Mark schemes

1 (a) (i) $mgh = \frac{1}{2} mv^2$ **or** correct numerical substitution

M1

13.3 m s^{-1}

no marks for use of equation of motion for constant acceleration

allow $gh = mv^2 / 2$ or $v^2 = 2gh$) but not $v^2 = 2as$

A1

(2)

(ii) mv = Ft (or F = ma and a = v / t)

(or numerical equivalent)

C1

48.8 to 50.0 N e.c.f. from (i) {3.75 × (i)}

A1

(2)

(iii) power = energy transformed / time

C1

or power = average force × average velocity

or $P = Fv$ leading to (i) × (ii) (664 W if (i) and (ii) are correct)

330 to 332 W e.c.f. from (i) and / or (ii) {(i) × (ii) / 2}

A1

(2)

(b) (i) the ball accelerates toward centre (of circular path) / the point of suspension / upwards

or the ball is changing direction upwards

B1

centripetal force / resultant force upwards / force towards centre of circular path

or string initially stretches producing an elastic force

B1

(2)

(ii) $T - mg = mv^2 / r$ **or** $F = mv^2 / r$ (or numerical equivalent)

or $F = ma$ **and** $a = v^2 / r$

C1

centripetal / resultant accelerating force = 6.6 N

e.c.f. from (i) (0.0375 × (a)(i)^2)

C1

tension = their centripetal force + 4.4 N (11 N)

A1

(3)

(c) (i) $\frac{1}{2} m(13.3)^2 = \frac{1}{2} mv^2 + mg \times 4.5$

or velocity is same as when falling 4.5 m so $\frac{1}{2} mv^2 = mg \times 4.5$
or KE at bottom = KE at half way + PE

allow $\frac{1}{2} mv^2 = mg \times 4.5$

B1

9.4 m s^{-1} (no marks if 9.4 m s^{-1} arrived at using equation of motion)

B1

(2)

(ii) horizontal velocity is constant after string breaks

or continued movement in the horizontal direction

oridea of KE due to horizontal motion

B1

at max height the ball still has KE so acquires less PE

ornot all KE becomes (gravitational) PE

B1

(2)

orupward velocity = 9.4 sin 51

B1

use of equation of motion leading to 2.72 m after the break

B1

orafter string breaks downward force increases /
the upward force ceases to exist

B1

there is greater vertical deceleration

B1

[15]

2 (a) (i) loss of PE = gain of KE or $mgh = ½mv^2$

allow for statement of conservation of energy

(energy can not be destroyed but can be converted from one form to another)

B1

correct height used (2.4 m or 2 × 1.2 seen in an equation)

B1

correct substitution including values for h and g (no u.p.)

B1

(3)

(ii) $F = mv^2 / r$

(allow $mr\omega^2$

C1

2800 N (2780 N) or

2700 N (2740 N) if using $v = 6.86$ m s^{-1}

A1

(2)

(iii) (ii) + 690 (3500 N or 3460 N)

(3400 N or 3430 N if using $v = 6.86$ m s^{-1})

B1

(1)

(iv) graph shape down up down up (condone linear); minima at 90° and 270°

M1

graph starts at 690 (N); this point labelled;

maximum labelled consistent with answer to (iii),

zero at 90 and 270 (allow any shape between these points)

A1

(2)

(b) stress = F / A and strain = extension /original length **and** E = stress / strain

or

$E = Fl / Ae$

C1

correct substitution using 690 N (condone 700 N)

or substitution with e.c.f. from graph

C1

allow e.c.f. for use of g without substitution if penalised in (i)

$8.9 \times 10^{-6} – 9.1 \times 10^{-6}$ m

A1

allow only 1 mark if candidate divides by 2 at any stage

(3)

[11]

3 (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]

4 C

[1]

5 C

[1]

6 C

[1]

7 C

[1]

8 B

[1]

9 A

[1]

10 A

[1]

11 D

[1]

12 A

[1]

13 C

[1]

14 D

[1]

15 D

[1]

16 A

[1]

17 D

[1]

18 B

[1]

Examiner reports

2 (a) (i) The majority of the candidates appreciated and tried to use the fact that the change in PE would be equal to the gain in KE. The most common error was to use 1.2 m as the change in height of the centre of mass. Even though this gave an incorrect answer few seemed to go back to check why their answer was incorrect.

(ii) Most candidates knew the correct equation and used correct data. Some however tried to use $F = mr\omega^2$, substituting 6.9 m s^{-1} for ω. A significant proportion of the candidates incurred a significant figure penalty in this part.

(iii) This part was not well done. Many candidates gave the answer as the weight of the gymnast mg (690 N) not appreciating that this had to be added to the force determined in (a)(ii). Some subtracted the weight.

(iv) The graph was partly a test in graphing data that had previously been determined and appreciating that in the initial position the force downwards is the weight of the gymnast and realising that the vertical force on the bar would be zero when the gymnast is in the horizontal position. Those who determined the weight in (a)(iii) could gain full marks here as error carried forward. Candidates were not expected to realise that the force acts upwards before this position is reached.

(b) Most candidates were able to quote a correct equation or series of equations. Candidates could gain full credit for using the weight or the value they had plotted on the graph for 0°. Many, however, used the value from part (a)(ii) or an incorrect value from (a)(iii). The 'record' for arm-stretching during this manoeuvre was 10^{13} m, arrived at without comment!

3 (a) (i) Very few candidates got this correct: even those who managed to draw correct forces in the correct places with appropriate labels tended to confuse their work by adding other incorrect forces. There was a surprising number who nominated centrifugal force. Common errors, for those whose answers were along the right lines, were to locate the normal reaction and the frictional forces through the centre of gravity.

(ii) This part was also badly done by many candidates. Quite a few candidates made reference to friction and some mentioned the normal reaction but few specified the horizontal components of these forces. Despite the fact that the diagram clearly showed the weight acting vertically downwards, many candidates thought that the horizontal component of the weight supplied the centripetal force. A large number of weaker candidates thought that the 'origins of the centripetal force' referred to the position from which the force acted.

(b) The calculation was well done by most candidates. A small number of candidates tried to solve the problem by equating potential and kinetic energies.

4 Over 70% of the students gave the required answer in this question but over 20% of them considered that a centripetal acceleration acts along a tangent to the circular path (distractor D).

5 This question had been used in a previous examination. Its facility this time was 67%, a marginal improvement over the value obtained when last used. Problems with algebra led to almost one quarter of the students selecting distractor D, where g appeared in the numerator instead of the denominator of the required fraction.

6 This question had been used in a previous examination, when only half of the students gave the correct response, this time 63% did so. Application of Newton's second law in the form 'resultant force towards centre = mass × centripetal acceleration' easily leads to a correct solution using the algebra. Incorrect responses were fairly evenly spread amongst the other three distractors.

7 Circular motion was also tested in the next two questions. This question solved by combining $F = m\omega^2 r$ and $\omega = 2\pi f$, was found to be easy by the 84% of students who gave the correct answer.

8 This question is a re-banked question, proved to be somewhat more demanding. Its facility was 56%, an improvement of 11% over last time. Possibly it was the use of the diameter of the wheel, instead of its radius, that caused almost a fifth of students to select distractor A, half the expected angular speed.

9 This question, on circular motion, had been used in a previous examination. The facility this time was 62%, an increase of 7% over the previous result. The most common incorrect choices were distractors C and D, each getting 15% of the responses. The popularity of C was probably caused by a failure to understand that momentum is a vector.

10 Knowledge of circular motion was tested in this question, where familiarity with $F = m\omega^2 r$, was the key to success. This turned out to be the easiest question on the paper, with 83% of the candidates giving correct responses; when pre-tested only 44% of answers were correct.

11 This question was a sterner test of motion in a circle, because it was a two-stage calculation with algebraic distractors. Just over half of the candidates arrived at the correct result by combining $a = v^2/r$ and $T = 2\pi r/v$. Almost a quarter of the responses were for distractor C, in which the squarerooted expression (r /a) is inverted. This is likely to have been caused by careless rearrangement of the algebra.

12 This question required candidates to find the linear speed of a point on the edge of a spinning disc. This is a two-stage calculation involving $\omega = \theta/t$ and $v = \omega r$. Candidates also had to appreciate that 30° is equivalent to p/6 rad, and that the radius of a disc is half of its diameter. 49% the candidates arrived at the correct response, whilst a quarter of them chose distractor B, indicating confusion between d and *r*.

13 This question was the first of the re-banked questions from a previous examination. Three-quarters of the candidates were able to correctly combine $v = 2\pi fr$ with $E_k = ½ m v^2$ to arrive at the required algebraic result. Distractor D attracted one in eight responses, suggesting that the factor of ½ had been overlooked.

14 This question was the first of a pair of questions on circular motion, both of which had appeared in previous examinations. The main failing exhibited in the responses was the fact that the ball, once it had broken away from the string, would fall under gravity. Only answer D offered the possibility of some vertical motion and it was chosen by 40% of the candidates. Distractors A and C each attracted 28% of the answers.

15 Candidates found the quantitative content of this question on circular motion more to their liking, because 63% of them chose the correct answer. Both of these questions gave statistics which were very similar to those obtained when last used.

16 This question proved to be the easiest question, with a facility of 87%. Application of $\omega = 2\pi/T$ with *T* equal to the period of Earth's rotation readily gave the correct answer.

17 This question asked candidates to identify a situation in which centripetal force would **not** be involved, so they ought to have known to look for the answer that did not involve circular motion. 61% realised that this was the α particle in an electric field, where the trajectory would be parabolic rather than circular. However, 30% of the candidates chose distractor C, where the α particle was in a magnetic field.

18 This question invited candidates to compare the accelerations of a mass in shm and an object in uniform circular motion. 67% of the candidates recognised that these accelerations would have opposite directions at time intervals of 772, but almost one fifth of them thought it would be 774. This question was not very successful at discriminating between more and less able candidates.