1

(a) $v = \omega r$ or $v = \frac{2_{\pi r}}{T}$ or $v = 2\pi rf$

C1

$\omega = 2\pi \times 45 / 60$ or correct substitutions for v

C1

0.59 ms^{-1}

A1

(b) (i) radial arrow from D towards centre of disc

B1

(ii) $a = \frac{v^2}{r}$ or $a = \omega^2 r$ condone $a = \omega^2 x$ **but not** $a = -(2\pi f)^2 x$

2.78 m s^{-2} **but not if shm equation clearly used**

A1

(c) recognition that closer toward centre particles need smaller centripetal force

B1

support for this: $v \propto r$ or ω = constant along disc

B1

idea that friction / electrostatic forces are sufficient to meet the requirements of particles close to centre but not for those further away

B1

[9]

2

(a) (i) a normal reaction shown and labelled on either diagram

B1

a frictional force correctly shown and labelled on either diagram (may be outward on second diagram)

deduct 1 mark for each wrong force (condone poor friction / reaction)

B1

(2)

(ii) friction (between surface and wheel / tyre)

B1

(normal) reaction (at the surface)

B1

horizontal component of either force / component towards the centre

B1

sum of horizontal components

B1

(4)

(b) use of $mg = mv^2 / r$ or $g = v^2r$, centripetal force = mv^2 / r

C1

correct substitution $v^2 = 9.8 \times 5.2$

C1

7.1 m s^{-1}

A1

(3)

[9]

3

(a) lowest energy state/level that the electron can occupy

or state in which electron needs most energy to be released

B1

1

or the level of an unexcited electron (not lowest orbit)

(b) (i) force = mv^2/r or $mr\omega^2$ and $v = r\omega$

B1

$8.1 \times 10^{-8} = 9.1 \times 10^{-31} \times v^2/5.3 \times 10^{-11}$
or (v^2 =) 4.72×10^{12} seen

B1

2.17×106 (m s^{-1})

B1

(ii) $\lambda = h/mv$ or $6.6 \times 10^{-34}/9.1 \times 10^{-31} \times 2.2 \times 10^6$

C1

7

3.3×10^{-10} m

A1

(iii) circumference = $2\pi 5.3 \times 10^{-11} = 3.3 \times 10^{-10}$ m

M1

1 (allow e.c.f. from (ii))

A1

(c) (i) $1.9(4) \times 10^{-18}$ J

B1

(ii) 5.6×10^{-19} J (e.c.f. 2.5×10^{-18} − their (i))

B1

(iii) energy difference $E = 3 \times 10^{-19}$ J
(condone any difference)

C1

$E = hc/\lambda$ *or* $E = hf$ *and* $c = f\lambda$

or their $E = 6.6 \times 10^{-34} \times 3.0 \times 108/\lambda$

C1

6.6 or 6.7×10^{-7} m

A1

5

[13]

4 (a) attempt to use power = *mgh/t* or *P* = *Fv* and *v* = *s/t*

C1

7546/7550/7600

A1

W (allow J s^{-1} and condone N ms^{-1})

B1

3

(b) loss of GPE = 550 × 9.81 × 35 = 189 kJ

C1

gain in KE = $0.5 \times 550 \times 22^2$ = 133 kJ

C1

resistance force = their difference/63 (890 N if correct)

A1

answer to 2 sf (allow if answer is from working even
if incorrect)

B1

4

(c) air resistance varies/increases

B1

frictional force varies/increases

B1

further detail: air resistance increases with speed/v
or normal reaction force varies with angle of the slope

B1

3

(d) use of $F = mv^2/r$

C1

arrives at r = 12 m (ignoring the weight)

C1

16.4 m

A1

3

[13]

5 (a) T = power/ω

Torque = 2500/0.47

5320 N m value to 2 or more sf needed

3

(b) (i) Deceleration= 0.47/34= 0.0138 (rad s^{-2})

moment of inertia = torque / angular deceleration
=5000/0.0138 = 3.57×10^5

kg m^2 (Allow N m s^2)

3.8×10^5 if 5320 used

3

(ii) Suitable equation of motion used with correct data but omitted minus sign

8.0 radian Allow (their $\omega/2\pi$)

1.27 revolutions

Condone 1 revolution

(allowed for thinking question refers to complete revolutions)

3

(c) (i) $F = 65 \times 2.2 \times 0.47^2$

32(31.6 N)

2

(ii) Force produced by friction between the feet and the roundabout

Centripetal force has to act through the centre of mass of the operator
or
The resultant of the frictional force and normal reaction has to pass through the centre of mass

Any indication (eg on diagram) of wrong direction = 0

2

(iii) Ticks 4th box

1

[14]

6 (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]

7

(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) ✓

$\theta = \frac{3.44}{2\pi \times 1.5}$ × 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 3 rd 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

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