M1.D

[1]

M2.(a) (i) $\omega \left(= \frac{v}{r} \right) = \frac{8.6}{1.5}$ (= 5.73 rad s^{-1}) ✓

$\theta (= \omega t)$ = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓

= $\frac{2.29}{2\pi}$ × 360 = 130 (131) (degrees) ✓

[**or** s$((= vt)$ = 8.6 × 0.40 (= 3.44 m) ✓

θ = $\frac{3.44}{2\pi \times 1.5}$ × 360 ✓ = 130 (131) (degrees) ✓]

Award full marks for any solution which arrives at the correct answer by valid physics.

3

(ii) tension $F(=m\omega^2 r)$ = 0.25 × 5.73^2 × 1.5 ✓ = 12(.3) (N) ✓

[**or** $F \left(= \frac{mv^2}{r} \right) = \frac{0.25 \times 8.6^2}{1.5}$ ✓ = 12(.3) (N) ✓]

Estimate because rope is not horizontal.

2

(b) maximum $\omega \left(= \sqrt{\frac{F}{mr}} \right) = \sqrt{\frac{60}{0.25 \times 1.5}}$ (= 12.6) (rad s^{-1}) ✓

maximum $f \left(= \frac{\omega}{2\pi} \right) = \frac{12.6}{2\pi}$ = 2.01 (rev s^{-1}) ✓

[**or** maximum $v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{60 \times 1.5}{0.25}}$ (= 19.0) (m s^{-1}) ✓

maximum $f \left(= \frac{v}{2\pi r}\right) = \frac{19.0}{2\pi \times 1.5}$ = 2.01 (rev s^{-1}) ✓]

Allow 2 (rev s^{-1}) for 2nd mark.
Ignore any units given in final answer.

2

(c) **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**
The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton's laws apply to the ball's circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.

*A **high level** answer must give a reasonable explanation of the application of at least two of Newton's laws, and an appreciation of why the rope will not be horizontal.*

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.
The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton's laws applies to the circular motion. The student's understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension.

*An **intermediate level** answer must show a reasonable understanding of how at least one of Newton's laws applies to the swinging ball.*

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The

form and style of writing may be only partly appropriate.
The student has a much weaker knowledge of how Newton's laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.

*A **low level** answer must show familiarity with at least one of Newton's laws, but may not show good understanding of how it applies to this situation.*

References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

- *First law:* ball does not travel in a straight line, so a force must be acting on it
- although the ball has a constant speed its velocity is not constant because its direction changes constantly
- because its velocity is changing it is accelerating
- *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force
- the acceleration (or change in momentum) is in the same direction as the force
- the force is centripetal: it acts towards the centre of the circle
- *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre
- the force acting on the point of support acts outwards
- *Support of ball*: the ball is supported because the rope is not horizontal
- there is equilibrium (or no resultant force) in the vertical direction
- the weight of the ball, mg, is supported by the vertical component of the tension, $F \cos \theta$, where θ is the angle between the rope and the vertical and F is the tension
- the horizontal component of the tension, $F \sin \theta$, provides the centripetal force $m \omega^2 r$

Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.

A reference to Newton's 3rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.

max 6

[13]

M3.(a) (i) Weight / *W* / *mg* − vertically downwards from some point on the body

B1

Friction − vertically upwards and touching both the wall and the body

B1

Centripetal force / normal reaction / R − horizontally to the left from the body
Each must be correct and correctly labelled
Minus one for each additional inappropriate force

B1

3

(ii) Centripetal force / reaction / R is smaller

B1

Frictional force reduces
Frictional force is less than weight
Resultant force is downward
Friction is proportional to (normal) reaction

B1

2

(b) (i) $r\omega^2 = 29$ or
$v^2 / r = 29$

B1

Use of correct radius leading to 3.590 (rad s^{-1}) to at least 3 sig figs

2.54 using wrong r = 1 mark

B1

2

(ii) Angular acceleration, $\alpha = 3.6 / 20$ OR 3.59 / 20 or 0.18 or 0.1795

C1

3.8 (3.77, 3.78) × 10^4 cao

A1

N m or kg m^2 s^{-2}

B1

3

(iii) 2200 N cao

B1

1

(c) (i) C

B1

1

(ii) Speed greatest (as all PE turned to KE)

B1

Total reaction force = $mr\omega^2 + mg$ or $v^2 / r + mg$ or R is largest or
$R = ma + mg$
OR
Acceleration = v^2 / r

B1

2

[14]

M4.C

[1]

M5.C

[1]

M6.D

[1]

M7.B

[1]

M8.D

[1]

M9.C

[1]

M10.D

[1]