1 A particle moves in a circular path at constant speed. Which one of the following statements is correct?

A The velocity of the particle is directed towards the centre of the circle.

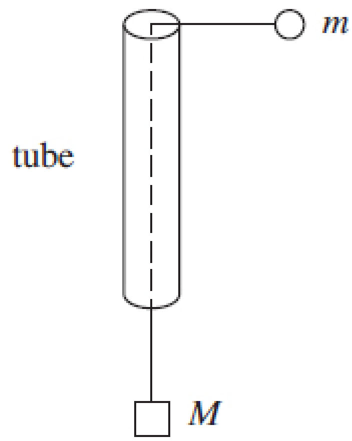
B There is no force acting on the particle.

C There is no change in the kinetic energy of the particle.

D The particle has an acceleration directed along a tangent to the circle.

(Total 1 mark)

2 The diagram shows a smooth thin tube through which passes a string with masses *m* and *M* attached to its ends. The tube is moved so that the mass *m* travels in a horizontal circle of constant radius *r* at constant speed *v*.



Which one of the following expressions is equal to *M*?

A $\frac{mv^2}{2r}$

B mv^2rg

C $\frac{mv^2}{rg}$

D $\frac{mv^2g}{r}$

(Total 1 mark)

3 A mass on the end of a spring undergoes vertical simple harmonic motion. At which point(s) is the magnitude of the resultant force on the mass a minimum?

A at the centre of the oscillation

B only at the top of the oscillation

C only at the bottom of the oscillation

D at both the top and bottom of the oscillation

(Total 1 mark)

4 A baby bouncer consisting of a harness and elastic ropes is suspended from a doorway. When a baby of mass 10 kg is placed in the harness, the ropes stretch by 0.25 m. When the baby bounces, she starts to move with vertical simple harmonic motion. What is the time period of her motion?

A 1.0 s

B 2.1 s

C 2.3 s

D 3.1 s

(Total 1 mark)

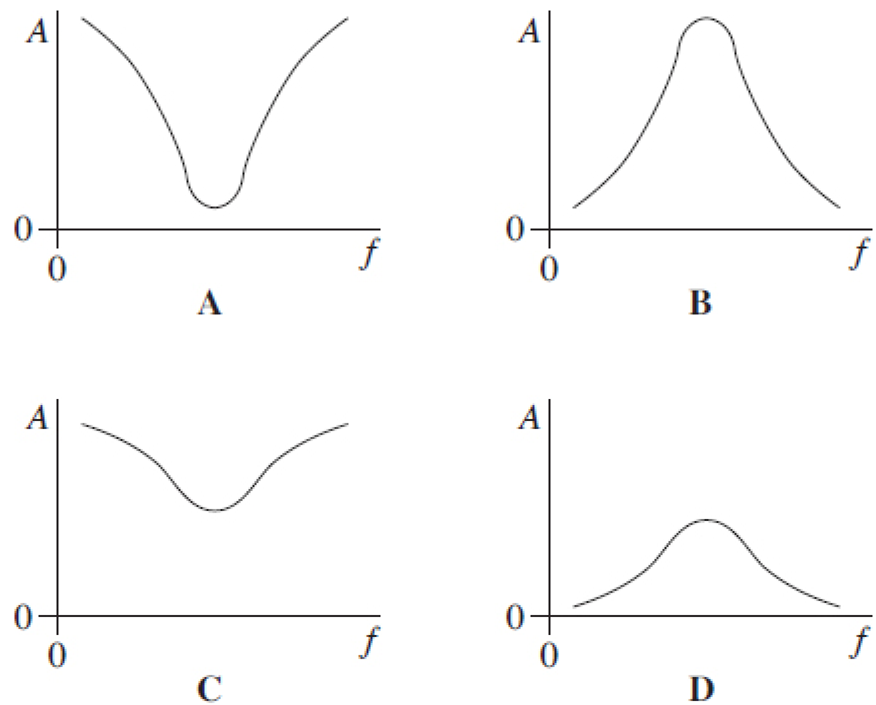
5 A simple pendulum and a mass-spring system both have the same time period *T* at the surface of the Earth. If taken to another planet where the acceleration due to gravity is twice that on Earth, which line, **A** to **D**, in the table gives the correct new time periods?

	simple pendulum	**mass-spring**
A	$T\sqrt{2}$	$\frac{T}{\sqrt{2}}$
B	$T\sqrt{2}$	T
C	$\frac{T}{\sqrt{2}}$	T
D	$\frac{T}{\sqrt{2}}$	$T\sqrt{2}$

(Total 1 mark)

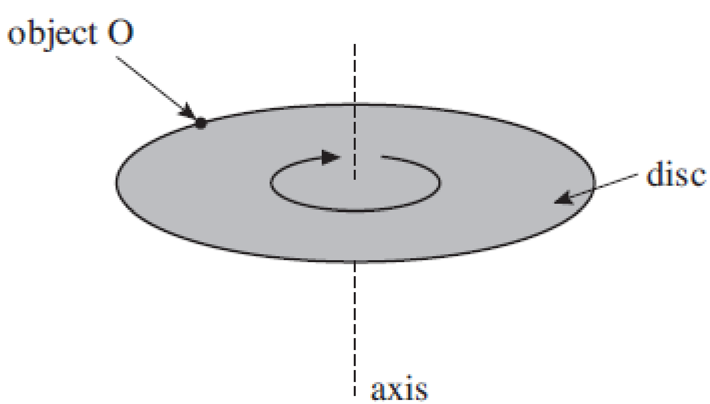
6 An oscillatory system, subject to damping, is set into vibration by a periodic driving force of frequency *f*. The graphs, **A** to **D**, which are to the same scale, show how the amplitude of vibration *A* of the system might vary with *f*, for various degrees of damping.

Which graph best shows the lightest damping?



(Total 1 mark)

7 A disc of diameter *D* is turning at a steady angular speed at frequency *f* about an axis through its centre.



What is the centripetal force on a small object O of mass *m* on the perimeter of the disc?

A $2\pi mfD$

B $2\pi mf^2D$

C $2\pi^2mf^2D$

D $2\pi mf^2D^2$

(Total 1 mark)

8 What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is 108 km h^{-1}?

A 75 rad s^{-1}

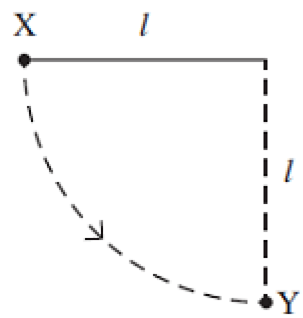
B 150 rad s^{-1}

C 270 rad s^{-1}

D 540 rad s^{-1}

(Total 1 mark)

9 A ball of mass m, which is fixed to the end of a light string of length l, is released from rest at X. It swings in a circular path, passing through the lowest point Y at speed v.



If the tension in the string at Y is T, which one of the following equations represents a correct application of Newton's laws of motion to the ball at Y?

A $T = \frac{mv^2}{l} - mg$

B $mg - T = \frac{mv^2}{l}$

C $T - mg = \frac{mv^2}{l}$

D $T + \frac{mv^2}{l} = mg$

(Total 1 mark)

10 Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

A The acceleration is always directed away from O.

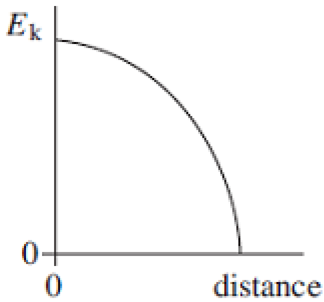
B The acceleration and velocity are always in opposite directions.

C The acceleration and the displacement from O are always in the same direction.

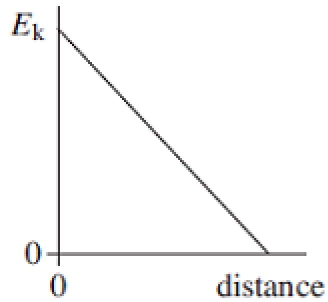
D The graph of acceleration against displacement is a straight line.

(Total 1 mark)

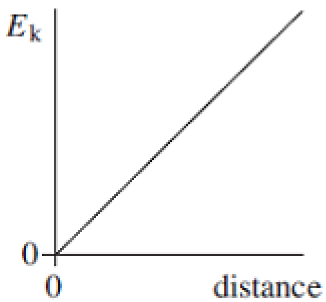
11 A body executes simple harmonic motion. Which one of the graphs, **A** to **D**, best shows the relationship between the kinetic energy, E_k, of the body and its distance from the centre of oscillation?



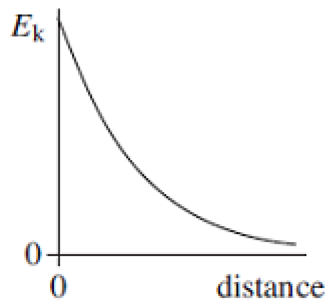
A



B



C



D

(Total 1 mark)

12 A mechanical system is oscillating at resonance with a constant amplitude. Which one of the following statements is **not** correct?

A The applied force prevents the amplitude from becoming too large.

B The frequency of the applied force is the same as the natural frequency of oscillation of the system.

C The total energy of the system is constant.

D The amplitude of oscillations depends on the amount of damping.

(Total 1 mark)

13 For a particle moving in a circle with uniform speed, which one of the following statements is correct?

A The kinetic energy of the particle is constant.

B The force on the particle is in the same direction as the direction of motion of the particle.

C The momentum of the particle is constant.

D The displacement of the particle is in the direction of the force.

(Total 1 mark)

14 A young child of mass 20 kg stands at the centre of a uniform horizontal platform which rotates at a constant angular speed of 3.0 rad s^{-1}. The child begins to walk radially outwards towards the edge of the platform. The maximum frictional force between the child and the platform is 200 N. What is the maximum distance from the centre of the platform to which the child could walk without the risk of slipping?

A 1.1 m

B 1.3 m

C 1.5 m

D 1.7 m

(Total 1 mark)

15 The time period of a pendulum on Earth is 1.0 s. What would be the period of a pendulum of the same length on a planet with half the density but twice the radius of Earth?

A 0.5 s

B 1.0 s

C 1.4 s

D 2.0 s

(Total 1 mark)

16 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.

B It is in the same direction as the displacement.

C It is in the opposite direction to the velocity.

D It is proportional to the displacement.

(Total 1 mark)

17 A satellite of mass *m* travels in a circular orbit of radius *r* around a planet of mass *M*. Which one of the following expressions gives the angular speed of the satellite?

A $\sqrt{GMr}$

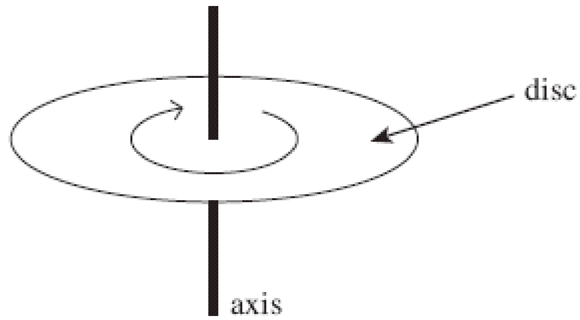
B $\sqrt{Gmr}$

C $\sqrt{\frac{Gm}{r^3}}$

D $\sqrt{\frac{GM}{r^3}}$

(Total 1 mark)

18 The diagram shows a disc of diameter 120 mm that can turn about an axis through its centre.



The disc is turned through an angle of 30° in 20 ms. What is the average speed of a point on the edge of the disc during this time?

A 0.5π m s^{-1}

B π m s^{-1}

C 1.5π m s^{-1}

D 2π m s^{-1}

(Total 1 mark)

19 A particle of mass *m* moves in a circle of radius *r* at a uniform speed with frequency *f*.
What is the kinetic energy of the particle?

A $\frac{mf^2r^2}{4\pi^2}$

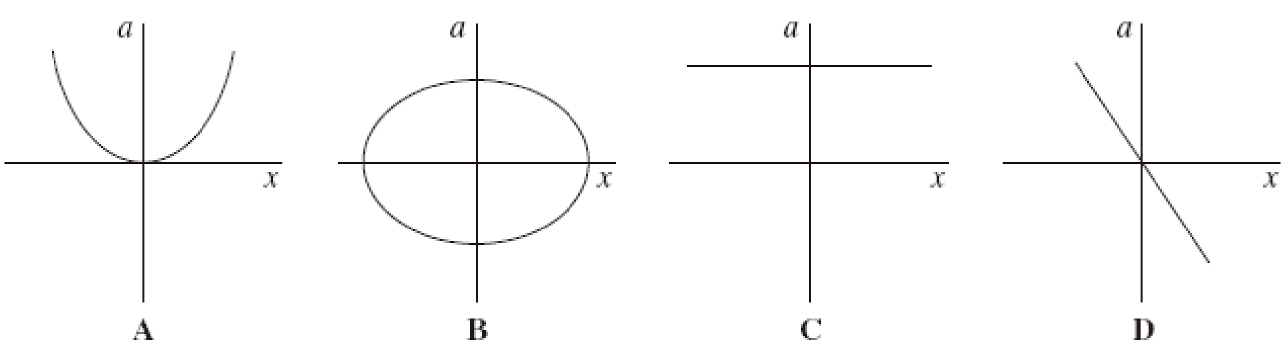
B $\frac{mf^2r}{2}$

C $2\pi^2 mf^2r^2$

D $4\pi^2 mf^2r^2$

(Total 1 mark)

20 Which one of the following graphs shows how the acceleration, *a*, of a body moving with simple harmonic motion varies with its displacement, *x*?



(Total 1 mark)

21 A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.

What is the magnitude of the acceleration when the body is at maximum displacement?

A zero

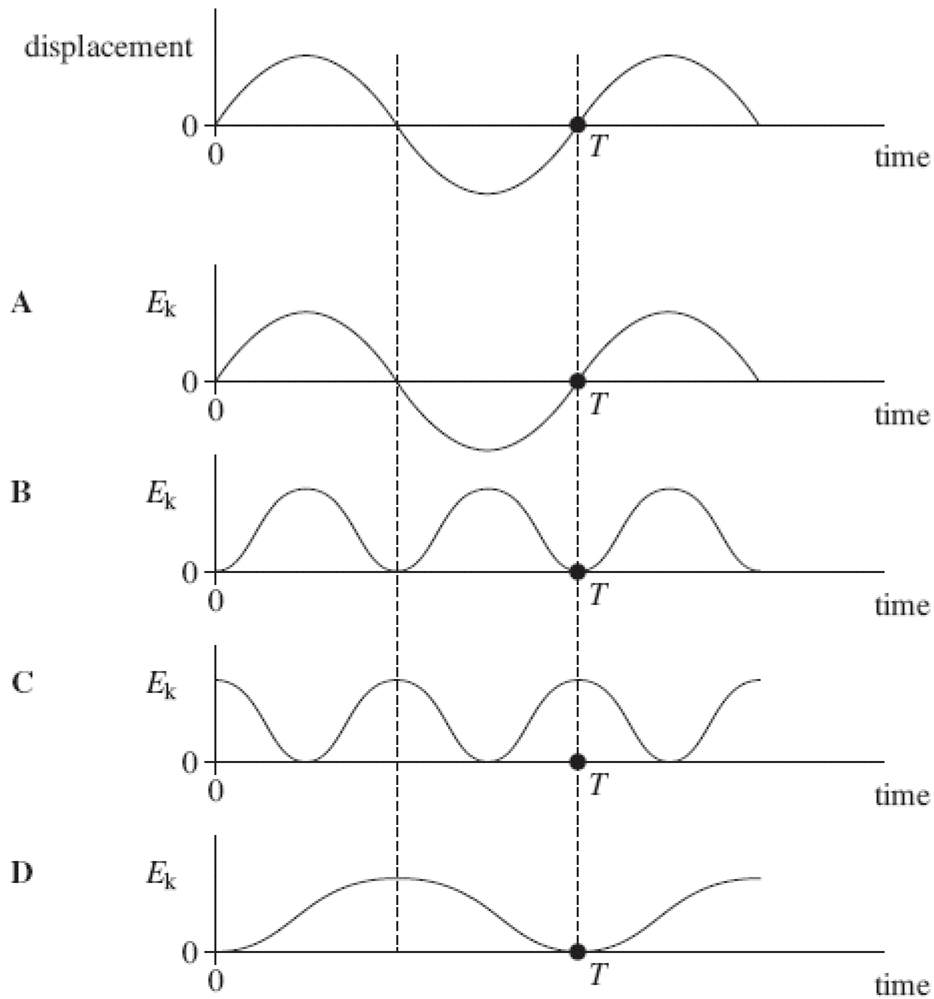
B $4\pi^2 A b^2$

C $A b^2$

D $\frac{4\pi^2 A}{b^2}$

(Total 1 mark)

22 An object oscillating in simple harmonic motion has a time period T. The first graph shows how its displacement varies with time. Which of the subsequent graphs, **A** to **D**, show how the kinetic energy, E_k, of the object varies with time?



(Total 1 mark)

23 The period of vertical oscillation of a mass-spring system is T when the spring carries a mass of 1.00 kg. What mass should be added to the 1.00 kg if the period is to be increased to 1.50 T?

A 0.25 kg

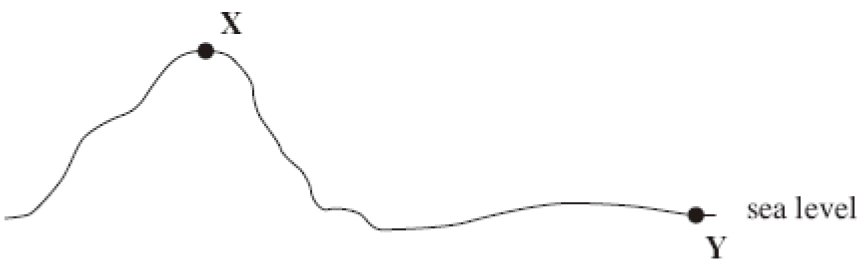
B 1.00 kg

C 1.25 kg

D 2.00 kg

(Total 1 mark)

24 The diagram shows two positions, **X** and **Y**, on the Earth's surface.



Which line, **A** to **D**, in the table gives correct comparisons at **X** and **Y** for gravitational potential and angular velocity?

	gravitational potential at X compared with Y	**angular velocity at X compared with Y**
A	greater	greater
B	greater	same
C	greater	smaller
D	same	same

(Total 1 mark)

25 What would the period of rotation of the Earth need to be if objects at the equator were to appear weightless?

radius of Earth = 6.4×10^6 m

A 4.5×10^{-2} hours

B 1.4 hours

C 24 hours

D 160 hours

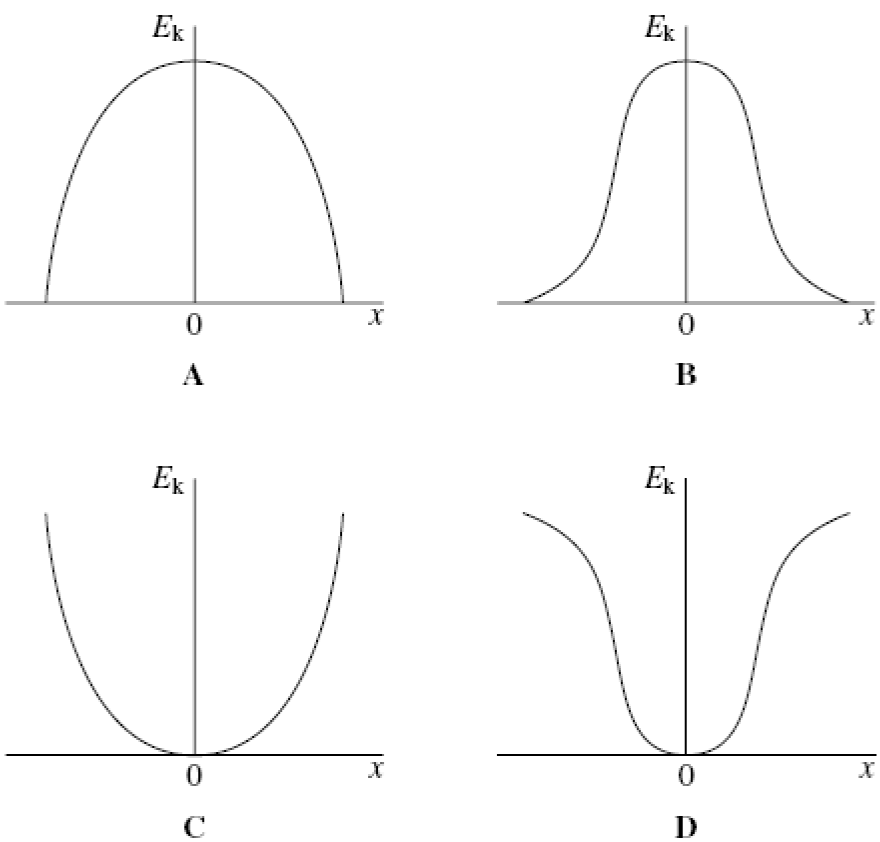
(Total 1 mark)

26 The time period of oscillation of a simple pendulum of length *l* is the same as the time period of oscillation of a mass *M* attached to a vertical spring. The length and mass are then changed. Which row, **A** to **D**, in the table would give a simple pendulum with a time period twice that of the spring oscillations?

	new pendulum length	**new mass on spring**
A	$2l$	$2M$
B	$2l$	$\frac{M}{2}$
C	$\frac{l}{2}$	$2M$
D	$\frac{l}{2}$	$\frac{M}{2}$

(Total 1 mark)

27 Which graph, **A** to **D**, shows the variation of the kinetic energy, E_k, with displacement x for a particle performing simple harmonic motion?



(Total 1 mark)

28 A mass on the end of a string is whirled round in a horizontal circle at increasing speed until the string breaks. The subsequent path taken by the mass is

A a straight line along a radius of the circle.

B a horizontal circle.

C a parabola in a horizontal plane.

D a parabola in a vertical plane.

(Total 1 mark)

29 A particle of mass *m* moves in a circle of radius *r* at uniform speed, taking time ***T*** for each revolution. What is the kinetic energy of the particle?

A $\frac{\pi^2 mr}{T^2}$

B $\frac{\pi^2 mr^2}{T^2}$

C $\frac{2\pi^2 mr^2}{T}$

D $\frac{2\pi^2 mr^2}{T^2}$

(Total 1 mark)

30 A body moves with simple harmonic motion of amplitude 0.90 m and period 8.9 s. What is the speed of the body when its displacement is 0.70 m?

A 0.11 m s^{-1}

B 0.22 m s^{-1}

C 0.40 m s^{-1}

D 0.80 m s^{-1}

(Total 1 mark)

31 What is the angular speed of a point on the Earth's equator?

A 7.3×10^{-5} rad s^{-1}

B 4.2×10^{-3} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 15 rad s^{-1}

(Total 1 mark)

32 Which one of the following does **not** involve a centripetal force?

A an electron in orbit around a nucleus

B a car going round a bend

C an α particle in a magnetic field, travelling at right angles to the field

D an α particle in a electric field, travelling at right angles to the field

(Total 1 mark)

33 Which one of the following gives the phase difference between the particle velocity and the particle displacement in simple harmonic motion?

A $\frac{\pi}{4}$ rad

B $\frac{\pi}{2}$ rad

C $\frac{3\pi}{4}$ rad

D 2π rad

(Total 1 mark)

34 A mass *M* hangs in equilibrium on a spring. *M* is made to oscillate about the equilibrium position by pulling it down 10 cm and releasing it. The time for *M* to travel back to the equilibrium position for the first time is 0.50 s. Which row, **A** to **D**, in the table is correct for these oscillations?

	amplitude / cm	**period / s**
A	10	1.0
B	10	2.0
C	20	2.0
D	20	1.0

(Total 1 mark)

35 Which one of the following statements concerning forced vibrations and resonance is correct?

A An oscillating body that is not resonating will return to its natural frequency when the forcing vibration is removed.

B At resonance, the displacement of the oscillating body is 180° out of phase with the forcing vibration.

C A pendulum with a dense bob is more heavily damped than one with a less dense bob of the same size.

D Resonance can only occur in mechanical systems.

(Total 1 mark)

Mark schemes

1 C **[1]**

2 C **[1]**

3 A **[1]**

4 A **[1]**

5 C **[1]**

6 B **[1]**

7 C **[1]**

8 B **[1]**

9 C **[1]**

10 D **[1]**

11 A **[1]**

12 A **[1]**

13 A **[1]**

14 A **[1]**

15 B **[1]**

16 C **[1]**

17 D **[1]**

18 A [1]

19 C [1]

20 D [1]

21 C [1]

22 C [1]

23 C [1]

24 B [1]

25 B [1]

26 B [1]

27 A [1]

28 D [1]

29 D [1]

30 C [1]

31 A [1]

32 D [1]

33 B [1]

34 B [1]

35 A [1]

Examiner reports

1 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).

2 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.

3 This question required students to identify the point (or points) at which the resultant force is a *minimum* when a mass on a spring moves with simple harmonic motion. Almost 60% of them recognised that this could only be at the central point of the oscillation. The most common incorrect response was distractor D (top and bottom of the oscillation), suggesting that there was confusion between the *minimum* and the *maximum* resultant force.

4 This question was a fairly direct test of $T = 2\pi(m/k)^{1/2}$ for a mass-spring system, but the spring constant k had to be determined first. The question turned out to be remarkably easy, with over 80% of students giving the correct response. When this question was pre-tested, only half of the students had done so.

5 This question about removing a simple pendulum and a mass-spring system from the Earth to another planet and determining the revised time periods, was a re-banked question from an earlier examination. Its facility in 2012 was 63%, which was a substantial improvement over the previous occasion, but its discrimination was slightly worse this time. Distractor B, chosen by 20% of the students, was the most popular incorrect choice.

6 This question presented students with four amplitude–frequency graphs for a resonant system, from which they were to select the best illustration of light damping. Around half of the students had this correct; incorrect answers were evenly distributed around the 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 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.

10 This question also re-banked questions, were about features of simple harmonic motion. Their facilities were 67% and 61% respectively, both significant improvements on the previous results.Those who chose distractor D in Question 7 (22% of students) clearly realised that the graph of kinetic energy against distance should be curved, but they chose the wrong shape of curve.

11 This question also re-banked questions, were about features of simple harmonic motion. Their facilities were 67% and 61% respectively, both significant improvements on the previous results.Those who chose distractor D (22% of students) clearly realised that the graph of kinetic energy against distance should be curved, but they chose the wrong shape of curve.

12 This question required students to choose an incorrect statement about a mechanical system oscillating at resonance. The question had been used in a 2004 examination when it was found to be easy. It proved to be slightly easier this time, with 72% of responses correct. None of the three distractors attracted a response that was significantly higher than the others.

13 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.

14 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.

15 This question was much more demanding because it required application of the relationship between mass and density for a uniform sphere, as well as $g = GM\ IR^2$. Just 41% of the responses were correct.

16 Candidates for this test were slightly less familiar with the direction of the damping force acting on a vibrating system, required in this question, than those in 2005 when this question was last used. On both occasions about three-fifths of candidates made the right choice. Incorrect responses were fairly evenly spread across the other distractors.

17 This question, with a facility of 71%, required the angular speed of a satellite in circular orbit to be found and appeared to cause little difficulty.

18 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*.

19 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.

20 In this question candidates had to know how the acceleration-displacement relationship for a simple harmonic oscillator translates into a graph; linear but having a negative gradient. Slightly less than half of the candidates chose the correct response. Almost as many chose distractor A, which would be the potential energy-displacement graph.

21 This question was concerned with simple harmonic motion. Candidates found the question, which had appeared in a previous examination, slightly easier than last time; three-quarters of them successfully applied $a = (2\pi f)^2 A$ to give the correct answer. This was the most discriminating question in the examination.

22 This question was another easy question, the correct kinetic energy-time graph being recognised by over 80% of the candidates.

23 Calculation of the *additional* mass to be placed on a vertical spring in order to increase the period of oscillations by half was the task in this question. 66% of the candidates did this correctly. Distractor A (where the value was 0.25 kg instead of the correct 1.25 kg) was the most popular alternative; it was chosen by about one-sixth of candidates.

24 This question was a re-banked question about the gravitational potential and angular velocity at two points whose height above the Earth's surface was different. The outcome was a very similar facility to that obtained on the previous occasion, with half of the candidates appreciating that the point at greater height would have greater V but the same ω. More than a quarter of responses were for distractor C (greater V, smaller ω) and almost a fifth for distractor A (both V and ω greater).

25 This question required familiarity with the idea that a body appears to become weightless when its centripetal acceleration is just equal to the local value of the acceleration due to gravity. Hence, if this were to happen at the surface of the Earth, $\omega^2 R$ would have to equal 9.81 m s^{-2}. The question had a facility of 55%, but one in five candidates selected distractor A.

26 Knowledge of both the simple pendulum and the mass spring system was required in this question. Application of the time period formulae should have led students to conclude that, since under the new conditions $T_{pendulum} = 2T_{spring}$, the new pendulum length should be four times greater than the new mass on the spring. 62% of the candidates made this correct choice, but (like the preceding question) this question did not discriminate well between the candidates.

27 In this question, 64% of the responses were for the correct shape of E_k against x curve. By selecting distractor B, 25% of the candidates showed that they understood the trend of the Ek cbehaviour but not the exact form of it.

28 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.

29 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.

30 This question does not appear to be easy – albeit it that a correct answer only requires care when working out the result from three values substituted into $v = \pm 2\pi f (A^2 - x^2)$. Yet, as on the previous occasion when this question was used, it turned out to have the highest facility on the paper – it was 88% this time.

31 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.

32 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.

33 This question, about phase differences in shm, had a facility of 72% but did not discriminate very well. 17% chose distractor A ($\pi/4$ instead of $\pi/2$); this may have been caused by a misunderstanding of the radian to degree conversion.

34 This question was concerned with the amplitude and period of a mass-spring system. The facility was 63%, but one in five of the candidates selected distractor A – where the amplitude was correct but the period was 1.0s instead of 2.0s. Answers in Section B also showed that there was widespread misunderstanding of what is meant by the time taken for *one oscillation*.

35 This question, on forced vibrations, had a facility of 59% and did not discriminate very well. Distractor B, where a phase relation was involved, attracted 23% of the candidates. This again may be an indication of a misunderstanding of phase angles, because the angle in the situation described is 90°, not 180°.