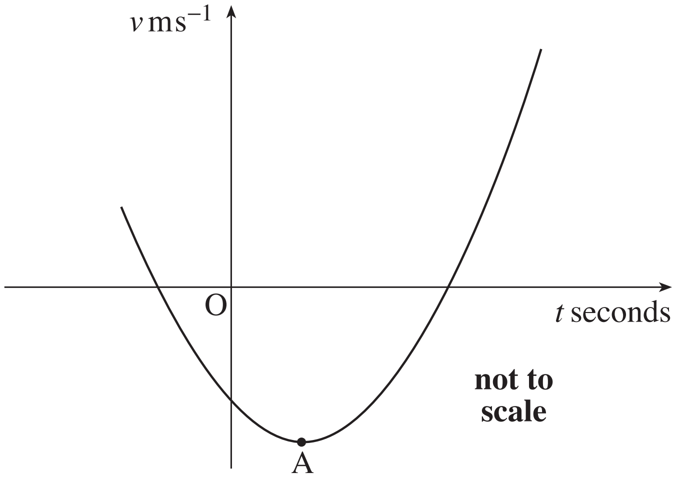

Fig. 7

(i) Write down the velocity of the insect when $t = 0$. [1]

(ii) Show that the insect is instantaneously at rest when $t = -2$ and when $t = 4$. [2]

(iii) Determine the velocity of the insect when its acceleration is zero.

Write down the coordinates of the point A shown in Fig. 7. [5]

(iv) Calculate the distance travelled by the insect from $t = 1$ to $t = 4$. [5]

(v) Write down the distance travelled by the insect in the time interval $-2 \leqslant t \leqslant 4$. [1]

(vi) How far does the insect walk in the time interval $1 \leqslant t \leqslant 5$? [3]

8 A ball is kicked from ground level over horizontal ground. It leaves the ground at a speed of $25\,\mathrm{m\,s^{-1}}$ and at an angle θ to the horizontal such that $\cos\theta = 0.96$ and $\sin\theta = 0.28$.

(i) Show that the height, y m, of the ball above the ground t seconds after projection is given by $y = 7t - 4.9t^2$. Show also that the horizontal distance, x m, travelled by this time is given by $x = 24t$. [3]

(ii) Calculate the maximum height reached by the ball. [2]

(iii) Calculate the times at which the ball is at half its maximum height.

Find the horizontal distance travelled by the ball between these times. [4]

(iv) Determine the following when $t = 1.25$.

(A) The vertical component of the velocity of the ball.

(B) Whether the ball is rising or falling. (You should give a reason for your answer.)

(C) The speed of the ball. [5]

(v) Show that the equation of the trajectory of the ball is

$$y = \frac{0.7x}{576}(240 - 7x).$$

Hence, or otherwise, find the range of the ball. [5]

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE **4761/01**

MATHEMATICS (MEI)

Mechanics 1

THURSDAY 17 JANUARY 2008 Afternoon

Time: 1 hour 30 minutes

Additional materials: Answer Booklet (8 pages)
Graph paper
MEI Examination Formulae and Tables (MF2)

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the spaces provided on the Answer Booklet.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
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- Final answers should be given to a degree of accuracy appropriate to the context.
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INFORMATION FOR CANDIDATES

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- The total number of marks for this paper is 72.
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This document consists of **6** printed pages and **2** blank pages.

Section A (36 marks)

1 A cyclist starts from rest and takes 10 seconds to accelerate at a constant rate up to a speed of $15\,\mathrm{m\,s^{-1}}$. After travelling at this speed for 20 seconds, the cyclist then decelerates to rest at a constant rate over the next 5 seconds.

(i) Sketch a velocity-time graph for the motion. [3]

(ii) Calculate the distance travelled by the cyclist. [3]

2 The force acting on a particle of mass 1.5 kg is given by the vector $\begin{pmatrix} 6 \\ 9 \end{pmatrix}$ N.

(i) Give the acceleration of the particle as a vector. [2]

(ii) Calculate the angle that the acceleration makes with the direction $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$. [2]

(iii) At a certain point of its motion, the particle has a velocity of $\begin{pmatrix} -2 \\ 3 \end{pmatrix}\,\mathrm{m\,s^{-1}}$. Calculate the displacement of the particle over the next two seconds. [3]

3

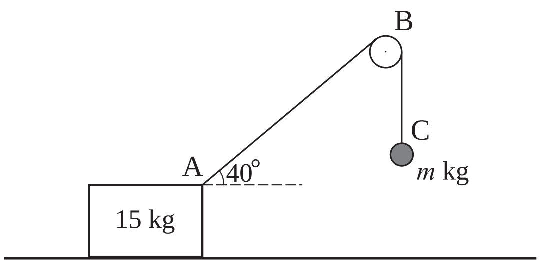

Fig. 3

Fig. 3 shows a block of mass 15 kg on a rough, horizontal plane. A light string is fixed to the block at A, passes over a smooth, fixed pulley B and is attached at C to a sphere. The section of the string between the block and the pulley is inclined at 40° to the horizontal and the section between the pulley and the sphere is vertical.

The system is in equilibrium and the tension in the string is 58.8 N.

(i) The sphere has a mass of m kg. Calculate the value of m. [2]

(ii) Calculate the frictional force acting on the block. [3]

(iii) Calculate the normal reaction of the plane on the block. [3]

4 Force **F** is $\begin{pmatrix} 4 \\ 1 \\ 2 \end{pmatrix}$ N and force **G** is $\begin{pmatrix} -6 \\ 2 \\ 4 \end{pmatrix}$ N.

(i) Find the resultant of **F** and **G** and calculate its magnitude. [4]

(ii) Forces **F**, 2**G** and **H** act on a particle which is in equilibrium. Find **H**. [3]

5

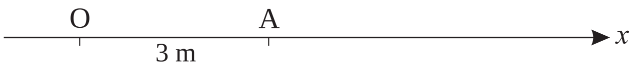

Fig. 5

A toy car is moving along the straight line Ox, where O is the origin. The time t is in seconds. At time $t = 0$ the car is at A, 3 m from O as shown in Fig. 5. The velocity of the car, v m s^{-1}, is given by

$$v = 2 + 12t - 3t^2.$$

Calculate the distance of the car from O when its acceleration is zero. [8]

[Turn over

Section B (36 marks)

6 A helicopter rescue activity at sea is modelled as follows. The helicopter is stationary and a man is suspended from it by means of a vertical, light, inextensible wire that may be raised or lowered, as shown in Fig. 6.1.

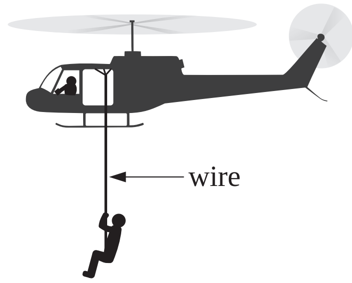

Fig. 6.1

(i) When the man is descending with an acceleration $1.5\,\mathrm{m\,s^{-2}}$ downwards, how much time does it take for his speed to increase from $0.5\,\mathrm{m\,s^{-1}}$ downwards to $3.5\,\mathrm{m\,s^{-1}}$ downwards?

How far does he descend in this time? [4]

The man has a mass of 80 kg. All resistances to motion may be neglected.

(ii) Calculate the tension in the wire when the man is being lowered

(A) with an acceleration of $1.5\,\mathrm{m\,s^{-2}}$ downwards,

(B) with an acceleration of $1.5\,\mathrm{m\,s^{-2}}$ upwards. [5]

Subsequently, the man is raised and this situation is modelled with a constant resistance of 116 N to his upward motion.

(iii) For safety reasons, the tension in the wire should not exceed 2500 N. What is the maximum acceleration allowed when the man is being raised? [4]

At another stage of the rescue, the man has equipment of mass 10 kg at the bottom of a vertical rope which is hanging from his waist, as shown in Fig. 6.2. The man and his equipment are being raised; the rope is light and inextensible and the tension in it is 80 N.

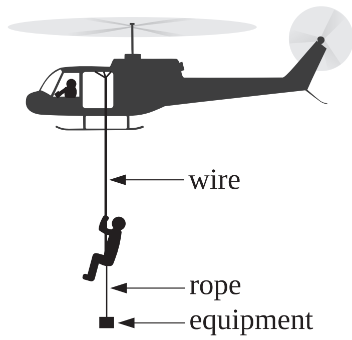

Fig. 6.2

(iv) Assuming that the resistance to the upward motion of the man is still 116 N and that there is negligible resistance to the motion of the equipment, calculate the tension in the wire. [4]

7 A small firework is fired from a point O at ground level over horizontal ground. The highest point reached by the firework is a horizontal distance of 60 m from O and a vertical distance of 40 m from O, as shown in Fig. 7. Air resistance is negligible.

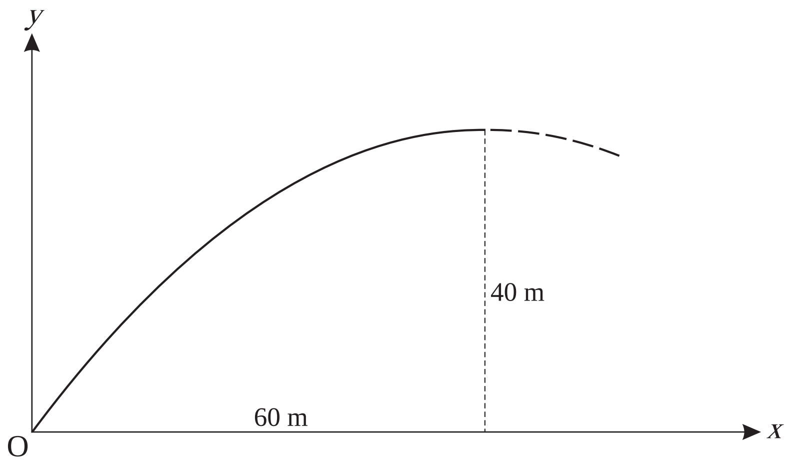

Fig. 7

The initial horizontal component of the velocity of the firework is $21\,\text{m s}^{-1}$.

(i) Calculate the time for the firework to reach its highest point and show that the initial vertical component of its velocity is $28\,\text{m s}^{-1}$. [4]

(ii) Show that the firework is $(28t - 4.9t^2)$ m above the ground t seconds after its projection. [1]

When the firework is at its highest point it explodes into several parts. Two of the parts initially continue to travel horizontally in the original direction, one with the original horizontal speed of $21\,\text{m s}^{-1}$ and the other with a quarter of this speed.

(iii) State why the two parts are always at the same height as one another above the ground and hence find an expression in terms of t for the distance between the parts t seconds after the explosion. [3]

(iv) Find the distance between these parts of the firework

(A) when they reach the ground, [2]

(B) when they are 10 m above the ground. [5]

(v) Show that the cartesian equation of the trajectory of the firework before it explodes is $y = \frac{1}{90}(120x - x^2)$, referred to the coordinate axes shown in Fig. 7. [4]

RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE **4761/01**

MATHEMATICS (MEI)

Mechanics 1

FRIDAY 23 MAY 2008 Morning

Time: 1 hour 30 minutes

Additional materials (enclosed): None

Additional materials (required):
Answer Booklet (8 pages)
Graph paper
MEI Examination Formulae and Tables (MF2)

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the spaces provided on the Answer Booklet.
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- The acceleration due to gravity is denoted by $g\,\text{m}\,\text{s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

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- The total number of marks for this paper is **72**.
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This document consists of **6** printed pages and **2** blank pages.

[Turn over

Section A (36 marks)

1 Fig. 1.1 shows a circular cylinder of mass 100 kg being raised by a light, inextensible vertical wire AB. There is negligible air resistance.

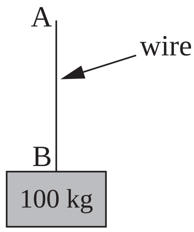

Fig. 1.1

(i) Calculate the acceleration of the cylinder when the tension in the wire is 1000 N. [3]

(ii) Calculate the tension in the wire when the cylinder has an upward acceleration of $0.8\,\mathrm{m\,s^{-2}}$. [2]

The cylinder is now raised inside a fixed smooth vertical tube that prevents horizontal motion but provides negligible resistance to the upward motion of the cylinder. When the wire is inclined at 30° to the vertical, as shown in Fig. 1.2, the cylinder again has an upward acceleration of $0.8\,\mathrm{m\,s^{-2}}$.

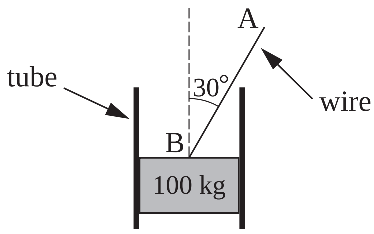

Fig. 1.2

(iii) Calculate the new tension in the wire. [3]

2 A particle has a position vector **r**, where **r** = 4**i** – 5**j** and **i** and **j** are unit vectors in the directions east and north respectively.

(i) Sketch **r** on a diagram showing **i** and **j** and the origin O. [1]

(ii) Calculate the magnitude of **r** and its direction as a bearing. [4]

(iii) Write down the vector that has the same direction as **r** and three times its magnitude. [1]

3 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]

4

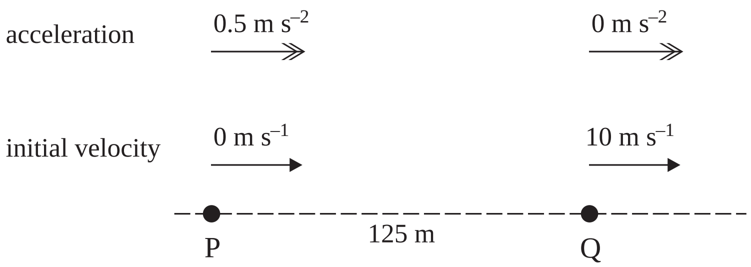

Fig. 4

Particles P and Q move in the same straight line. Particle P starts from rest and has a constant acceleration towards Q of 0.5 m s^{-2}. Particle Q starts 125 m from P at the same time and has a constant speed of 10 m s^{-1} away from P. The initial values are shown in Fig. 4.

(i) Write down expressions for the distances travelled by P and by Q at time t seconds after the start of the motion. [2]

(ii) How much time does it take for P to catch up with Q and how far does P travel in this time? [5]

5 Boxes A and B slide on a smooth, horizontal plane. Box A has a mass of 4 kg and box B a mass of 5 kg. They are connected by a light, inextensible, horizontal wire. Horizontal forces of 9 N and 135 N act on A and B in the directions shown in Fig. 5.

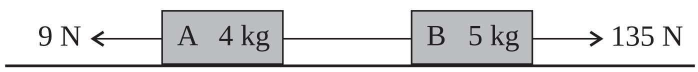

Fig. 5

Calculate the tension in the wire joining the boxes. [4]

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

A golf ball is hit from ground level over horizontal ground. The initial velocity of the ball is 40 m s^{-1} at an angle α to the horizontal, where $\sin\alpha = 0.6$ and $\cos\alpha = 0.8$. Air resistance may be neglected.

(i) Find an expression for the height of the ball above the ground t seconds after projection. [2]

(ii) Calculate the horizontal range of the ball. [4]

Section B (36 marks)

7

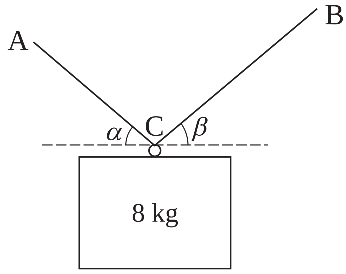

Fig. 7.1

A box of mass 8 kg is supported by a continuous light string ACB that is fixed at A and at B and passes through a smooth ring on the box at C, as shown in Fig. 7.1. The box is in equilibrium and the tension in the string section AC is 60 N.

(i) What information in the question indicates that the tension in the string section CB is also 60 N? [2]

(ii) Show that the string sections AC and CB are equally inclined to the horizontal (so that $\alpha = \beta$ in Fig. 7.1). [2]

(iii) Calculate the angle of the string sections AC and CB to the horizontal. [5]

In a different situation the same box is supported by two separate light strings, PC and QC, that are tied to the box at C. There is also a horizontal force of 10 N acting at C. This force and the angles between these strings and the horizontal are shown in Fig. 7.2. The box is in equilibrium.

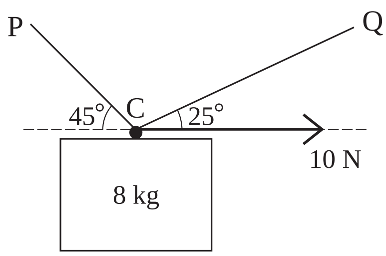

Fig. 7.2

(iv) Calculate the tensions in the two strings. [8]

8 The displacement, x m, from the origin O of a particle on the x-axis is given by

$$x = 10 + 36t + 3t^2 - 2t^3,$$

where t is the time in seconds and $-4 \leqslant t \leqslant 6$.

(i) Write down the displacement of the particle when $t = 0$. [1]

(ii) Find an expression in terms of t for the velocity, $v \text{ m s}^{-1}$, of the particle. [2]

(iii) Find an expression in terms of t for the acceleration of the particle. [2]

(iv) Find the maximum value of v in the interval $-4 \leqslant t \leqslant 6$. [3]

(v) Show that $v = 0$ only when $t = -2$ and when $t = 3$. Find the values of x at these times. [5]

(vi) Calculate the *distance* travelled by the particle from $t = 0$ to $t = 4$. [3]

(vii) Determine how many times the particle passes through O in the interval $-4 \leqslant t \leqslant 6$. [3]

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

MATHEMATICS (MEI) 4761

Mechanics 1

Candidates answer on the Answer Booklet

OCR Supplied Materials:
- 8 page Answer Booklet
- Graph paper
- MEI Examination Formulae and Tables (MF2)

Other Materials Required:
None

Wednesday 21 January 2009
Afternoon

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the spaces provided on the Answer Booklet.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- You are permitted to use a graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\text{ m s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

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Section A (36 marks)

1 A particle is travelling in a straight line. Its velocity $v\,\text{m}\,\text{s}^{-1}$ at time t seconds is given by

$$v = 6 + 4t \quad \text{for } 0 \leqslant t \leqslant 5.$$

(i) Write down the initial velocity of the particle and find the acceleration for $0 \leqslant t \leqslant 5$. **[2]**

(ii) Write down the velocity of the particle when $t = 5$. Find the distance travelled in the first 5 seconds. **[3]**

For $5 \leqslant t \leqslant 15$, the acceleration of the particle is $3\,\text{m}\,\text{s}^{-2}$.

(iii) Find the total distance travelled by the particle during the 15 seconds. **[3]**

2 Fig. 2 shows an acceleration-time graph modelling the motion of a particle.

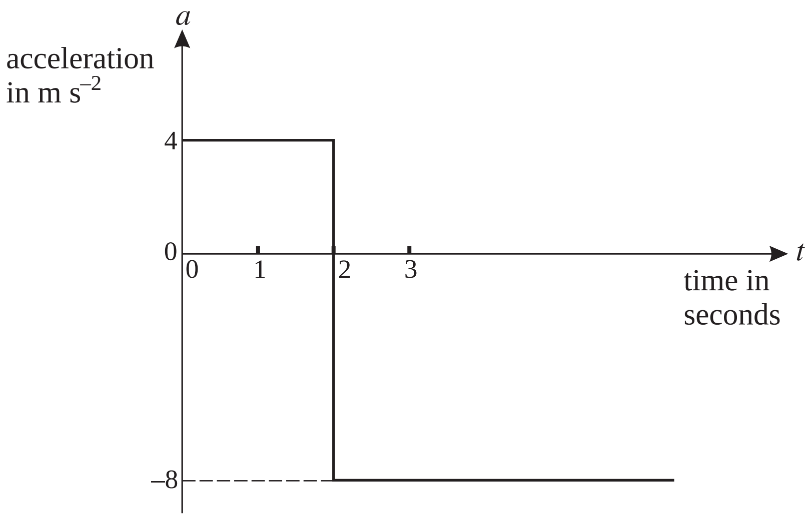

Fig. 2

At $t = 0$ the particle has a velocity of $6\,\text{m}\,\text{s}^{-1}$ in the positive direction.

(i) Find the velocity of the particle when $t = 2$. **[2]**

(ii) At what time is the particle travelling in the negative direction with a speed of $6\,\text{m}\,\text{s}^{-1}$? **[2]**

3 The resultant of the force $\begin{pmatrix} -4 \\ 8 \end{pmatrix}$ N and the force **F** gives an object of mass 6 kg an acceleration of $\begin{pmatrix} 2 \\ 3 \end{pmatrix}$ $\text{m}\,\text{s}^{-2}$.

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

(ii) Calculate the angle between **F** and the vector $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$. **[2]**

4 Sandy is throwing a stone at a plum tree. The stone is thrown from a point O at a speed of 35 m s^{-1} at an angle of α to the horizontal, where $\cos\alpha = 0.96$. You are *given* that, t seconds after being thrown, the stone is $(9.8t - 4.9t^2)$ m higher than O.

When descending, the stone hits a plum which is 3.675 m higher than O. Air resistance should be neglected.

Calculate the horizontal distance of the plum from O. **[6]**

5 A man of mass 75 kg is standing in a lift. He is holding a parcel of mass 5 kg by means of a light inextensible string, as shown in Fig. 5. The tension in the string is 55 N.

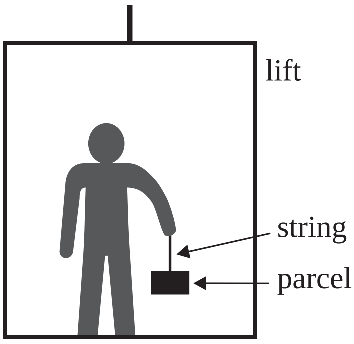

Fig. 5

(i) Find the upward acceleration. **[3]**

(ii) Find the reaction on the man of the lift floor. **[2]**

6 Small stones A and B are initially in the positions shown in Fig. 6 with B a height H m directly above A.

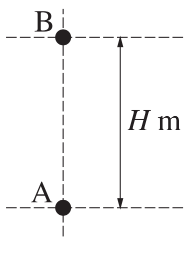

Fig. 6

At the instant when B is released from rest, A is projected vertically upwards with a speed of 29.4 m s^{-1}. Air resistance may be neglected.

The stones collide T seconds after they begin to move. At this instant they have the same speed, $V\text{ m s}^{-1}$, and A is still rising.

By considering when the speed of A upwards is the same as the speed of B downwards, or otherwise, show that $T = 1.5$ and find the values of V and H. **[7]**

Section B (36 marks)

7 An explorer is trying to pull a loaded sledge of total mass 100 kg along horizontal ground using a light rope. The only resistance to motion of the sledge is from friction between it and the ground.

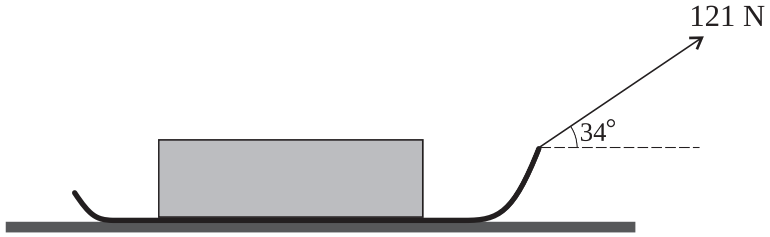

Fig. 7

Initially she pulls with a force of 121 N on the rope inclined at 34° to the horizontal, as shown in Fig. 7, but the sledge does not move.

(i) Draw a diagram showing all the forces acting on the sledge.

Show that the frictional force between the ground and the sledge is 100 N, correct to 3 significant figures.

Calculate the normal reaction of the ground on the sledge. **[7]**

The sledge is given a small push to set it moving at $0.5\,\mathrm{m\,s^{-1}}$. The explorer continues to pull on the rope with the same force and the same angle as before. The frictional force is also unchanged.

(ii) Describe the subsequent motion of the sledge. **[2]**

The explorer now pulls the rope, still at an angle of 34° to the horizontal, so that the tension in it is 155 N. The frictional force is now 95 N.

(iii) Calculate the acceleration of the sledge. **[3]**

In a new situation, there is no rope and the sledge slides down a uniformly rough slope inclined at 26° to the horizontal. The sledge starts from rest and reaches a speed of $5\,\mathrm{m\,s^{-1}}$ in 2 seconds.

(iv) Calculate the frictional force between the slope and the sledge. **[5]**

8 A toy boat moves in a horizontal plane with position vector $\mathbf{r} = x\mathbf{i} + y\mathbf{j}$, where $\mathbf{i}$ and $\mathbf{j}$ are the standard unit vectors east and north respectively. The origin of the position vectors is at O. The displacements x and y are in metres.

First consider only the motion of the boat parallel to the x-axis. For this motion

$$x = 8t - 2t^2.$$

The velocity of the boat in the x-direction is $v_x\,\mathrm{m\,s^{-1}}$.

(i) Find an expression in terms of t for v_x and determine when the boat instantaneously has zero speed in the x-direction. **[3]**

Now consider only the motion of the boat parallel to the y-axis. For this motion

$$v_y = (t-2)(3t-2),$$

where $v_y\,\mathrm{m\,s^{-1}}$ is the velocity of the boat in the y-direction at time t seconds.

(ii) Given that $y = 3$ when $t = 1$, use integration to show that $y = t^3 - 4t^2 + 4t + 2$. **[4]**

The position vector of the boat is given in terms of t by $\mathbf{r} = (8t - 2t^2)\mathbf{i} + (t^3 - 4t^2 + 4t + 2)\mathbf{j}$.

(iii) Find the time(s) when the boat is due north of O and also the distance of the boat from O at any such times. **[4]**

(iv) Find the time(s) when the boat is instantaneously at rest. Find the distance of the boat from O at any such times. **[5]**

(v) Plot a graph of the path of the boat for $0 \leqslant t \leqslant 2$. **[3]**

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ADVANCED SUBSIDIARY GCE

MATHEMATICS (MEI) 4761

Mechanics 1

Candidates answer on the Answer Booklet

OCR Supplied Materials:
- 8 page Answer Booklet
- Graph paper
- MEI Examination Formulae and Tables (MF2)

Other Materials Required:
None

Thursday 11 June 2009
Morning

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

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RP–8K12

Section A (36 marks)

1 The velocity-time graph shown in Fig. 1 represents the straight line motion of a toy car. All the lines on the graph are straight.

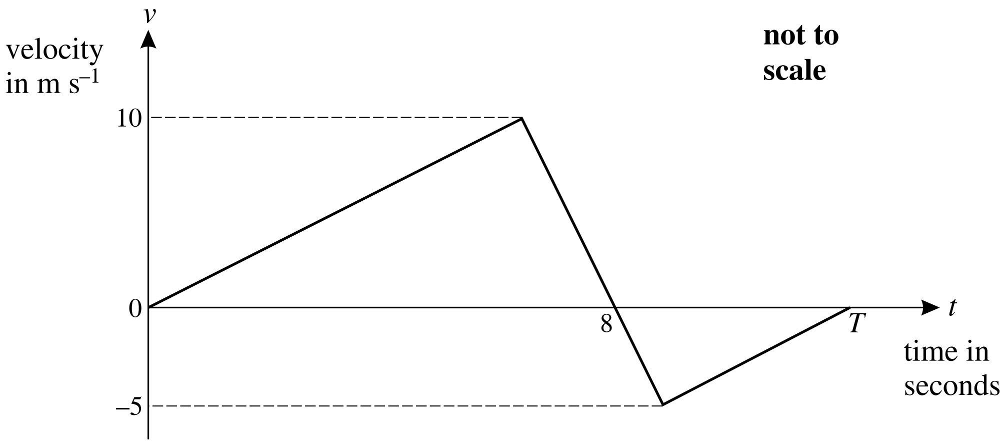

Fig. 1

The car starts at the point A at $t = 0$ and in the next 8 seconds moves to a point B.

(i) Find the distance from A to B. **[2]**

T seconds after leaving A, the car is at a point C which is a distance of 10 m from B.

(ii) Find the value of T. **[3]**

(iii) Find the displacement from A to C. **[1]**

2 A small box has weight **W** N and is held in equilibrium by two strings with tensions $\mathbf{T}_1$ N and $\mathbf{T}_2$ N. This situation is shown in Fig. 2 which also shows the standard unit vectors **i** and **j** that are horizontal and vertically upwards, respectively.

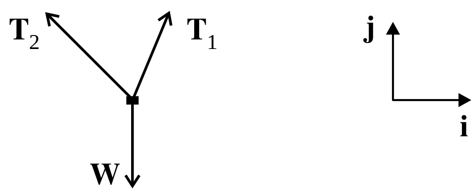

Fig. 2

The tension $\mathbf{T}_1$ is $10\mathbf{i} + 24\mathbf{j}$.

(i) Calculate the magnitude of $\mathbf{T}_1$ and the angle between $\mathbf{T}_1$ and the vertical. **[3]**

The magnitude of the weight is w N.

(ii) Write down the vector **W** in terms of w and **j**. **[1]**

The tension $\mathbf{T}_2$ is $k\mathbf{i} + 10\mathbf{j}$, where k is a scalar.

(iii) Find the values of k and of w. **[3]**

3 Fig. 3 is a sketch of the velocity-time graph modelling the velocity of a sprinter at the start of a race.

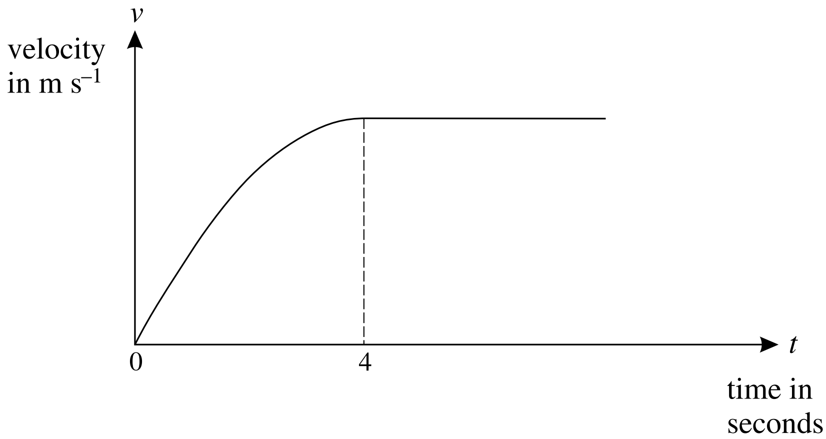

Fig. 3

(i) How can you tell from the sketch that the acceleration is not modelled as being constant for $0 \leqslant t \leqslant 4$? **[1]**

The velocity of the sprinter, v m s^{-1}, for the time interval $0 \leqslant t \leqslant 4$ is modelled by the expression

$$v = 3t - \tfrac{3}{8}t^2.$$

(ii) Find the acceleration that the model predicts for $t = 4$ and comment on what this suggests about the running of the sprinter. **[3]**

(iii) Calculate the distance run by the sprinter from $t = 1$ to $t = 4$. **[4]**

4 Fig. 4 shows a particle projected over horizontal ground from a point O at ground level. The particle initially has a speed of $32\,\text{m s}^{-1}$ at an angle α to the horizontal. The particle is a horizontal distance of 44.8 m from O after 5 seconds. Air resistance should be neglected.

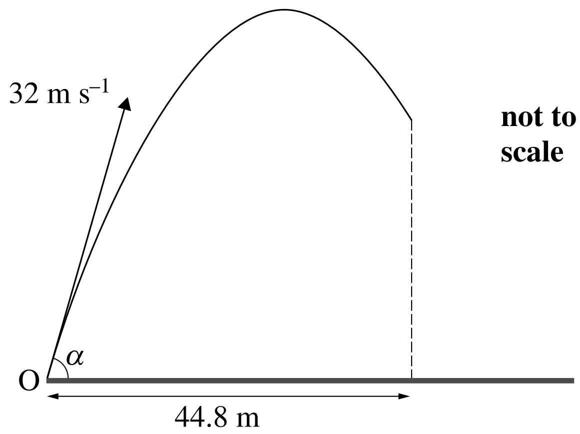

Fig. 4

(i) Write down an expression, in terms of α and t, for the horizontal distance of the particle from O at time t seconds after it is projected. **[1]**

(ii) Show that $\cos\alpha = 0.28$. **[2]**

(iii) Calculate the greatest height reached by the particle. **[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, $\mathbf{i}$ and $\mathbf{j}$ 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 $\mathbf{i}$ and $\mathbf{j}$, respectively, with origin O. You are not required to simplify your answer. **[2]**

Section B (36 marks)

6 An empty open box of mass 4 kg is on a plane that is inclined at 25° to the horizontal.

In one model the plane is taken to be smooth.

The box is held in equilibrium by a string with tension T N parallel to the plane, as shown in Fig. 6.1.

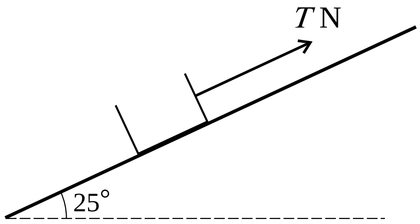

Fig. 6.1

(i) Calculate T. **[2]**

A rock of mass m kg is now put in the box. The system is in equilibrium when the tension in the string, still parallel to the plane, is 50 N.

(ii) Find m. **[3]**

In a refined model the plane is rough.

The empty box, of mass 4 kg, is in equilibrium when a frictional force of 20 N acts down the plane and the string has a tension of P N inclined at 15° to the plane, as shown in Fig. 6.2.

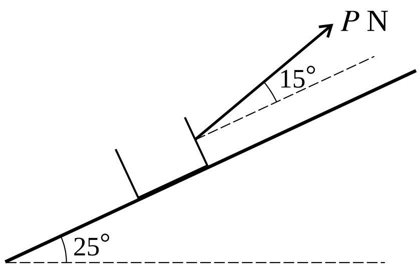

Fig. 6.2

(iii) Draw a diagram showing all the forces acting on the box. **[2]**

(iv) Calculate P. **[5]**

(v) Calculate the normal reaction of the plane on the box. **[4]**

7 A box of mass 8 kg slides on a horizontal table against a constant resistance of 11.2 N.

(i) What horizontal force is applied to the box if it is sliding with acceleration of magnitude $2\,\text{m s}^{-2}$? **[3]**

Fig. 7 shows the box of mass 8 kg on a long, rough, horizontal table. A sphere of mass 6 kg is attached to the box by means of a light inextensible string that passes over a smooth pulley. The section of the string between the pulley and the box is parallel to the table. The constant frictional force of 11.2 N opposes the motion of the box. A force of 105 N parallel to the table acts on the box in the direction shown, and the acceleration of the system is in that direction.

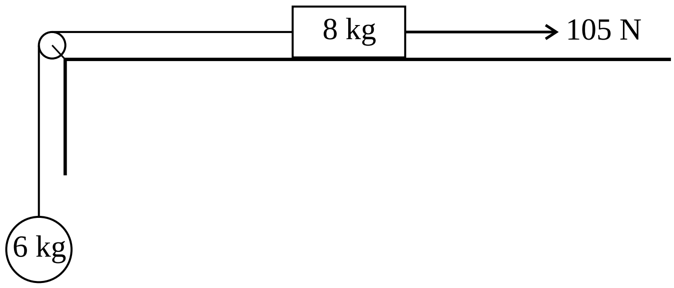

Fig. 7

(ii) What information in the question indicates that while the string is taut the box and sphere have the same acceleration? **[1]**

(iii) Draw two separate diagrams, one showing all the horizontal forces acting on the box and the other showing all the forces acting on the sphere. **[2]**

(iv) Show that the magnitude of the acceleration of the system is $2.5\,\text{m s}^{-2}$ and find the tension in the string. **[7]**

The system is stationary when the sphere is at point P. When the sphere is 1.8 m above P the string breaks, leaving the sphere moving upwards at a speed of $3\,\text{m s}^{-1}$.

(v) (*A*) Write down the value of the acceleration of the sphere after the string breaks. **[1]**

(*B*) The sphere passes through P again at time T seconds after the string breaks. Show that T is the positive root of the equation $4.9T^2 - 3T - 1.8 = 0$. **[2]**

(*C*) Using part (*B*), or otherwise, calculate the total time that elapses after the sphere moves from P before the sphere again passes through P. **[4]**

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
MATHEMATICS (MEI) 4761
Mechanics 1

Candidates answer on the Answer Booklet

OCR Supplied Materials:
- 8 page Answer Booklet
- Graph paper
- MEI Examination Formulae and Tables (MF2)

Other Materials Required:
None

Wednesday 27 January 2010
Afternoon

Duration: 1 hour 30 minutes

* 4 7 6 1 *

INSTRUCTIONS TO CANDIDATES

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Section A (36 marks)

1 A ring is moving up and down a vertical pole. The displacement, s m, of the ring above a mark on the pole is modelled by the displacement-time graph shown in Fig. 1. The three sections of the graph are straight lines.

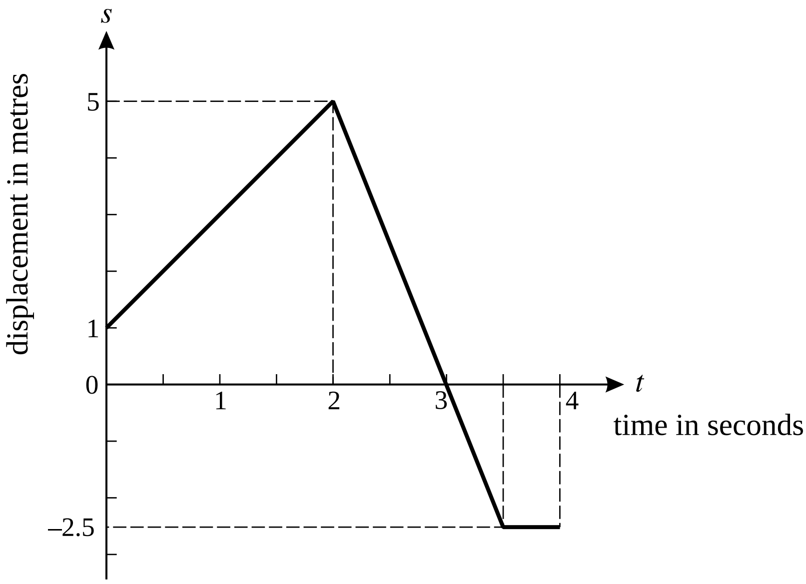

Fig. 1

(i) Calculate the velocity of the ring in the interval $0 < t < 2$ and in the interval $2 < t < 3.5$. **[2]**

(ii) Sketch a velocity-time graph for the motion of the ring during the 4 seconds. **[2]**

(iii) State the direction of motion of the ring when

(A) $t = 1$,

(B) $t = 2.75$,

(C) $t = 3.25$. **[1]**

2 A particle of mass 5 kg has constant acceleration. Initially, the particle is at $\begin{pmatrix} -1 \\ 2 \end{pmatrix}$ m with velocity $\begin{pmatrix} 2 \\ -3 \end{pmatrix}$ m s^{-1}; after 4 seconds the particle has velocity $\begin{pmatrix} 12 \\ 9 \end{pmatrix}$ m s^{-1}.

(i) Calculate the acceleration of the particle. **[2]**

(ii) Calculate the position of the particle at the end of the 4 seconds. **[3]**

(iii) Calculate the force acting on the particle. **[2]**

3 In this question, **i** is a horizontal unit vector and **j** is a unit vector pointing vertically upwards.

A force **F** is $-\mathbf{i} + 5\mathbf{j}$.

(i) Calculate the magnitude of **F**.

Calculate also the angle between **F** and the upward vertical. **[4]**

Force **G** is $2a\mathbf{i} + a\mathbf{j}$ and force **H** is $-2\mathbf{i} + 3b\mathbf{j}$, where a and b are constants. The force **H** is the resultant of forces 4**F** and **G**.

(ii) Find **G** and **H**. **[4]**

4 A box of mass 2.5 kg is on a smooth horizontal table, as shown in Fig. 4. A light string AB is attached to the table at A and the box at B. AB is at an angle of 50° to the vertical. Another light string is attached to the box at C; this string is inclined at 15° above the horizontal and the tension in it is 20 N. The box is in equilibrium.

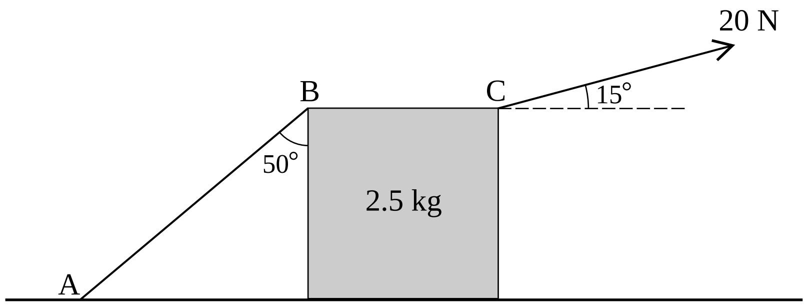

Fig. 4

(i) Calculate the horizontal component of the force exerted on the box by the string at C. **[1]**

(ii) Calculate the tension in the string AB. **[2]**

(iii) Calculate the normal reaction of the table on the box. **[4]**

The string at C is replaced by one inclined at 15° below the horizontal with the same tension of 20 N.

(iv) Explain why this has no effect on the tension in string AB. **[1]**

5 The velocity, $v \text{ m s}^{-1}$, of a particle moving along a straight line is given by

$$v = 3t^2 - 12t + 14,$$

where t is the time in seconds.

(i) Find an expression for the acceleration of the particle at time t. **[2]**

(ii) Find the displacement of the particle from its position when $t = 1$ to its position when $t = 3$. **[4]**

(iii) You are *given* that v is always positive. Explain how this tells you that the distance travelled by the particle between $t = 1$ and $t = 3$ has the same value as the displacement between these times. **[2]**

Section B (36 marks)

6

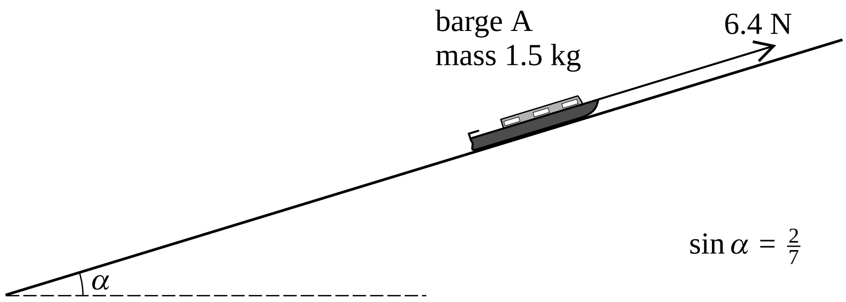

Fig. 6.1

Fig. 6.1 shows a toy barge A of mass 1.5 kg on a rough plane. The plane is at an angle α to the horizontal where $\sin\alpha = \frac{2}{7}$.

(i) Show that the component of the weight of the barge down the slope is 4.2 N. **[2]**

The barge is held in equilibrium by a force of 6.4 N acting up and parallel to the plane.

(ii) Determine the frictional force on the barge and state whether it acts up or down the plane. **[2]**

The force of 6.4 N is removed and the barge now slides down the plane with acceleration $1.2\,\mathrm{m\,s^{-2}}$.

(iii) Calculate the new frictional force on the barge. **[4]**

(iv) Determine how far the barge travels while its speed increases from $0.8\,\mathrm{m\,s^{-1}}$ to $2\,\mathrm{m\,s^{-1}}$. **[3]**

Fig. 6.2 shows barge A on the same slope with a second barge B of mass 2 kg attached to it by means of a light rigid coupling parallel to the plane. The frictional force on barge B is 0.7 N and the frictional force on barge A is now 2.3 N. At one stage of the motion the two barges are being pulled up the plane by a force of 10 N parallel to the plane.

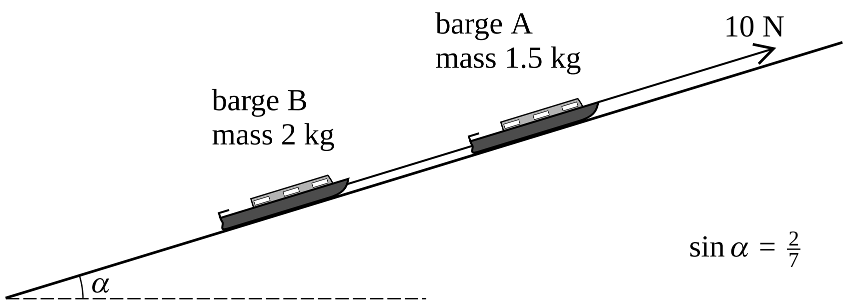

Fig. 6.2

(v) Draw diagrams showing the forces acting on each barge.

Calculate the acceleration of the barges and clearly indicate its direction.

Find the force in the coupling, stating whether this is a tension or a thrust (compression). **[7]**

7

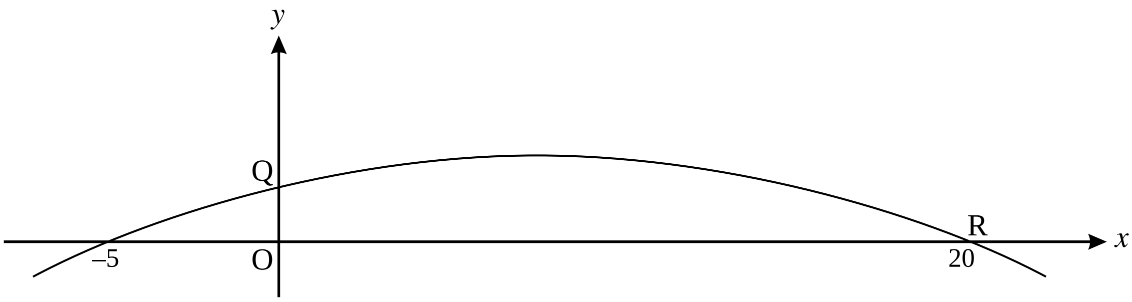

Fig. 7

Fig. 7 shows the graph of $y = \frac{1}{100}(100 + 15x - x^2)$.

For $0 \leqslant x \leqslant 20$, this graph shows the trajectory of a small stone projected from the point Q where y m is the height of the stone above horizontal ground and x m is the horizontal displacement of the stone from O. The stone hits the ground at the point R.

(i) Write down the height of Q above the ground. **[1]**

(ii) Find the horizontal distance from O of the highest point of the trajectory and show that this point is 1.5625 m above the ground. **[5]**

(iii) Show that the time taken for the stone to fall from its highest point to the ground is 0.565 seconds, correct to 3 significant figures. **[3]**

(iv) Show that the horizontal component of the velocity of the stone is $22.1\,\text{m}\,\text{s}^{-1}$, correct to 3 significant figures. Deduce the time of flight from Q to R. **[5]**

(v) Calculate the speed at which the stone hits the ground. **[4]**

RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

MATHEMATICS (MEI) 4761

Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book

OCR Supplied Materials:
- Printed Answer Book 4761
- MEI Examination Formulae and Tables (MF2)

Other Materials Required:
- Scientific or graphical calculator

Tuesday 15 June 2010
Morning

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the spaces provided on the Printed Answer Book.
- **The questions are on the inserted Question Paper.**
- **Write your answer to each question in the space provided in the Printed Answer Book.** Additional paper may be used if necessary but you must clearly show your Candidate Number, Centre Number and question number(s).
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- You are permitted to use a graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

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- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **12** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or destroyed.

Section A (36 marks)

1 An egg falls from rest a distance of 75 cm to the floor.

Neglecting air resistance, at what speed does it hit the floor? **[3]**

2 Fig. 2 shows a sack of rice of weight 250 N hanging in equilibrium supported by a light rope AB. End A of the rope is attached to the sack. The rope passes over a small smooth fixed pulley.

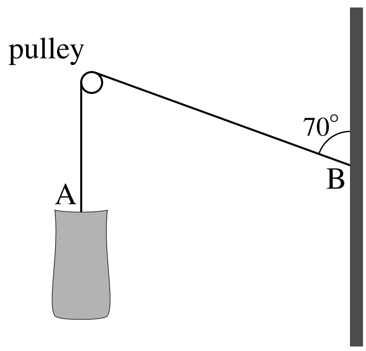

Fig. 2

Initially, end B of the rope is attached to a vertical wall as shown in Fig. 2.

(i) Calculate the horizontal and the vertical forces acting on the wall due to the rope. **[3]**

End B of the rope is now detached from the wall and attached instead to the top of the sack. The sack is in equilibrium with both sections of the rope vertical.

(ii) Calculate the tension in the rope. **[1]**

3 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]**

4 As shown in Fig. 4, boxes P and Q are descending vertically supported by a parachute. Box P has mass 75 kg. Box Q has mass 25 kg and hangs from box P by means of a light vertical wire. Air resistance on the boxes should be neglected.

At one stage the boxes are slowing in their descent with the parachute exerting an upward vertical force of 1030 N on box P. The acceleration of the boxes is $a\ \text{m s}^{-2}$ upwards and the tension in the wire is T N.

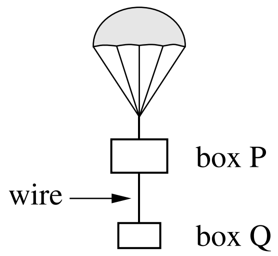

Fig. 4

(i) Draw a labelled diagram showing all the forces acting on box P and another diagram showing all the forces acting on box Q. **[2]**

(ii) Write down separate equations of motion for box P and for box Q. **[3]**

(iii) Calculate the tension in the wire. **[2]**

5 In this question the unit vectors **i** and **j** are pointing east and north respectively.

(i) Calculate the bearing of the vector $-4\mathbf{i} - 6\mathbf{j}$. **[2]**

The vector $-4\mathbf{i} - 6\mathbf{j} + k(3\mathbf{i} - 2\mathbf{j})$ is in the direction $7\mathbf{i} - 9\mathbf{j}$.

(ii) Find k. **[4]**

6 A small ball is kicked off the edge of a jetty over a calm sea. Air resistance is negligible. Fig. 6 shows

- the point of projection, O,
- the initial horizontal and vertical components of velocity,
- the point A on the jetty vertically below O and at sea level,
- the height, OA, of the jetty above the sea.

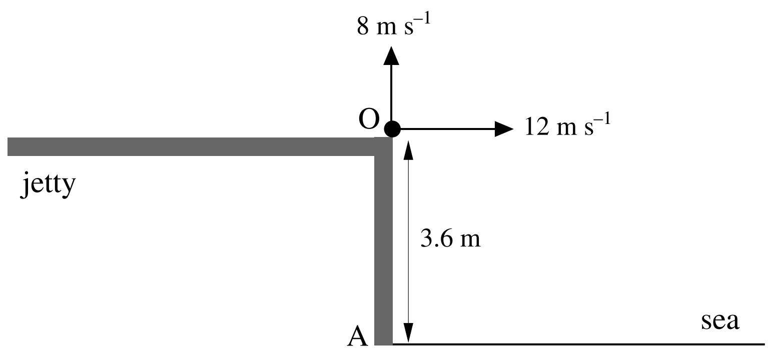

Fig. 6

The time elapsed after the ball is kicked is t seconds.

(i) Find an expression in terms of t for the height of the ball above O at time t. Find also an expression for the horizontal distance of the ball from O at this time. **[3]**

(ii) Determine how far the ball lands from A. **[5]**

Section B (36 marks)

7 A point P on a piece of machinery is moving in a vertical straight line. The displacement of P above ground level at time t seconds is y metres. The displacement-time graph for the motion during the time interval $0 \leqslant t \leqslant 4$ is shown in Fig. 7.

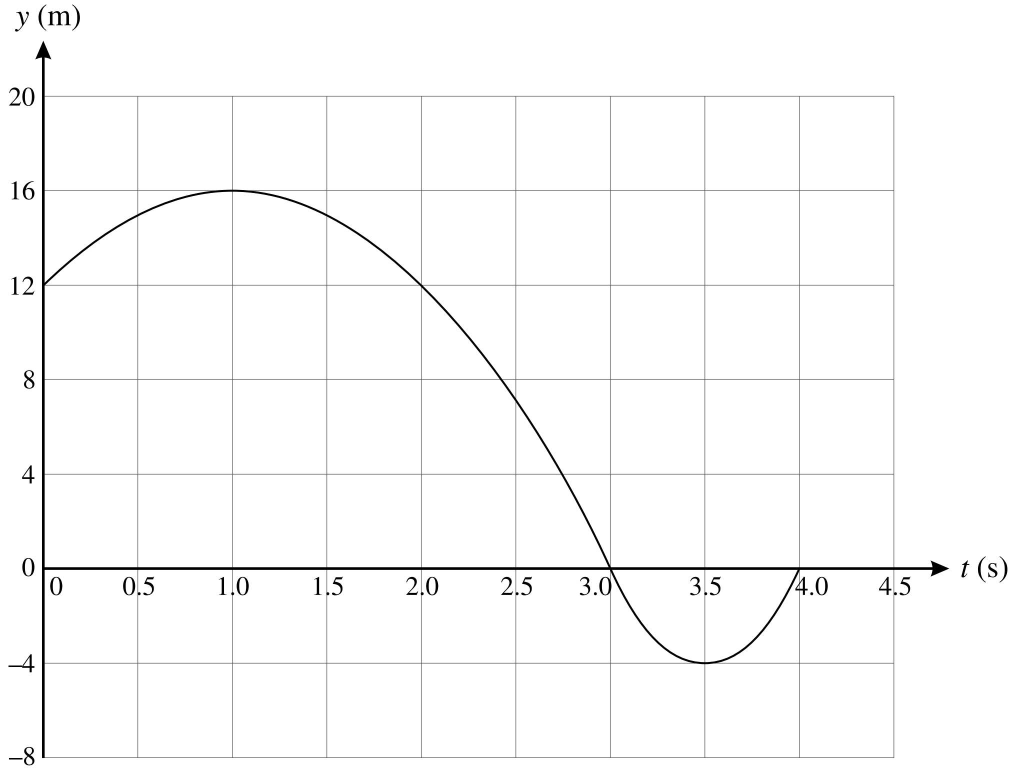

Fig. 7

(i) Using the graph, determine for the time interval $0 \leqslant t \leqslant 4$

(A) the greatest displacement of P above its position when $t = 0$,

(B) the greatest distance of P from its position when $t = 0$,

(C) the time interval in which P is moving downwards,

(D) the times when P is instantaneously at rest. **[6]**

The displacement of P in the time interval $0 \leqslant t \leqslant 3$ is given by $y = -4t^2 + 8t + 12$.

(ii) Use calculus to find expressions in terms of t for the velocity and for the acceleration of P in the interval $0 \leqslant t \leqslant 3$. **[3]**

(iii) At what times does P have a speed of $4\ \text{m s}^{-1}$ in the interval $0 \leqslant t \leqslant 3$? **[2]**

In the time interval $3 \leqslant t \leqslant 4$, P has a constant acceleration of $32\ \text{m s}^{-2}$. There is no sudden change in velocity when $t = 3$.

(iv) Find an expression in terms of t for the displacement of P in the interval $3 \leqslant t \leqslant 4$. **[5]**

8 A cylindrical tub of mass 250 kg is on a horizontal floor. Resistance to its motion other than that due to friction is negligible.

The first attempt to move the tub is by pulling it with a force of 150 N in the **i** direction, as shown in Fig. 8.1.

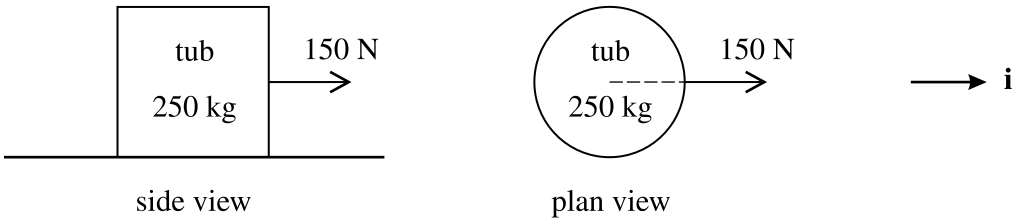

Fig. 8.1

(i) Calculate the acceleration of the tub if friction is ignored. **[2]**

In fact, there is friction and the tub does not move.

(ii) Write down the magnitude and direction of the frictional force opposing the pull. **[2]**

Two more forces are now added to the 150 N force in a second attempt to move the tub, as shown in Fig. 8.2.

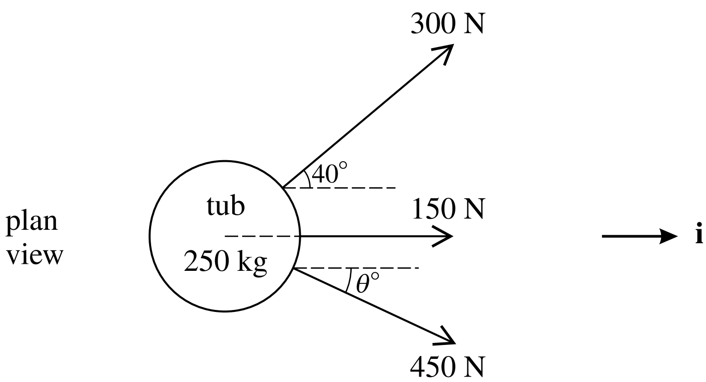

Fig. 8.2

Angle θ is acute and chosen so that the resultant of the three forces is in the **i** direction.

(iii) Determine the value of θ and the resultant of the three forces. **[6]**

With this resultant force, the tub moves with constant acceleration and travels 1 metre from rest in 2 seconds.

(iv) Show that the magnitude of the friction acting on the tub is 661 N, correct to 3 significant figures. **[5]**

When the speed of the tub is $1.8\ \mathrm{m\,s^{-1}}$, it comes to a part of the floor where the friction on the tub is 200 N greater. The pulling forces stay the same.

(v) Find the velocity of the tub when it has moved a further 1.65 m. **[5]**

4 (i)	box P box Q
4 (ii)	
4 (iii)	

ADVANCED SUBSIDIARY GCE

MATHEMATICS (MEI) 4761

Mechanics 1

QUESTION PAPER

Candidates answer on the printed answer book.

OCR supplied materials:
- Printed answer book 4761
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Wednesday 26 January 2011
Afternoon

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the printed answer book and the question paper.

- The question paper will be found in the centre of the printed answer book.
- Write your name, centre number and candidate number in the spaces provided on the printed answer book. Please write clearly and in capital letters.
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INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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Section A (36 marks)

1 An object C is moving along a vertical straight line. Fig. 1 shows the velocity-time graph for part of its motion. Initially C is moving upwards at $14\,\text{m}\,\text{s}^{-1}$ and after 10 s it is moving downwards at $6\,\text{m}\,\text{s}^{-1}$.

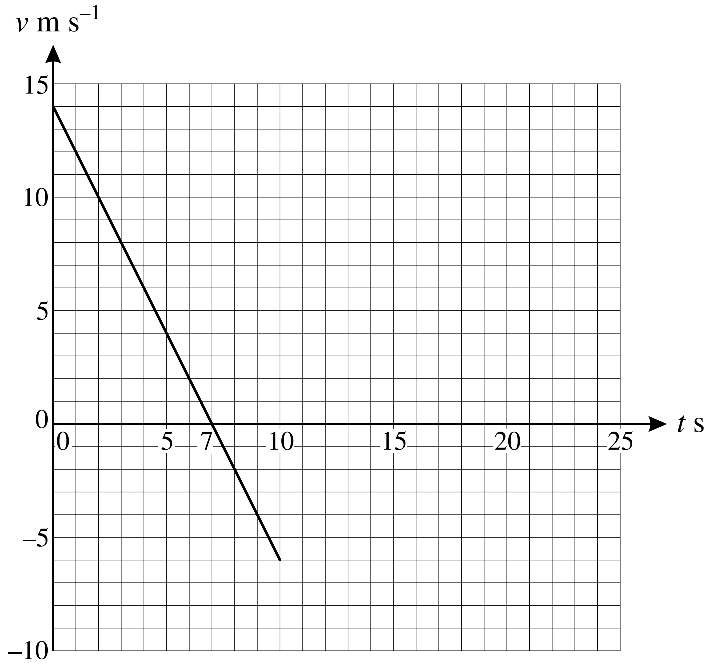

Fig. 1

C then moves as follows.

- In the interval $10 \leqslant t \leqslant 15$, the velocity of C is constant at $6\,\text{m}\,\text{s}^{-1}$ downwards.
- In the interval $15 \leqslant t \leqslant 20$, the velocity of C increases uniformly so that C has zero velocity at $t = 20$.

(i) Complete the velocity-time graph for the motion of C in the time interval $0 \leqslant t \leqslant 20$. **[2]**

(ii) Calculate the acceleration of C in the time interval $0 < t < 10$. **[2]**

(iii) Calculate the displacement of C from $t = 0$ to $t = 20$. **[4]**

2 Fig. 2 shows two forces acting at A. The figure also shows the perpendicular unit vectors **i** and **j** which are respectively horizontal and vertically upwards.

The resultant of the two forces is **F** N.

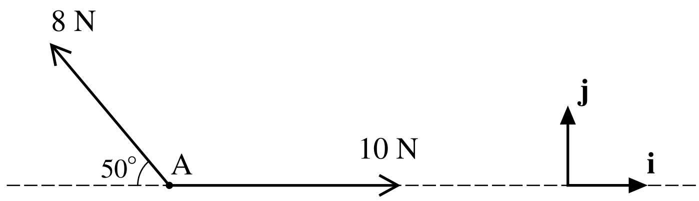

Fig. 2

(i) Find **F** in terms of **i** and **j**, giving your answer correct to three significant figures. **[3]**

(ii) Calculate the magnitude of **F** and the angle that **F** makes with the upward vertical. **[3]**

3 Two cars, P and Q, are being crashed as part of a film 'stunt'.

At the start

- P is travelling directly towards Q with a speed of $8\,\text{m s}^{-1}$,
- Q is instantaneously at rest and has an acceleration of $4\,\text{m s}^{-2}$ directly towards P.

P continues with the same velocity and Q continues with the same acceleration. The cars collide T seconds after the start.

(i) Find expressions in terms of T for how far each of the cars has travelled since the start. **[2]**

At the start, P is 90 m from Q.

(ii) Show that $T^2 + 4T - 45 = 0$ and hence find T. **[5]**

4 At time t seconds, a particle has position with respect to an origin O given by the vector

$$\mathbf{r} = \begin{pmatrix} 8t \\ 10t^2 - 2t^3 \end{pmatrix},$$

where $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are perpendicular unit vectors east and north respectively and distances are in metres.

(i) When $t = 1$, the particle is at P. Find the bearing of P from O. **[2]**

(ii) Find the velocity of the particle at time t and show that it is never zero. **[3]**

(iii) Determine the time(s), if any, when the acceleration of the particle is zero. **[3]**

5 Fig. 5 shows two boxes, A of mass 12 kg and B of mass 6 kg, sliding in a straight line on a rough horizontal plane. The boxes are connected by a light rigid rod which is parallel to the line of motion. The only forces acting on the boxes in the line of motion are those due to the rod and a constant force of F N on each box.

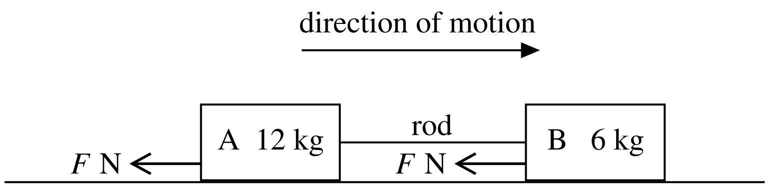

Fig. 5

The boxes have an initial speed of 1.5 m s^{-1} and come to rest after sliding a distance of 0.375 m.

(i) Calculate the deceleration of the boxes and the value of F. **[4]**

(ii) Calculate the magnitude of the force in the rod and state, with a reason, whether it is a tension or a thrust (compression). **[3]**

Section B (36 marks)

6 A toy sledge of mass 4 kg is being pulled in a straight line by a light string. The resistance to its motion is 6 N.

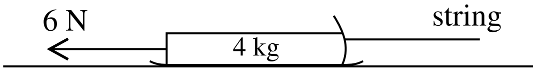

Fig. 6.1

At one time, the string is horizontal and the sledge is on horizontal ground, as shown in Fig. 6.1. The acceleration of the sledge is $3\,\text{m}\,\text{s}^{-2}$ forwards.

(i) Calculate the tension in the string. **[3]**

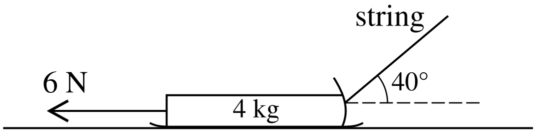

Fig. 6.2

At another time, the sledge is again on horizontal ground but the string is now at 40° to the horizontal, as shown in Fig. 6.2. The tension in the string is 25 N.

(ii) Calculate the acceleration of the sledge. **[3]**

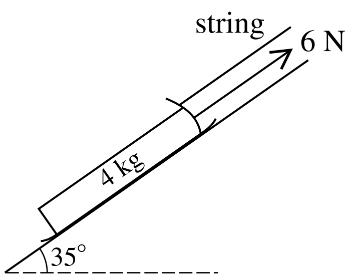

Fig. 6.3

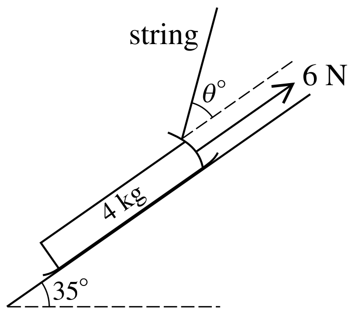

Fig. 6.4

In another situation the sledge is on a slope inclined at 35° to the horizontal, as shown in Fig. 6.3. It is held in equilibrium by the light string parallel to the slope. The resistance to motion of 6 N acts up the slope.

(iii) Calculate the tension in the string. **[3]**

The sledge is now held in equilibrium with the light string inclined at $\theta°$ to the slope, as shown in Fig. 6.4. The tension in the string is 25 N and the resistance to motion remains 6 N acting up the slope.

(iv) (*A*) Show all the forces acting on the sledge. **[2]**

(*B*) Calculate the angle θ. **[3]**

(*C*) Calculate the normal reaction of the slope on the sledge. **[3]**

7

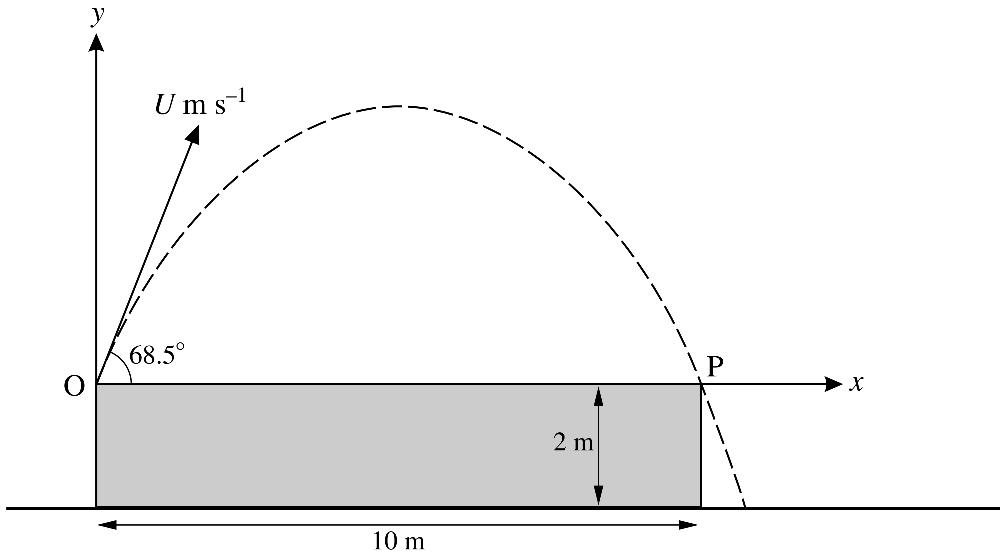

Fig. 7

Fig. 7 shows a platform 10 m long and 2 m high standing on horizontal ground. A small ball projected from the surface of the platform at one end, O, just misses the other end, P. The ball is projected at 68.5° to the horizontal with a speed of $U\,\mathrm{m\,s^{-1}}$. Air resistance may be neglected.

At time t seconds after projection, the horizontal and vertical displacements of the ball from O are x m and y m.

(i) Obtain expressions, in terms of U and t, for

(A) x,

(B) y. **[3]**

(ii) The ball takes T s to travel from O to P.

Show that $T = \dfrac{U \sin 68.5°}{4.9}$ and write down a second equation connecting U and T. **[4]**

(iii) Hence show that $U = 12.0$ (correct to three significant figures). **[3]**

(iv) Calculate the horizontal distance of the ball from the platform when the ball lands on the ground. **[5]**

(v) Use the expressions you found in part **(i)** to show that the cartesian equation of the trajectory of the ball in terms of U is

$$y = x \tan 68.5° - \frac{4.9x^2}{U^2(\cos 68.5°)^2}.$$

Use this equation to show again that $U = 12.0$ (correct to three significant figures). **[4]**

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ADVANCED SUBSIDIARY GCE

MATHEMATICS (MEI) 4761

Mechanics 1

QUESTION PAPER

Candidates answer on the printed answer book.

OCR supplied materials:
- Printed answer book 4761
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Thursday 16 June 2011
Afternoon

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the printed answer book and the question paper.

- The question paper will be found in the centre of the printed answer book.
- Write your name, centre number and candidate number in the spaces provided on the printed answer book. Please write clearly and in capital letters.
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- Answer **all** the questions.
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INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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Section A (36 marks)

1 A pellet is fired vertically upwards at a speed of $11\,\mathrm{m\,s^{-1}}$. Assuming that air resistance may be neglected, calculate the speed at which the pellet hits a ceiling 2.4 m above its point of projection. **[3]**

2 A particle travels with constant acceleration along a straight line. A and B are points on this line 8 m apart.

The motion of the particle is as follows.

- Initially it is at A.
- After 32 s it is at B.
- When it is at B its speed is $2.25\,\mathrm{m\,s^{-1}}$ and it is moving away from A.

In either order, calculate the acceleration and the initial velocity of the particle, making the directions clear. **[5]**

3 Force **F** is $\begin{pmatrix} -2 \\ 3 \\ -4 \end{pmatrix}$ N, force **G** is $\begin{pmatrix} -6 \\ y \\ z \end{pmatrix}$ N and force **H** is $\begin{pmatrix} 3 \\ -5 \\ -1 \end{pmatrix}$ N.

(i) Given that **F** and **G** act in parallel lines, find y and z. **[2]**

Forces **F** and **H** are the only forces acting on an object of mass 5 kg.

(ii) Calculate the acceleration of the object. Calculate also the magnitude of this acceleration. **[5]**

4 Fig. 4 shows a block of mass 15 kg on a smooth plane inclined at 20° to the horizontal. The block is held in equilibrium by a horizontal force of magnitude P N.

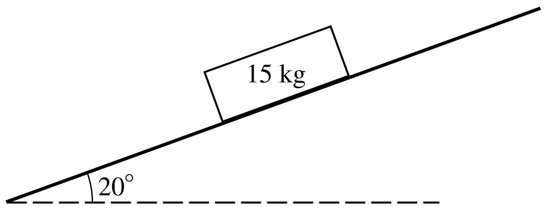

Fig. 4

(i) Show all the forces acting on the block. **[2]**

(ii) Calculate P. **[3]**

5 A small object is projected over horizontal ground from a point O at ground level and makes a loud noise on landing. It has an initial speed of $30\,\mathrm{m\,s^{-1}}$ at 35° to the horizontal.

Assuming that air resistance on the object may be neglected and that the speed of sound in air is $343\,\mathrm{m\,s^{-1}}$, calculate how long after projection the noise is heard at O. **[8]**

6 In this question, $\mathbf{i}$ and $\mathbf{j}$ are unit vectors east and north respectively. Position vectors are with respect to an origin O. Time t is in seconds.

A skater has a constant acceleration of $-2\mathbf{j}\,\text{m}\,\text{s}^{-2}$. At $t = 0$, his velocity is $4\mathbf{i}\,\text{m}\,\text{s}^{-1}$ and his position vector is $3\mathbf{j}$ m.

(i) Find expressions in terms of t for the velocity and the position vector of the skater at time t. **[5]**

(ii) Calculate as a bearing the direction of motion of the skater when $t = 2.5$. **[3]**

Section B (36 marks)

7 A ring is moving on a straight wire. Its velocity is $v\,\mathrm{m\,s^{-1}}$ at time t seconds after passing a point Q.

Model A for the motion of the ring gives the velocity-time graph for $0 \leqslant t \leqslant 6$ shown in Fig. 7.

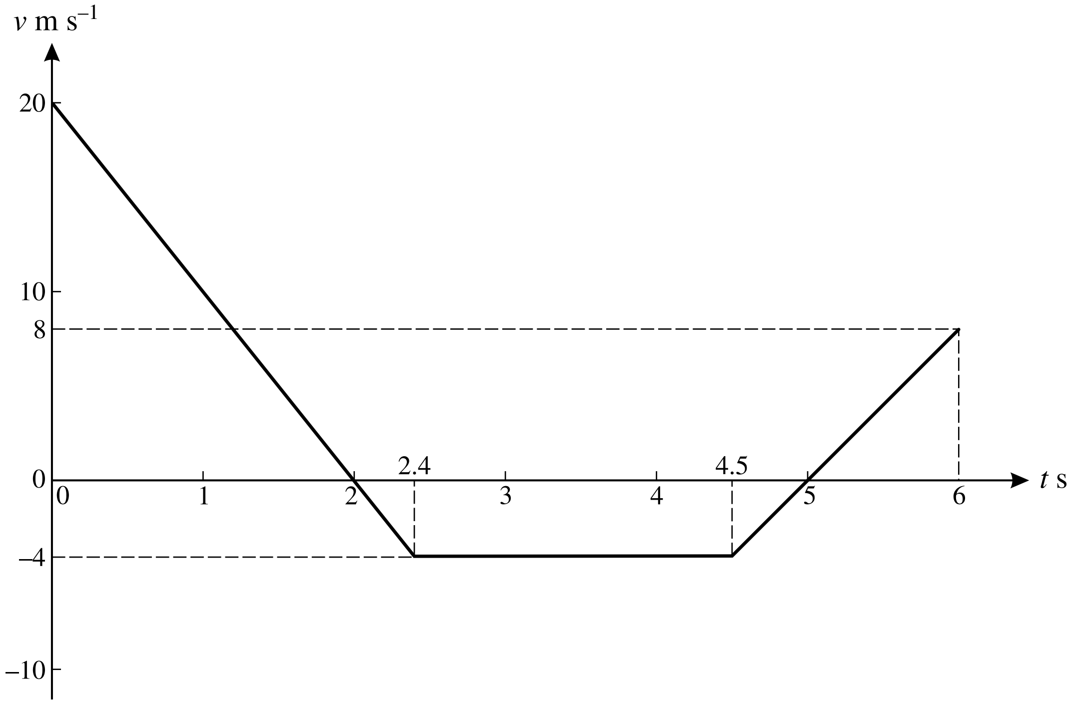

Fig. 7

Use model A to calculate the following.

(i) The acceleration of the ring when $t = 0.5$. **[2]**

(ii) The displacement of the ring from Q when

(A) $t = 2$,

(B) $t = 6$. **[5]**

In an alternative model B, the velocity of the ring is given by $v = 2t^2 - 14t + 20$ for $0 \leqslant t \leqslant 6$.

(iii) Calculate the acceleration of the ring at $t = 0.5$ as given by model B. **[3]**

(iv) Calculate by how much the models differ in their values for the least v in the time interval $0 \leqslant t \leqslant 6$. **[4]**

(v) Calculate the displacement of the ring from Q when $t = 6$ as given by model B. **[4]**

8 A trolley C of mass 8 kg with rusty axle bearings is initially at rest on a horizontal floor.

The trolley stays at rest when it is pulled by a horizontal string with tension 25 N, as shown in Fig. 8.1.

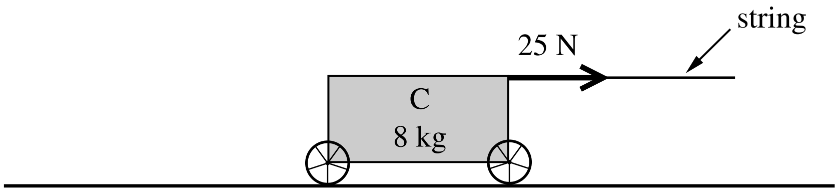

Fig. 8.1

(i) State the magnitude of the horizontal resistance opposing the pull. **[1]**

A second trolley D of mass 10 kg is connected to trolley C by means of a light, horizontal rod.

The string now has tension 50 N, and is at an angle of 25° to the horizontal, as shown in Fig. 8.2. The two trolleys stay at rest.

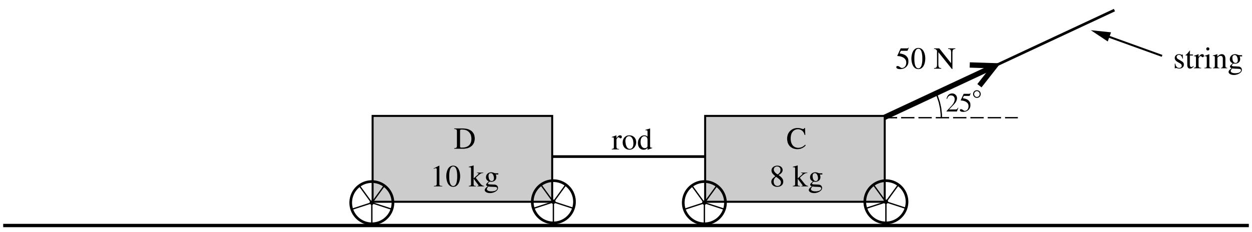

Fig. 8.2

(ii) Calculate the magnitude of the total horizontal resistance acting on the two trolleys opposing the pull. **[2]**

(iii) Calculate the normal reaction of the floor on trolley C. **[3]**

The axle bearings of the trolleys are oiled and the total horizontal resistance to the motion of the two trolleys is now 20 N. The two trolleys are still pulled by the string with tension 50 N, as shown in Fig. 8.2.

(iv) Calculate the acceleration of the trolleys. **[3]**

In a new situation, the trolleys are on a slope at 5° to the horizontal and are initially travelling down the slope at 3 m s^{-1}. The resistances are 15 N to the motion of D and 5 N to the motion of C. There is no string attached. The rod connecting the trolleys is parallel to the slope. This situation is shown in Fig. 8.3.

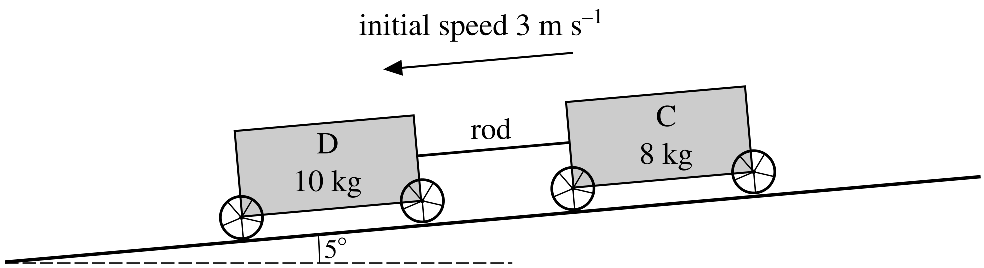

Fig. 8.3

(v) Calculate the speed of the trolleys after 2 seconds and also the force in the rod connecting the trolleys, stating whether this rod is in tension or thrust (compression). **[9]**

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Wednesday 25 January 2012 – Afternoon

AS GCE MATHEMATICS (MEI)

4761 Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4761
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

4733230112

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found in the centre of the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
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- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
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INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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Section A (36 marks)

1 Fig. 1 shows two blocks of masses 3 kg and 5 kg connected by a light string which passes over a smooth, fixed pulley.

Initially the blocks are held at rest but then they are released.

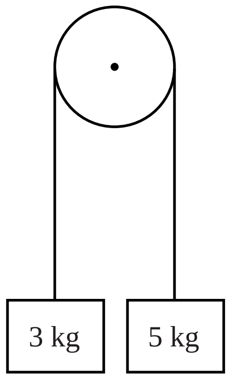

Fig. 1

Find the acceleration of the blocks when they start to move, and the tension in the string. **[5]**

2 Fig. 2 shows a small object, P, of weight 20 N, suspended by two light strings. The strings are tied to points A and B on a sloping ceiling which is at an angle of 60^{o} to the upward vertical. The string AP is at 60^{o} to the downward vertical and the string BP makes an angle of 30^{o} with the ceiling.

The object is in equilibrium.

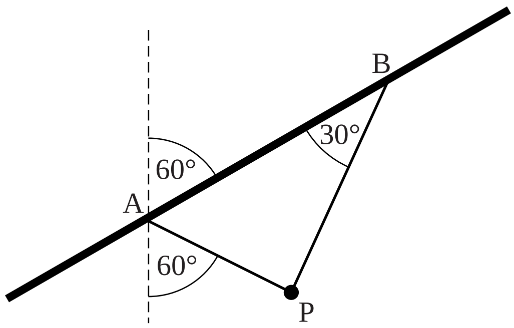

Fig. 2

(i) Show that $\angle APB = 90°$. **[1]**

(ii) Draw a labelled triangle of forces to represent the three forces acting on P. **[3]**

(iii) Hence, or otherwise, find the tensions in the two strings. **[3]**

3 Two girls, Marie and Nina, are members of an Olympic hockey team. They are doing fitness training.

Marie runs along a straight line at a constant speed of $6\,\text{m s}^{-1}$.

Nina is stationary at a point O on the line until Marie passes her. Nina immediately runs after Marie until she catches up with her.

The time, t s, is measured from the moment when Nina starts running. So when $t = 0$, both girls are at O.

Nina's acceleration, $a\,\text{m s}^{-2}$, is given by

$$a = 4 - t \qquad \text{for } 0 \leqslant t \leqslant 4,$$
$$a = 0 \qquad \text{for } t > 4.$$

(i) Show that Nina's speed, $v\,\text{m s}^{-1}$, is given by

$$v = 4t - \tfrac{1}{2}t^2 \quad \text{for } 0 \leqslant t \leqslant 4,$$
$$v = 8 \qquad \text{for } t > 4.$$

[3]

(ii) Find an expression for the distance Nina has run at time t, for $0 \leqslant t \leqslant 4$.

Find how far Nina has run when $t = 4$ and when $t = 5\frac{1}{3}$. **[4]**

(iii) Show that Nina catches up with Marie when $t = 5\frac{1}{3}$. **[1]**

4 A projectile P travels in a vertical plane over level ground. Its position vector $\mathbf{r}$ at time t seconds after projection is modelled by

$$\mathbf{r} = \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 0 \\ 5 \end{pmatrix} + \begin{pmatrix} 30 \\ 40 \end{pmatrix} t - \begin{pmatrix} 0 \\ 5 \end{pmatrix} t^2,$$

where distances are in metres and the origin is a point on the level ground.

(i) Write down

(A) the height from which P is projected,

(B) the value of g in this model. **[2]**

(ii) Find the displacement of P from $t = 3$ to $t = 5$. **[2]**

(iii) Show that the equation of the trajectory is

$$y = 5 + \frac{4}{3}x - \frac{x^2}{180}.$$

[4]

5 The vectors **p** and **q** are given by

$$\mathbf{p} = 8\mathbf{i} + \mathbf{j} \quad \text{and} \quad \mathbf{q} = 4\mathbf{i} - 7\mathbf{j}.$$

(i) Show that **p** and **q** are equal in magnitude. **[3]**

(ii) Show that $\mathbf{p} + \mathbf{q}$ is parallel to $2\mathbf{i} - \mathbf{j}$. **[2]**

(iii) Draw $\mathbf{p} + \mathbf{q}$ and $\mathbf{p} - \mathbf{q}$ on the grid.

Write down the angle between these two vectors. **[3]**

Section B (36 marks)

6 Robin is driving a car of mass 800 kg along a straight horizontal road at a speed of $40\,\text{m}\,\text{s}^{-1}$.

Robin applies the brakes and the car decelerates uniformly; it comes to rest after travelling a distance of 125 m.

(i) Show that the resistance force on the car when the brakes are applied is 5120 N. **[4]**

(ii) Find the time the car takes to come to rest. **[2]**

For the rest of this question, assume that when Robin applies the brakes there is a constant resistance force of 5120 N on the car.

The car returns to its speed of $40\,\text{m}\,\text{s}^{-1}$ and the road remains straight and horizontal.

Robin sees a red light 155 m ahead, takes a short time to react and then applies the brakes.

The car comes to rest before it reaches the red light.

(iii) Show that Robin's reaction time is less than 0.75 s. **[2]**

The 'stopping distance' is the total distance travelled while a driver reacts and then applies the brakes to bring the car to rest. For the rest of this question, assume that Robin is still driving the car described above and has a reaction time of 0.675 s. (This is the figure used in calculating the stopping distances given in the Highway Code.)

(iv) Calculate the stopping distance when Robin is driving at $20\,\text{m}\,\text{s}^{-1}$ on a horizontal road. **[3]**

The car then travels down a hill which has a slope of 5° to the horizontal.

(v) Find the stopping distance when Robin is driving at $20\,\text{m}\,\text{s}^{-1}$ down this hill. **[6]**

(vi) By what percentage is the stopping distance increased by the fact that the car is going down the hill? Give your answer to the nearest 1%. **[1]**

7 Fig. 7 shows the trajectory of an object which is projected from a point O on horizontal ground. Its initial velocity is $40\,\mathrm{m\,s^{-1}}$ at an angle of α to the horizontal.

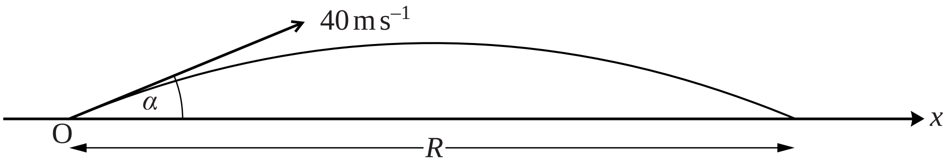

Fig. 7

(i) Show that, according to the standard projectile model in which air resistance is neglected, the flight time, T s, and the range, R m, are given by

$$T = \frac{80\sin\alpha}{g} \quad \text{and} \quad R = \frac{3200\sin\alpha\cos\alpha}{g}.$$ **[6]**

A company is designing a new type of ball and wants to model its flight.

(ii) Initially the company uses the standard projectile model.

Use this model to show that when $\alpha = 30°$ and the initial speed is $40\,\mathrm{m\,s^{-1}}$, T is approximately 4.08 and R is approximately 141.4.

Find the values of T and R when $\alpha = 45°$. **[3]**

The company tests the ball using a machine that projects it from ground level across horizontal ground. The speed of projection is set at $40\,\mathrm{m\,s^{-1}}$.

When the angle of projection is set at 30°, the range is found to be 125 m.

(iii) Comment briefly on the accuracy of the standard projectile model in this situation. **[1]**

The company refines the model by assuming that the ball has a constant deceleration of $2\,\mathrm{m\,s^{-2}}$ in the horizontal direction.

In this new model, the resistance to the vertical motion is still neglected and so the flight time is still 4.08 s when the angle of projection is 30°.

(iv) Using the new model, with $\alpha = 30°$, show that the horizontal displacement from the point of projection, x m at time t s, is given by

$$x = 40t\cos 30° - t^2.$$

Find the range and hence show that this new model is reasonably accurate in this case. **[4]**

The company then sets the angle of projection to 45° while retaining a projection speed of $40\,\mathrm{m\,s^{-1}}$. With this setting the range of the ball is found to be 135 m.

(v) Investigate whether the new model is also accurate for this angle of projection. **[3]**

(vi) Make one suggestion as to how the model could be further refined. **[1]**

Friday 1 June 2012 – Morning

AS GCE MATHEMATICS (MEI)

4761 Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4761
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

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Section A (36 marks)

1 Fig. 1 shows the speed-time graph of a runner during part of his training.

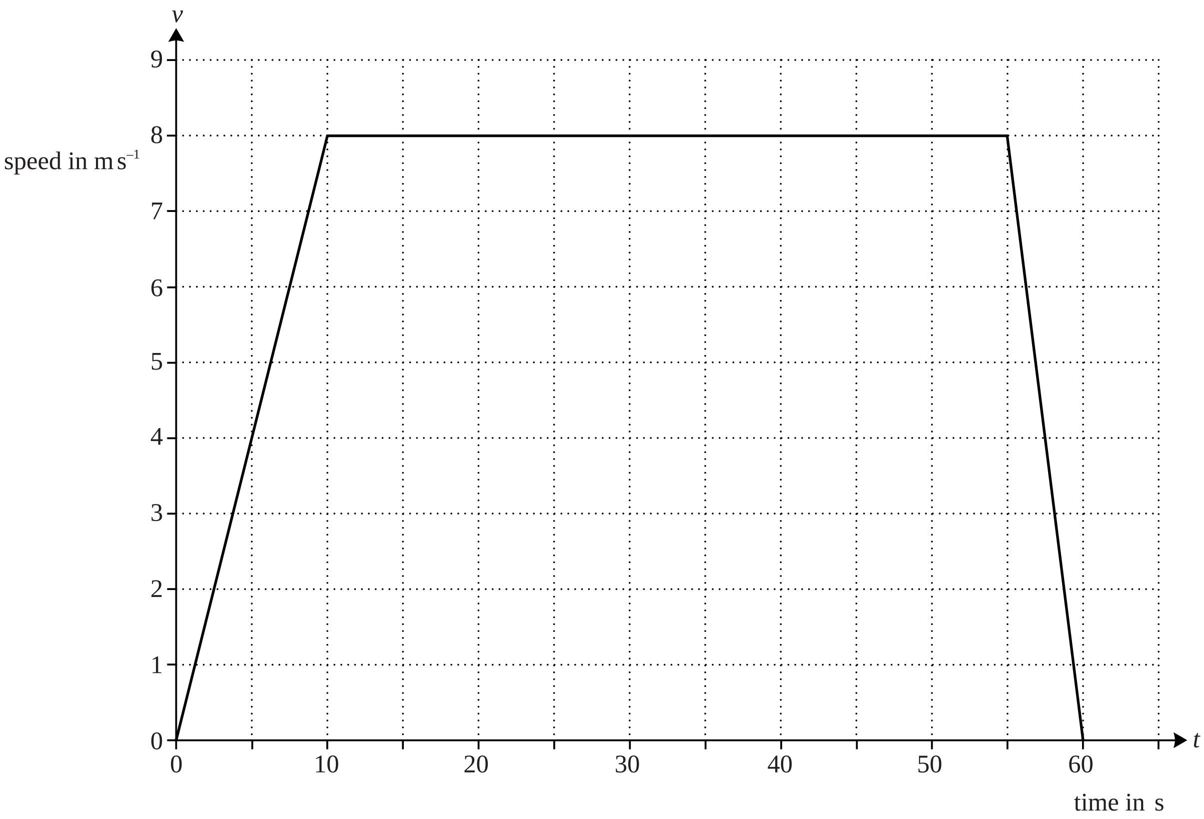

Fig. 1

For each of the following statements, say whether it is true or false. If it is false give a brief explanation.

(*A*) The graph shows that the runner finishes where he started.

(*B*) The runner's maximum speed is $8\,\mathrm{m\,s^{-1}}$.

(*C*) At time 58 seconds, the runner is slowing down at a rate of $1.6\,\mathrm{m\,s^{-2}}$.

(*D*) The runner travels 400 m altogether. **[6]**

2 A particle is moving along a straight line and its position is relative to an origin on the line. At time t s, the particle's acceleration, $a\ \mathrm{m\,s^{-2}}$, is given by

$$a = 6t - 12\ .$$

At $t = 0$ the velocity of the particle is $+9\,\mathrm{m\,s^{-1}}$ and its position is -2 m.

(i) Find an expression for the velocity of the particle at time t s and verify that it is stationary when $t = 3$. **[4]**

(ii) Find the position of the particle when $t = 2$. **[3]**

3 The vectors **P**, **Q** and **R** are given by

$$\mathbf{P} = 5\mathbf{i} + 4\mathbf{j}, \quad \mathbf{Q} = 3\mathbf{i} - 5\mathbf{j}, \quad \mathbf{R} = -8\mathbf{i} + \mathbf{j}.$$

(i) Find the vector **P** + **Q** + **R**. **[1]**

(ii) Interpret your answer to part **(i)** in the cases

(A) **P**, **Q** and **R** represent three forces acting on a particle, **[1]**

(B) **P**, **Q** and **R** represent three stages of a hiker's walk. **[1]**

4 Fig. 4 illustrates points A, B and C on a straight race track. The distance AB is 300 m and AC is 500 m.

A car is travelling along the track with uniform acceleration.

Fig. 4

Initially the car is at A and travelling in the direction AB with speed $5\,\mathrm{m\,s^{-1}}$. After 20 s it is at C.

(i) Find the acceleration of the car. **[2]**

(ii) Find the speed of the car at B and how long it takes to travel from A to B. **[3]**

5 Fig. 5 shows a block of mass 10 kg at rest on a rough horizontal floor. A light string, at an angle of 30° to the vertical, is attached to the block. The tension in the string is 50 N.

The block is in equilibrium.

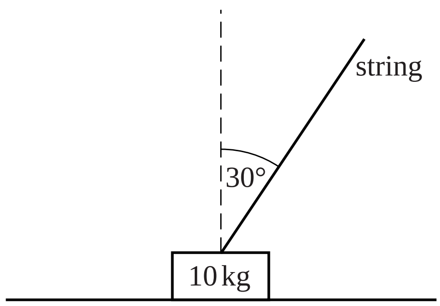

Fig. 5

(i) Show all the forces acting on the block. **[2]**

(ii) Show that the frictional force acting on the block is 25 N. **[2]**

(iii) Calculate the normal reaction of the floor on the block. **[2]**

(iv) Calculate the magnitude of the total force the floor is exerting on the block. **[2]**

6 A football is kicked with speed $31\,\text{m}\,\text{s}^{-1}$ 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]**

Section B (36 marks)

7 A train consists of a locomotive pulling 17 identical trucks.

The mass of the locomotive is 120 tonnes and the mass of each truck is 40 tonnes. The locomotive gives a driving force of 121 000 N.

The resistance to motion on each truck is R N and the resistance on the locomotive is $5R$ N.

Initially the train is travelling on a straight horizontal track and its acceleration is $0.11\,\text{m}\,\text{s}^{-2}$.

(i) Show that $R = 1500$. **[4]**

(ii) Find the tensions in the couplings between

(A) the last two trucks, **[4]**

(B) the locomotive and the first truck. **[3]**

The train now comes to a place where the track goes up a straight, uniform slope at an angle α with the horizontal, where $\sin\alpha = \frac{1}{80}$.

The driving force and the resistance forces remain the same as before.

(iii) Find the magnitude and direction of the acceleration of the train. **[4]**

The train then comes to a straight uniform downward slope at an angle β to the horizontal.

The driver of the train reduces the driving force to zero and the resistance forces remain the same as before.

The train then travels at a constant speed down the slope.

(iv) Find the value of β. **[3]**

8 In this question, positions are given relative to a fixed origin, O. The x-direction is east and the y-direction north; distances are measured in kilometres.

Two boats, the *Rosemary* and the *Sage*, are having a race between two points A and B.

The position vector of the *Rosemary* at time t hours after the start is given by

$$\mathbf{r} = \begin{pmatrix} 3 \\ 2 \end{pmatrix} + \begin{pmatrix} 6 \\ 8 \end{pmatrix} t, \text{ where } 0 \leqslant t \leqslant 2 .$$

The *Rosemary* is at point A when $t = 0$, and at point B when $t = 2$.

(i) Find the distance AB. **[3]**

(ii) Show that the *Rosemary* travels at constant velocity. **[1]**

The position vector of the *Sage* is given by

$$\mathbf{r} = \begin{pmatrix} 3(2t+1) \\ 2(2t^2+1) \end{pmatrix} .$$

(iii) Plot the points A and B.

Draw the paths of the two boats for $0 \leqslant t \leqslant 2$. **[3]**

(iv) What can you say about the result of the race? **[1]**

(v) Find the speed of the *Sage* when $t = 2$. Find also the direction in which it is travelling, giving your answer as a compass bearing, to the nearest degree. **[6]**

(vi) Find the displacement of the *Rosemary* from the *Sage* at time t and hence calculate the greatest distance between the boats during the race. **[4]**

OCR
RECOGNISING ACHIEVEMENT

Monday 28 January 2013 – Morning

AS GCE MATHEMATICS (MEI)

4761/01 Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4761/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

* 4 7 3 4 1 2 0 1 1 3 *

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INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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This paper has been pre modified for carrier language

Section A (36 marks)

1 Fig. 1 shows a block of mass 3 kg on a plane which is inclined at an angle of 30° to the horizontal.

A force P N is applied to the block parallel to the plane in the upwards direction.

The plane is rough so that a frictional force of 10 N opposes the motion.

The block is moving at constant speed up the plane.

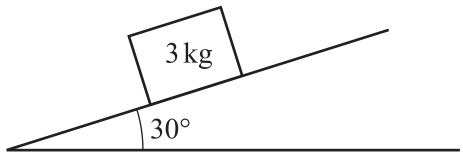

Fig. 1

(i) Mark and label all the forces acting on the block. **[3]**

(ii) Calculate the magnitude of the normal reaction of the plane on the block. **[1]**

(iii) Calculate the magnitude of the force P. **[2]**

2 In this question, the unit vectors $\begin{pmatrix}1\\0\end{pmatrix}$ and $\begin{pmatrix}0\\1\end{pmatrix}$ are in the directions east and north.

Distance is measured in metres and time, t, in seconds.

A radio-controlled toy car moves on a flat horizontal surface. A child is standing at the origin and controlling the car.

When $t = 0$, the displacement of the car from the origin is $\begin{pmatrix}0\\-2\end{pmatrix}$ m, and the car has velocity $\begin{pmatrix}2\\0\end{pmatrix}$ m s^{-1}.

The acceleration of the car is constant and is $\begin{pmatrix}-1\\1\end{pmatrix}$ m s^{-2}.

(i) Find the velocity of the car at time t and its speed when $t = 8$. **[4]**

(ii) Find the distance of the car from the child when $t = 8$. **[4]**

3 Fig. 3 shows two people, Sam and Tom, pushing a car of mass 1000 kg along a straight line l on level ground.

Sam pushes with a constant horizontal force of 300 N at an angle of 30° to the line l.

Tom pushes with a constant horizontal force of 175 N at an angle of 15° to the line l.

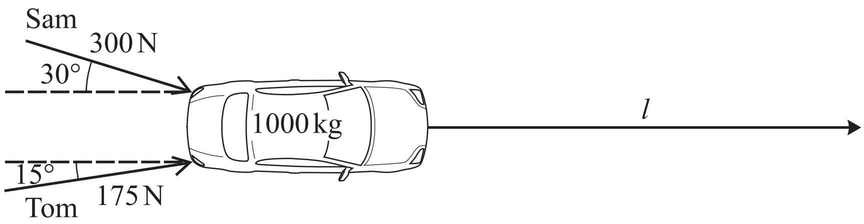

Fig. 3

(i) The car starts at rest and moves with constant acceleration. After 6 seconds it has travelled 7.2 m.

Find its acceleration. **[3]**

(ii) Find the resistance force acting on the car along the line l. **[4]**

(iii) The resultant of the forces exerted by Sam and Tom is not in the direction of the car's acceleration. Explain briefly why. **[1]**

4 A particle is travelling along a straight line with constant acceleration. P, O and Q are points on the line, as illustrated in Fig. 4. The distance from P to O is 5 m and the distance from O to Q is 30 m.

Fig. 4

Initially the particle is at O. After 10 s, it is at Q and its velocity is $9\,\text{m s}^{-1}$ in the direction $\overrightarrow{OQ}$.

(i) Find the initial velocity and the acceleration of the particle. **[4]**

(ii) Prove that the particle is never at P. **[3]**

5 Ali is throwing flat stones onto water, hoping that they will bounce, as illustrated in Fig. 5.

Ali throws one stone from a height of 1.225 m above the water with initial speed $20\,\mathrm{m\,s^{-1}}$ in a horizontal direction. Air resistance should be neglected.

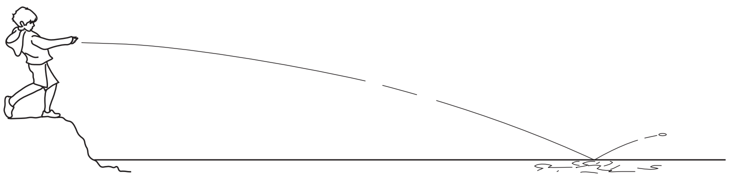

Fig. 5

(i) Find the time it takes for the stone to reach the water. **[2]**

(ii) Find the speed of the stone when it reaches the water and the angle its trajectory makes with the horizontal at this time. **[5]**

Section B (36 marks)

6 The speed of a 100 metre runner in m s^{-1} is measured electronically every 4 seconds.

The measurements are plotted as points on the speed-time graph in Fig. 6. The vertical dotted line is drawn through the runner's finishing time.

Fig. 6 also illustrates Model P in which the points are joined by straight lines.

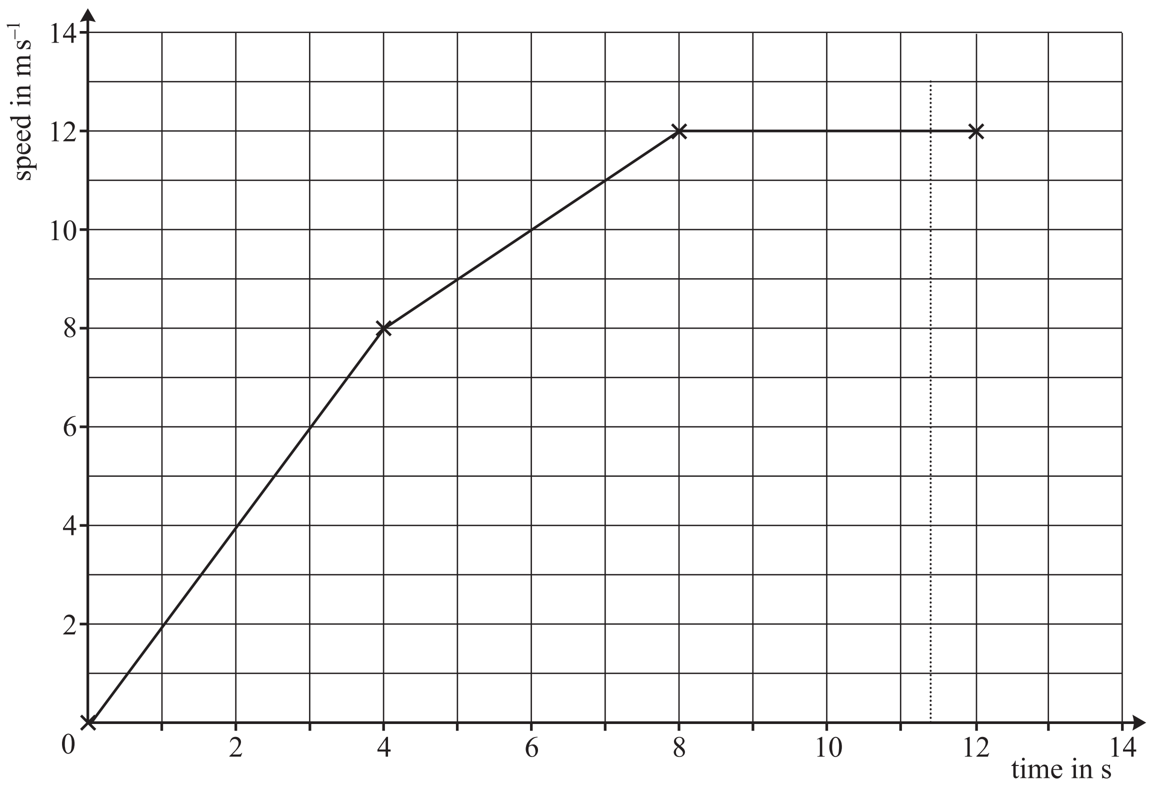

Fig. 6

(i) Use Model P to estimate

(*A*) the distance the runner has gone at the end of 12 seconds,

(*B*) how long the runner took to complete 100 m. **[6]**

A mathematician proposes Model Q in which the runner's speed, $v\ \text{m s}^{-1}$ at time t s, is given by

$$v = \frac{5}{2}t - \frac{1}{8}t^2.$$

(ii) Verify that Model Q gives the correct speed for $t = 8$. **[1]**

(iii) Use Model Q to estimate the distance the runner has gone at the end of 12 seconds. **[4]**

(iv) The runner was timed at 11.35 seconds for the 100 m.

Which model places the runner closer to the finishing line at this time? **[3]**

(v) Find the greatest acceleration of the runner according to each model. **[4]**

7 A block of weight 50 N is in equilibrium, suspended from fixed points A and B which are 2 m apart on a horizontal ceiling.

Fig. 7.1 illustrates one way of doing this. A light, inextensible string of length 2.8 m is passed round a small smooth light pulley attached to a point C on the block. The parts of the string from C to A and from C to B should be treated as straight lines making angles θ and ϕ with the vertical.

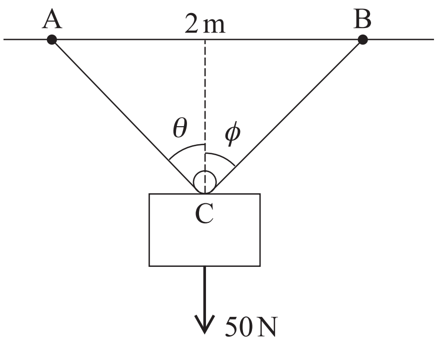

Fig. 7.1

(i) (*A*) State which piece of the information that you have been given tells you that the tension in the string is the same on each side of the pulley. **[1]**

(*B*) Hence show that $\theta = \phi$. **[2]**

(ii) Show that $\cos\theta = \frac{\sqrt{24}}{7}$. **[2]**

(iii) Find the tension in the string. **[3]**

Fig. 7.2 illustrates another way of suspending the block from the same two points, A and B, with the string now cut into two parts, AC and BC. The length of AC is 1.2 m and BC is 1.6 m. The angles the strings make with the horizontal are α and β. The tension in the string AC is T_1 N and the tension in the string BC is T_2 N.

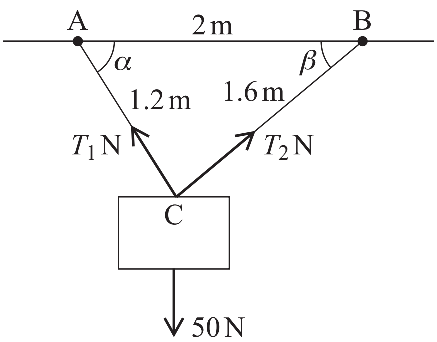

Fig. 7.2

(iv) Show that $\angle ACB = 90°$.

Write down the values of $\cos\alpha$ and $\cos\beta$. **[2]**

(v) Find T_1 and T_2. **[5]**

In a different arrangement, the string is cut so that the lengths of the two parts are 0.5 m and 2.3 m.

(vi) Describe how the block hangs in equilibrium in this case and state the tensions in the two strings. **[3]**

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE.

OCR
RECOGNISING ACHIEVEMENT

Monday 10 June 2013 – Morning

AS GCE MATHEMATICS (MEI)

4761/01 Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4761/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

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INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found in the centre of the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book**. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\text{m s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

This information is the same on the Printed Answer Book and the Question Paper.

- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

Turn over

Section A (36 marks)

1 Fig. 1 shows a pile of four uniform blocks in equilibrium on a horizontal table. Their masses, as shown, are 4 kg, 5 kg, 7 kg and 10 kg.

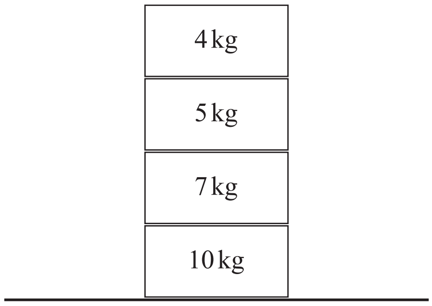

Fig. 1

Mark on the diagram the magnitude and direction of each of the forces acting on the 7 kg block. **[3]**

2 In this question, air resistance should be neglected.

Fig. 2 illustrates the flight of a golf ball. The golf ball is initially on the ground, which is horizontal.

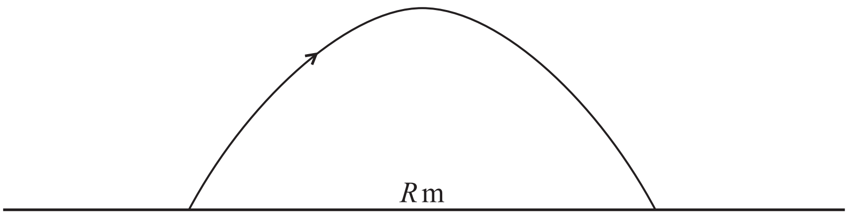

Fig. 2

It is hit and given an initial velocity with components of $15\,\mathrm{m\,s^{-1}}$ in the horizontal direction and $20\,\mathrm{m\,s^{-1}}$ in the vertical direction.

(i) Find its initial speed. **[1]**

(ii) Find the ball's flight time and range, R m. **[4]**

(iii) (*A*) Show that the range is the same if the components of the initial velocity of the ball are $20\,\mathrm{m\,s^{-1}}$ in the horizontal direction and $15\,\mathrm{m\,s^{-1}}$ in the vertical direction. **[1]**

(*B*) State, justifying your answer, whether the range is the same whenever the ball is hit with the same initial speed. **[2]**

3 **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 $\mathbf{p}$, $\mathbf{q}$ and $\mathbf{r}$ 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 $\mathbf{p}$, $\mathbf{q}$ and $\mathbf{r}$ has the greatest magnitude. **[2]**

(ii) A particle has mass 0.4 kg. The forces acting on it are $\mathbf{p}$, $\mathbf{q}$, $\mathbf{r}$ and its weight.

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

4 The directions of the unit vectors $\mathbf{i}$ and $\mathbf{j}$ are east and north.

The velocity of a particle, $\mathbf{v}\,\mathrm{m\,s^{-1}}$, 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]**

5 Fig. 5 shows blocks of mass 4 kg and 6 kg on a smooth horizontal table. They are connected by a light, inextensible string. As shown, a horizontal force F N acts on the 4 kg block and a horizontal force of 30 N acts on the 6 kg block.

The magnitude of the acceleration of the system is $2\,\mathrm{m\,s^{-2}}$.

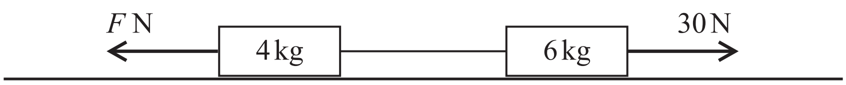

Fig. 5

(i) Find the two possible values of F. **[4]**

(ii) Find the tension in the string in each case. **[3]**

6 A particle moves along a straight line through an origin O. Initially the particle is at O.

At time t s, its displacement from O is x m and its velocity, $v\,\mathrm{m\,s^{-1}}$, is given by

$$v = 24 - 18t + 3t^2.$$

(i) Find the times, T_1 s and T_2 s (where $T_2 > T_1$), at which the particle is stationary. **[2]**

(ii) Find an expression for x at time t s.

Show that when $t = T_1$, $x = 20$ and find the value of x when $t = T_2$. **[4]**

Section B (36 marks)

7 Abi and Bob are standing on the ground and are trying to raise a small object of weight 250 N to the top of a building. They are using long light ropes. Fig. 7.1 shows the initial situation.

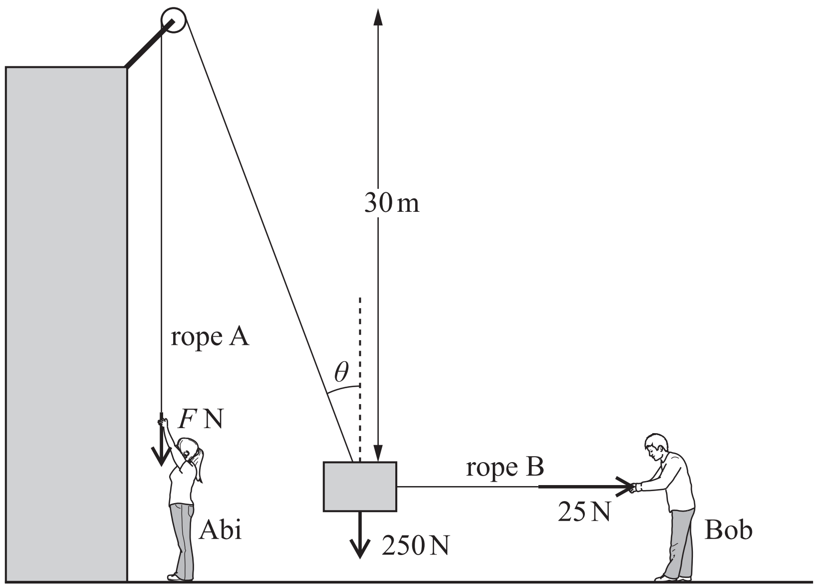

Fig. 7.1

Abi pulls vertically downwards on the rope A with a force F N. This rope passes over a small smooth pulley and is then connected to the object. Bob pulls on another rope, B, in order to keep the object away from the side of the building.

In this situation, the object is stationary and in equilibrium. The tension in rope B, which is horizontal, is 25 N. The pulley is 30 m above the object. The part of rope A between the pulley and the object makes an angle θ with the vertical.

(i) Represent the forces acting on the object as a fully labelled triangle of forces. **[3]**

(ii) Find F and θ.

Show that the distance between the object and the vertical section of rope A is 3 m. **[5]**

[Question 7 is continued on the next page.]

Abi then pulls harder and the object moves upwards. Bob adjusts the tension in rope B so that the object moves along a vertical line.

Fig. 7.2 shows the situation when the object is part of the way up. The tension in rope A is S N and the tension in rope B is T N. The ropes make angles α and β with the vertical as shown in the diagram. Abi and Bob are taking a rest and holding the object stationary and in equilibrium.

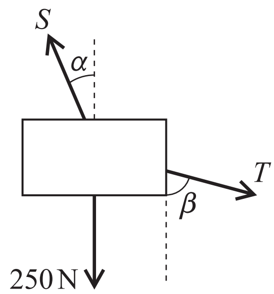

Fig. 7.2

(iii) Give the equations, involving S, T, α and β, for equilibrium in the vertical and horizontal directions. **[3]**

(iv) Find the values of S and T when $\alpha = 8.5°$ and $\beta = 35°$. **[4]**

(v) Abi's mass is 40 kg.

Explain why it is not possible for her to raise the object to a position in which $\alpha = 60°$. **[3]**

[Question 8 is printed overleaf.]

8 Fig. 8.1 shows a sledge of mass 40 kg. It is being pulled across a horizontal surface of deep snow by a light horizontal rope. There is a constant resistance to its motion.

The tension in the rope is 120 N.

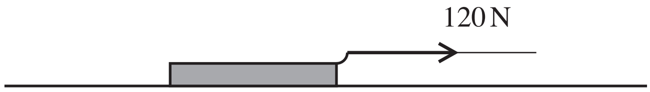

Fig. 8.1

The sledge is initially at rest. After 10 seconds its speed is $5\,\mathrm{m\,s^{-1}}$.

(i) Show that the resistance to motion is 100 N. **[4]**

When the speed of the sledge is $5\,\mathrm{m\,s^{-1}}$, the rope breaks.

The resistance to motion remains 100 N.

(ii) Find the speed of the sledge

(A) 1.6 seconds after the rope breaks, **[3]**

(B) 6 seconds after the rope breaks. **[1]**

The sledge is then pushed to the bottom of a ski slope. This is a plane at an angle of 15° to the horizontal.

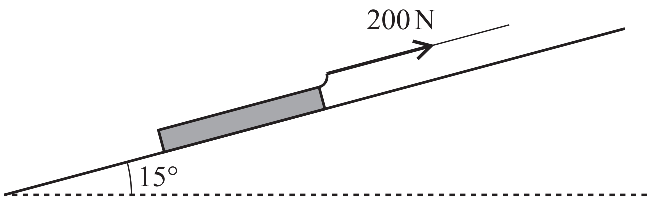

Fig. 8.2

The sledge is attached by a light rope to a winch at the top of the slope. The rope is parallel to the slope and has a constant tension of 200 N. Fig. 8.2 shows the situation when the sledge is part of the way up the slope.

The ski slope is smooth.

(iii) Show that when the sledge has moved from being at rest at the bottom of the slope to the point when its speed is $8\,\mathrm{m\,s^{-1}}$, it has travelled a distance of 13.0 m (to 3 significant figures). **[4]**

When the speed of the sledge is $8\,\mathrm{m\,s^{-1}}$, this rope also breaks.

(iv) Find the time between the rope breaking and the sledge reaching the bottom of the slope. **[6]**

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