

## INSTRUCTIONS TO CANDIDATES

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

- The Question Paper will be found inside 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 barcodes.
- 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 $\mathrm{g} \mathrm{ms}^{-2}$. 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 $\mathbf{1 6}$ pages. The Question Paper consists of $\mathbf{8}$ 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.


## Section A (36 marks)

1 Fig. 1 shows a block of mass 5 kg on a rough plane inclined at an angle $\alpha$ to the horizontal. The block is in equilibrium.


Fig. 1
(i) Draw a force diagram showing all the forces acting on the block.
(ii) The normal reaction of the plane on the block is 37.5 N .

Find $\alpha$, giving your answer to the nearest degree.

Find also the frictional force acting on the block.

2 In this question, $\binom{1}{0}$ and $\binom{0}{1}$ are unit vectors in the $x$ - and $y$-directions.

A bird is flying in the vertical plane defined by these directions.

The origin is a point on the ground.
The position vector, $\mathbf{r} \mathrm{m}$, of the bird at time $t$ seconds, where $t \geqslant 0$, is given by

$$
\mathbf{r}=\binom{0}{8}+\binom{2}{-4} t+\binom{0}{1} t^{2}
$$

(i) Find the velocity of the bird when $t=2.5$.
(ii) Find the time at which the speed of the bird is $10 \mathrm{~ms}^{-1}$.
(iii) Find the times at which the bird is flying at an angle of $45^{\circ}$ to the horizontal.

3 Olga and Petya are using light ropes to pull a sledge across rough snow.

- The surface of the snow is horizontal.
- The mass of the sledge and its load is 430 kg .
- Both ropes are horizontal.
- Olga pulls with a force of 120 N at an angle of $20^{\circ}$ to the line of motion of the sledge.
- Petya also pulls with a force of 120 N at an angle of $20^{\circ}$ to the line of motion of the sledge.

This is illustrated in a plan view in Fig. 2.


Fig. 2
(i) The sledge has acceleration $0.05 \mathrm{~m} \mathrm{~s}^{-2}$ in the direction of its line of motion.

Find the frictional force acting on the sledge.

Olga and Petya then change to walking side by side. Their ropes, which are still horizontal, are now along the line of motion of the sledge. They maintain the forces on their ropes at 120 N and the frictional force remains the same.
(ii) Find the percentage increase in the acceleration of the sledge.

4 Fig. 4 shows two small blocks, Q of mass 8 kg and R of mass 6 kg . They are connected by a light string which passes over a pulley.

The pulley is light and smooth. It is rigidly suspended from the ceiling.

The system is released from rest with the two blocks at the same height

Initially the blocks are 2 m above the floor and 3 m below the pulley.


Fig. 4
(i) Draw diagrams showing the forces acting on each of the blocks Q and R .
(ii) Write down the equations of motion of each of the blocks Q and R .
(iii) Find the time between the system being released and one of the blocks reaching the floor.

5 Two cars, A and B , are travelling in different lanes in the same direction along a straight road.

The initial situation is illustrated in Fig. 5.

- At this time, A is stationary at traffic lights at O . The lights have just turned green and A is on the point of moving off.
- $\quad \mathrm{B}$ is travelling towards O with speed $20 \mathrm{~m} \mathrm{~s}^{-1}$. B is 75 m behind A .


Fig. 5
During the subsequent motion,

- A has constant acceleration $2 \mathrm{~m} \mathrm{~s}^{-2}$,
- the traffic lights remain green and B maintains a constant speed $20 \mathrm{~m} \mathrm{~s}^{-1}$.

In order to model the subsequent motion you should make two assumptions.

- The cars can overtake each other with no interference from other traffic.
- The position of a car is defined by a point at its front and so the length of the car need not be considered.
(i) Find the times at which the two cars are side by side.
(ii) Find the distance A travels while it is behind B .
(iii) There is a speed camera 400 m from O .

How fast is A travelling when it passes the speed camera?

## Section B (36 marks)

6 A train is travelling along a straight test track. It starts from rest and reaches its maximum speed after a time of 2 minutes and 21 seconds. During that time it travels 5 km .

Two models, A and B, are considered for its motion.
In Model A , it is assumed that the train has constant acceleration.
(i) Find the acceleration of the train and its maximum speed according to Model A .

In Model B, it is assumed that the acceleration, $a \mathrm{~m} \mathrm{~s}^{-2}$ at time $t$ seconds after starting, is given by

$$
a=0.6-3 \times 10^{-5} \times t^{2}
$$

(ii) Show that, according to Model B , the time taken for the train to reach its maximum speed is 2 minutes 21.42 seconds (to the nearest 0.01 s ).
(iii) Find expressions for the speed of the train and the distance that it has travelled at time $t$, according to Model B.
(iv) Hence show that Model B is consistent with the train travelling a distance of 5 km to attain maximum speed.

Find the maximum speed of the train according to this model.
(v) When the train reaches its maximum speed it continues at that speed.

Draw the speed-time graphs for both models on the grid provided, labelling them A and B.

7 In this question you should use the standard projectile model with $g=9.8 \mathrm{~ms}^{-2}$.
Fig. 7 illustrates the trajectory of a tennis ball which has been served by a player. It is not drawn to scale.

- The ball must pass over the net and land in the service court.
- The player hits the ball at an angle of $\alpha$ above the horizontal.

Three junior members of a tennis club take turns to serve a tennis ball. They are Hamish (a beginner), Oscar (of medium standard) and Tara (a good player). They each stand at the same point and hit the ball in the same vertical plane at the same point P. The following figures apply to their serves.

- The player hits the ball from a height of 2.22 m .
- The height of the net is 0.995 m .
- The player is 12.5 m from the net.
- The ball must bounce within 6.5 m of the net.


Fig. 7
Hamish serves the ball with components of velocity $10 \mathrm{~m} \mathrm{~s}^{-1}$ horizontally and $5.5 \mathrm{~m} \mathrm{~s}^{-1}$ vertically upwards.
(i) Find the speed of Hamish's serve and the value of $\alpha$.
(ii) Show that Hamish's serve passes over the net.
(iii) Find the time at which Hamish's serve hits the ground. Does it land in the service court?

Oscar hits the ball horizontally, so $\alpha=0$. The initial speed of the ball is $u \mathrm{~m} \mathrm{~s}^{-1}$.
(iv) Find the range of possible values of $u$ for which the ball lands in the service court.

Tara serves the ball at an angle of $2^{\circ}$ below the horizontal. The ball clears the net and bounces after 0.57 seconds.
(v) Find the initial speed of Tara's serve.

## END OF QUESTION PAPER



6 (v)

$\square$

| Qu | Part | Answer | Mark | Guidance |
| :---: | :---: | :---: | :---: | :---: |
| 1 | (i) |  | B1 <br> B1 B1 | Forces 3 correct forces. <br> Labels $\quad$ Accept $5 g$ and $m g$ for weight. <br> Arrows <br> Missing force(s) <br> If at least one of the 3 forces is missing, allow SC1 for each fully correct force (ie including label and arrow ) and ignore any additional forces that may be present. <br> Extra force(s) <br> Allow B0 for Forces and up to B1 for each of Labels and Arrows based on the correct forces and ignoring any extra(s). <br> Components of weight <br> Allow weight resolved into components parallel and perpendicular to the slope <br> Accept both the weight and its components if the components are shown to be clearly different from the other forces (eg drawn with broken lines). <br> Do not accept both the weight and its components if they all look the same; mark this as detailed under Extra force(s). |
|  |  |  | [3] |  |


| 1 | (ii) | $\begin{aligned} & N=5 g \cos \alpha(\text { or } 37.5=5 g \cos \alpha) \\ & \cos \alpha=\frac{37.5}{49} \\ & \alpha=40.065 \ldots{ }^{\circ} \text { so } 40^{\circ} \text { to the nearest degree } \\ & \text { Frictional force }=\text { component of weight down the slope } \\ & =5 g \sin 40.065 \ldots{ }^{\circ}(=31.539 \ldots) \text { so } 31.5 \mathrm{~N} \end{aligned}$ | M1 <br> A1 <br> B1 | Do not allow sin-cos interchange <br> Must be rounded to $40^{\circ}$ <br> Allow any answer that rounds to 31.5 N <br> Allow answer 31.5 N following two consistent sin-cos interchanges. |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [3] |  |
|  |  | Alternative Using a triangle of forces $\begin{aligned} & \cos \alpha=\frac{37.5}{49} \Rightarrow \alpha=40^{\circ} \\ & =5 g \sin 40.065 \ldots{ }^{\circ}(=31.539 \ldots) \text { so } 31.5 \mathrm{~N} \end{aligned}$ | M1 <br> A1 <br> B1 | Condone no arrows. Do not allow sin-cos interchange <br> Must be rounded to $40^{\circ}$ <br> Allow any answer that rounds to 31.5 N <br> Allow answer 31.5 N following two consistent sin-cos interchanges. |


| 1. | (ii) | Alternative Using Lami's theorem | M1 <br> A1 <br> B1 | Must be rounded to $40^{\circ}$ <br> Allow any answer that rounds to 31.5 N |
| :---: | :---: | :---: | :---: | :---: |


| 2 | (i) | Differentiating $\mathbf{r}$ $\begin{aligned} & \mathbf{v}=\binom{2}{-4}+\binom{0}{2} t \\ & \mathbf{v}=\binom{2}{1} \end{aligned}$ | $\begin{aligned} & \text { M1 } \\ & \text { A1 } \\ & \text { B1 } \end{aligned}$ | Attempt at differentiation must be seen Apply ISW for speed $=\sqrt{5}$ providing $\binom{2}{1}$ is seen. |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [3] |  |
|  | (ii) | $\sqrt{2^{2}+(-4+2 t)^{2}}=10$ $\begin{aligned} & t^{2}-4 t-20=0 \\ & t=\frac{4 \pm \sqrt{4^{2}-4 \times 1 \times-20}}{2}(=6.898 \ldots \text { or }-2.898 \ldots) \\ & t=6.9(\text { or }-2.9)(\text { to } 2 \mathrm{sf}) \end{aligned}$ | M1 <br> M1 <br> A1 | Attempt at formulation of the given information using their vector $\mathbf{v}$ from part (i). Must involve both components. $\text { e.g. }-4+2 t=\sqrt{96}$ <br> Accept drawing triangle of velocities <br> Attempted solution of an equation for $t$. Dependent on previous M mark <br> Allow FT from their vector expression for $\mathbf{v}$ in part (i). Else CAO. Condone not giving the negative value of $t$ as well as the correct value. Dependent on both M marks. |
|  |  |  | [3] |  |
|  | (iii) | Either $2=-4+2 t \Rightarrow t=3$ <br> Or $-2=-4+2 t \Rightarrow t=1$ | $\begin{aligned} & \text { B1 } \\ & \text { B1 } \end{aligned}$ | FT from their vector expression for $\mathbf{v}$ in part (i). <br> FT from their vector expression for $\mathbf{v}$ in part (i). |
|  |  |  | [2] |  |


| 3 | (i) | $2 \times 120 \times \cos 20^{\circ}-F=430 \times 0.05$ $F=204(.026 \ldots)$ | M1 <br> A1 <br> A1 | Newton's 2nd law, including ma term, friction and resolved force(s); allow sin-cos interchange for this mark only. <br> All terms and signs correct |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [3] |  |
|  | (ii) | $430 \times a=240-204.026 \ldots$ $a=0.08366 \ldots$ <br> Percentage increase is $\frac{0.0836 \ldots-0.05}{0.05} \times 100 \quad(=67.32 \ldots)$ <br> Percentage increase is $67.3 \%$ (to nearest 0.1 ) | M1 <br> A1 <br> M1 <br> A1 | Apply FT from their $F$ from part (i) throughout this part. <br> All forces present <br> Condone 0.08 for this mark <br> There must be evidence of a complete method for finding percentage change. The denominator must be the original acceleration and the original value must be subtracted from the new value at some stage. <br> To allow for rounding and truncation, allow answers between $66 \%$ and $68 \%$ inclusive following otherwise correct working. |
|  |  |  | [4] |  |


| 4 | (i) |  | B1 | The same symbol for $T$ must be used in both diagrams. |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [1] |  |
|  | (ii) | $\mathrm{Q}:$ $8 g-T=8 a$ <br> $\mathrm{R}:$ $T-6 g=6 a$ | $\begin{aligned} & \text { B1 } \\ & \text { B1 } \end{aligned}$ | Allow the equivalent equations with the direction of $a$ reversed |
|  |  |  | [2] |  |
|  | (iii) | Adding the equations of motion $2 g=14 a$ $a=\frac{2 g}{14} \quad\left(=1.4 \mathrm{~m} \mathrm{~s}^{-2}\right)$ <br> For Q: $\quad s=u t+\frac{1}{2} a t^{2}$ $2=\frac{1}{2} \times 1.4 \times t^{2}$ <br> $\Rightarrow t=1.690 \ldots$ so the time is 1.69 s | M1 <br> A1 <br> M1 <br> A1 | Eliminating one variable from the two equations. May be implied by subsequent working. <br> This answer must be consistent with the direction of $a$ used in part (ii) <br> Or an equivalent sequence of constant acceleration formulae <br> Dependent on previous M mark. FT for their $a$ but do not allow if it is $g$ <br> CAO |
|  |  |  | [4] |  |


| 5 | (i) | A: $x=t^{2}$ <br> B: $x=-75+20 t$ <br> When the cars are side by side, $t^{2}=-75+20 t$ $\begin{aligned} & t^{2}-20 t+75=0 \\ & (t-5)(t-15)=0 \end{aligned}$ <br> The times are 5 seconds and 15 seconds | B1 <br> B1 <br> M1 <br> A1 | Or displacements from B's start point: $x=t^{2}+75$ and $x=20 t$ <br> Must be consistent <br> For equating two distances even if inconsistent |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [4] |  |
|  | (ii) | For A, $\quad s=225$ when $t=15$ $s=25 \text { when } t=5$ <br> So A is behind B for 200 m | $\begin{aligned} & \text { M1 } \\ & \text { A1 } \end{aligned}$ | FT for two positive times from part (i) for the M mark only <br> Both values of $s$ attempted <br> CAO |
|  |  |  | [2] |  |
|  |  | Alternative Using motion of B <br> Speed of B is (constant at) $20 \mathrm{~m} \mathrm{~s}^{-1}$ <br> So between $t=5$ and $t=15$, B travels $20 \times(15-5)(=200 \mathrm{~m})$ <br> So A is behind B for 200 m | M1 A1 | Or equivalent, eg using $s=u t+\frac{1}{2} a t^{2}$ with $a=0$ |


| 5. | (ii) | Alternative Using motion of A with the clock re-set <br> When the cars are first level, the motion of A is defined by $u=10$ and $a=2$. <br> If the clock is re-set at this moment, $t=0$ <br> In this case, when they are next level, $t=10$ $\begin{aligned} & s=u t+\frac{1}{2} a t^{2} \Rightarrow s=10 \times 10+\frac{1}{2} \times 2 \times 10^{2} \\ & \Rightarrow s=200 \end{aligned}$ | M1 A1 | Or $v=u+a t \Rightarrow v=10+2 \times 10=30$ followed by use of $v^{2}-u^{2}=2 a s$ |
| :---: | :---: | :---: | :---: | :---: |
| 5 | (iii) | For A $\quad v^{2}-u^{2}=2 a s$ $\begin{aligned} & v^{2}=2 \times 2 \times 400 \\ & v=40,\left(\text { so speed } 40 \mathrm{~m} \mathrm{~s}^{-1}\right) \end{aligned}$ | $\begin{aligned} & \text { M1 } \\ & \text { A1 } \end{aligned}$ | There must be an attempt to use the formula |
|  |  |  | [2] |  |
|  |  | Alternative finding the time first <br> For A $\quad s=400 \Rightarrow t=20$ $v=u+a t$ $\Rightarrow \quad v=40 \text { so } 40 \mathrm{~m} \mathrm{~s}^{-1}$ | M1 <br> A1 | There must be evidence of a complete method that can lead to the value of $v$ |

## SECTION B

| 6 | (i) | 2 minutes 21 seconds is 141 seconds $\begin{aligned} & s=u t+\frac{1}{2} a t^{2} \\ & 5000=0+0.5 \times a \times 141^{2} \\ & a=0.503 \quad\left(\mathrm{~m} \mathrm{~s}^{-2}\right) \end{aligned}$ | B1 <br> M1 <br> A1 | Allow 0.50 but not 0.5 |
| :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & v=u+a t \\ & v=0.503 \times 141=70.9 \text { so } 70.9 \mathrm{~m} \mathrm{~s}^{-1} \end{aligned}$ | M1 A1 | Or equivalent, eg $v^{2}-u^{2}=2 a s$ CAO (including $70.5 \mathrm{~m} \mathrm{~s}^{-1}$ ) |
|  |  |  | [5] |  |
|  |  | Alternative using $s=\frac{1}{2}(u+v) t$ $\begin{aligned} & 5000=\frac{1}{2} \times(0+v) \times 141 \\ & v=\frac{10000}{141}=70.9 \ldots \text { so } 70.9 \mathrm{~ms}^{-1} \end{aligned}$ | M1 A1 | CAO |


| 6 | (ii) | At maximum speed the acceleration is zero $t=\sqrt{\frac{0.6}{3 \times 10^{-5}}}(=\sqrt{20000})=141.421 \ldots$ <br> So 2 minutes 21.42 seconds | M1 <br> A1 | Setting $a=0$ in the given equation for $a$. <br> Accept answer in seconds |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [2] |  |
| 6 | (iii) | Integrating $\begin{aligned} & v=0.6 t-0.00001 t^{3}(+c), \quad(t=0, v=0 \Rightarrow c=0) \\ & s=0.3 t^{2}-0.0000025 t^{4}(+k) \end{aligned}$ $t=0, \mathrm{~s}=0 \Rightarrow k=0$ | M1 <br> A1 <br> A1 <br> A1 | Attempt at integration. <br> Or equivalent, eg $v=0.6 t-10^{-5} \times t^{3}(+c)$ <br> Coefficients do not need to be simplified in either integral. <br> FT from $v$. Integration must be attempted. <br> Or equivalent, eg $s=0.3 t^{2}-2.5 \times 10^{-6} \times t^{4}(+k)$ <br> Use of mechanics and not assertion to show $k=0$ |
|  |  |  | [4] |  |
|  | (iv) | Substituting $t=141.42 \ldots$ in $s=0.3 t^{2}-0.0000025 t^{4}$ $s=5000$ so consistent with 5 km Substituting $t=141.42 \ldots$ in $v=0.6 t-0.00001 t^{3}$ $v=56.57 \mathrm{~m} \mathrm{~s}^{-1}$ | M1 <br> A1 <br> B1 | Allow substituting $s=5000$ to show that $t=141.42 \ldots$ <br> Notice that $141.42 \ldots=\sqrt{20000}$ and so the answer of 5000 is exact |
|  |  |  | [3] |  |



| 7. | (i) | $\begin{aligned} & \text { Initial speed }=\sqrt{10^{2}+5.5^{2}}=11.412 \ldots \text { so } 11.4 \mathrm{~m} \mathrm{~s}-1(\text { to } 1 \mathrm{dp}) \\ & \alpha=\arctan \left(\frac{5.5}{10}\right)=28.810 \ldots \text { so } 28.8^{\circ}\left(\text { to the nearest } 0.1^{\circ}\right) \end{aligned}$ | B1 <br> B1 |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [2] |  |
|  | (ii) | Horizontal motion: Time to net $10 t=12.5$ so 1.25 s <br> Vertical motion $s=s_{0}+u t+\frac{1}{2} a t^{2}$ $y=2.22+5.5 \times 1.25-4.9 \times 1.25^{2}$ $=1.43875$ <br> This is greater than 0.995 so the ball goes over the net. | B1 <br> M1 <br> A1 | A complete method for finding the height of the ball when it crosses the net. <br> With the point of projection as the origin for vertical motion, the distance fallen in 1.25 s is 0.78125 m and $2.22-0.78125=1.43875$ <br> Conclusion stated |
|  |  |  | [3] |  |
|  |  | Alternative using time to net level and horizontal distance $0.995=2.22+5.5 t-4.9 t^{2} \Rightarrow t=1.313$ <br> Horizontal distance $10 \times 1.313=13.13$ <br> $13.13>12.5$ so the ball passes over the net | B1 <br> M1 <br> A1 | A complete method for finding the position of the ball when it is at the height of the top of the net. <br> Conclusion stated. |


| (iii) | Vertical motion $s=s_{0}+u t+\frac{1}{2} a t^{2}$ $0=2.22+5.5 t-4.9 t^{2}$ $t=\frac{5.5 \pm \sqrt{5.5^{2}+4 \times 4.9 \times 2.22}}{2 \times 4.9}=1.437 \ldots(\text { or }-0.315 \ldots)$ <br> Horizontal motion $x=10 \times 1.437 \ldots=14.37 \ldots$ <br> $14.37 \ldots<19$ so the ball does land in the service court | M1 <br> A1 <br> M1 <br> A1 | Setting up an equation for vertical motion containing the right elements. (Vertical velocity on landing $=8.59 \mathrm{~m} \mathrm{~s}^{-1}$ ) <br> Allow for $10 \times$ their time. This may be implied. <br> Conclusion stated. FT for their value of $t$. |
| :---: | :---: | :---: | :---: |
|  |  | [4] |  |


| 7 | (iv) | Clearing the net <br> The ball falls 2.22-0.995 $=1.225 \mathrm{~m}$ to the height of the net <br> Time taken is given by $1.225=4.9 t^{2}$ <br> So $t=0.5$ <br> Speed must be greater than $\frac{12.5}{0.5}=25 \mathrm{~m} \mathrm{~s}^{-1}$ <br> Not going too far <br> Time to fall to the ground is given by $2.22=4.9 t^{2}$ <br> So $t=0.673 \ldots$ <br> Horizontal distance must not exceed 19 m $\text { Maximum speed }=\frac{19}{0.673 \ldots}=28.227 \ldots \mathrm{~ms}^{-1}$ <br> (Overall) <br> (So the ball's speed must be between 25 and $28.2 \mathrm{~m} \mathrm{~s}^{-1}$.) | M1 <br> A1 <br> A1 <br> M1 <br> A1 <br> A1 | The value of $t$ can be implied and need not be seen. <br> The value of $t$ can be implied and need not be seen. |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [6] |  |


| 7 | (v) | Vertical motion $s=s_{0}+u t+\frac{1}{2} a t^{2}$ <br> Using $\boldsymbol{u}$ to be the initial speed $0=2.22-u \times \sin 2^{\circ} \times 0.57-4.9 \times 0.57^{2}$ $u=\frac{2.22-4.9 \times 0.57^{2}}{0.57 \times \sin 2^{\circ}}$ <br> $u=31.568 \ldots$ so the speed of Tara's serve is $31.6 \mathrm{~m} \mathrm{~s}^{-1}$ | M1 <br> A1 <br> A1 | An equation for vertical motion which could be used to find $u$. It must contain all three elements. No sin-cos interchange. <br> If $\sin 2^{\circ}$ is not seen use the alternative method. <br> The equation must be correct including signs. |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [3] |  |
|  |  | Alternative Using $\boldsymbol{U}$ as the initial vertical component downwards $\begin{aligned} & 0=2.22-U \times 0.57-4.9 \times 0.57^{2} \\ & U=\frac{2.22-4.9 \times 0.57^{2}}{0.57}=1.10173 \ldots \\ & \text { Speed }=\frac{U}{\sin 2^{\circ}}=31.568 \ldots \end{aligned}$ <br> So the speed of Tara's serve is $31.6 \mathrm{~m} \mathrm{~s}^{-1}$ | $\begin{aligned} & \text { M1 } \\ & \text { A1 } \\ & \text { A1 } \end{aligned}$ | Or equivalent for vertical motion upwards <br> The value of $U$ is calculated correctly. <br> It should be negative if the direction of $U$ is upwards. |

7. Alternative mark schemes for parts (ii), (iii) and (iv) using the equation of the trajectory

| 7. | (ii) | $\begin{aligned} & y=y_{0}+x \tan \alpha-\frac{g x^{2}}{2 u^{2} \cos ^{2} \alpha} \\ & y=2.22+0.55 x-0.049 x^{2} \\ & x=12.25 \\ & \Rightarrow y=1.438 \ldots>0.995 \end{aligned}$ | B1 <br> M1 <br> A1 |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [3] |  |
|  | (iii) | $y=2.22+0.55 x-0.049 x^{2}$ | M1 |  |
|  |  | $x=19$ Or $y=0$ <br> $\Rightarrow y=-5.019$ $x=14.376 \ldots \quad($ or $-3.151 \ldots)$ | M1 <br> A1 | Dependent on both M marks |
|  |  | So the ball lands in the service court | A1 |  |
|  |  |  | [4] |  |


| 7 | (iv) | $y=2.22-0.049\left(\frac{x}{u}\right)^{2}$ <br> Clearing the net <br> To clear the net $2.22-4.9\left(\frac{12.5}{u}\right)^{2}>0.995$ $\Rightarrow\left(\frac{u}{12.5}\right)^{2}>\left(\frac{4.9}{1.225}\right)$ <br> Speed must be greater than $\frac{12.5}{0.5}=25 \mathrm{~ms}^{-1}$ <br> Not going too far <br> To land inside the service court, horizontal distance must not exceed $19 \mathrm{~m} \quad \Rightarrow 2.22-4.9 \times\left(\frac{19}{u}\right)^{2}<0$ $\begin{aligned} & \frac{u}{19}<\sqrt{\frac{4.9}{2.22}} \\ & u<28.227 \end{aligned}$ <br> Maximum speed $=28.227 \ldots \mathrm{~ms}^{-1}$ <br> (So the ball's speed must be between 25 and $28.2 \mathrm{~m} \mathrm{~s}^{-1}$.) | M1 <br> A1 <br> B1 <br> M1 <br> A1 <br> A1 |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | [6] |  |

