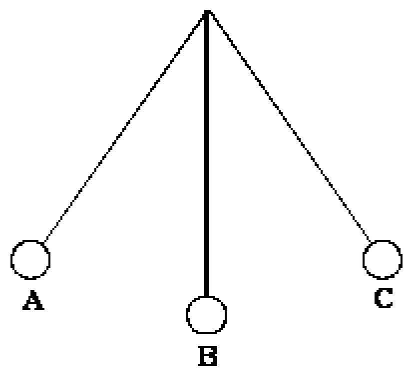
1 The diagram below shows a simple pendulum that consists of a large mass at the end of a long string. **A**, **B** and **C** are positions of the pendulum as it oscillates in the air. **A** and **C** are the extreme positions of the motion and **B** is the centre of the motion.



(a) State clearly in terms of the positions shown on the diagram what is meant by the *period of oscillation* of the pendulum.

___

___

___

___

(2)

(b) The diagram shows positions of the bob during an oscillation. State at which position the damping is greatest. Explain why the damping is greatest in the position you have quoted.

___

___

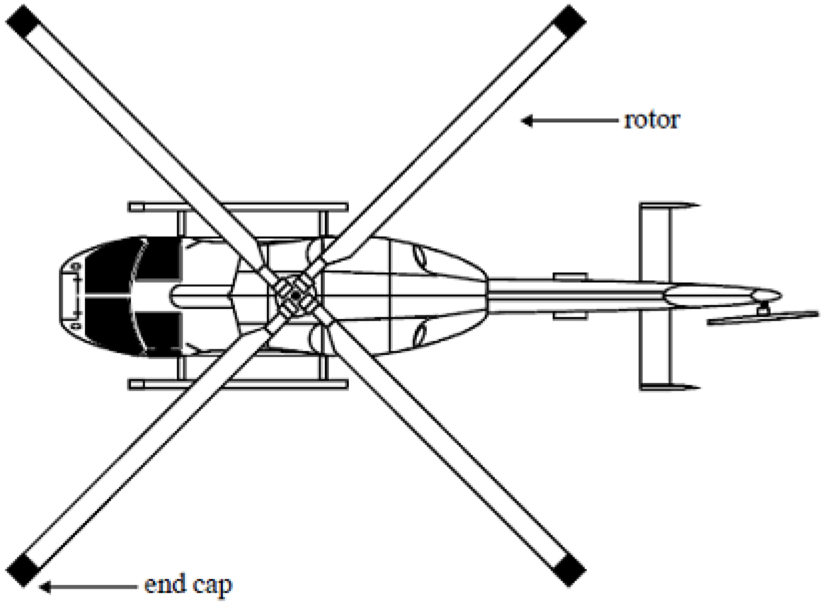
___

___

(3)

(Total 5 marks)

2 The diagram below shows the rotor-blade arrangement used in a model helicopter. Each of the blades is 0.55 m long with a uniform cross-sectional area of 3.5×10^{-4} m^2 and negligible mass. An end-cap of mass 1.5 kg is attached to the end of each blade.



(a) (i) Show that there is a force of about 7 kN acting on each end-cap when the blades rotate at 15 revolutions per second.

(3)

(ii) State the direction in which the force acts on the end-cap.

____

(1)

(iii) Show that this force leads to a longitudinal stress in the blade of about 20 MPa.

(2)

(iv) Calculate the change in length of the blade as a result of its rotation.

Young modulus of the blade material = 6.0×10^{10} Pa

(2)

(v) Calculate the total strain energy stored in one of the blades due to its extension.

(2)

(b) The model helicopter can be made to hover above a point on the ground by directing the air from the rotors vertically downwards at speed v.

(i) Show that the change in momentum of the air each second is $A\rho v^2$, where A is the area swept out by the blades in one revolution and ρ is the density of air.

(2)

(ii) The model helicopter has a weight of 900 N. Calculate the speed of the air downwards when the helicopter has no vertical motion.

Density of air = 1.3 kg m^{-3}

(3)
(Total 15 marks)

3 A gymnast does a hand-stand on a horizontal bar. The gymnast then rotates in a vertical circle with the bar as a pivot. The gymnast and bar remain rigid during the rotation and when friction and air resistance are negligible the gymnast returns to the original stationary position.

Figure 1 shows the gymnast's position at the start and **Figure 2** shows the position after completing half the circle.

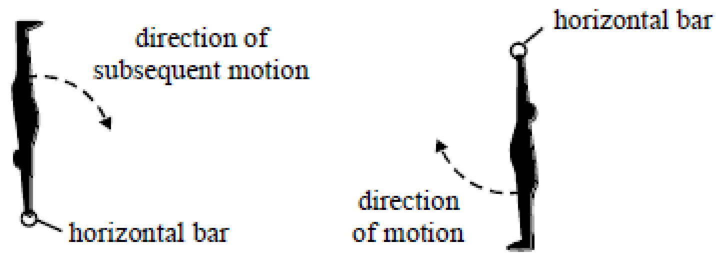


Figure 1 **Figure 2**

(a) The gymnast has a mass of 70 kg and the centre of mass of the gymnast is 1.20 m from the axis of rotation.

acceleration of free fall, g = 9.8 m s^{-2}

(i) Show clearly how the principle of conservation of energy predicts a speed of 6.9 m s^{-1} for the centre of mass when in the position shown in **Figure 2**.

(3)

(ii) The maximum force on the arms of the gymnast occurs when in the position shown in **Figure 2**.

Calculate the centripetal force required to produce circular motion of the gymnast when the centre of mass is moving at 6.9 m s^{-1}.

(2)

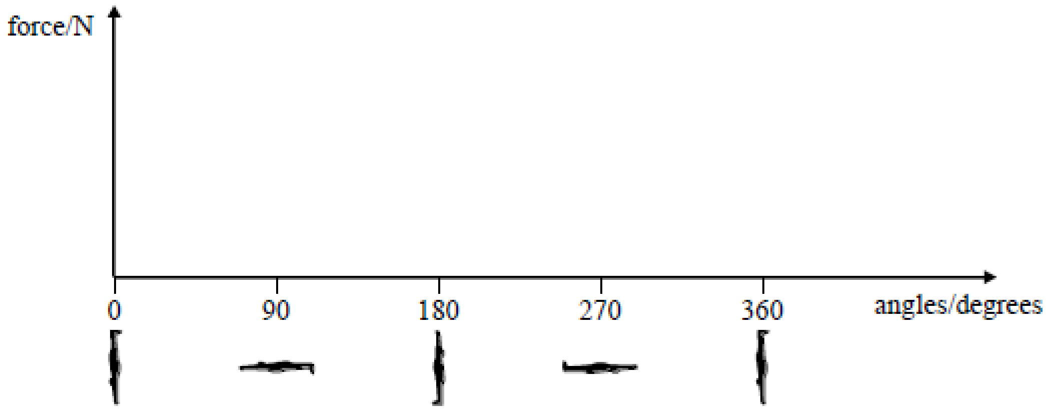
(iii) Determine the maximum tension in the arms of the gymnast when in the position shown in **Figure 2**.

(1)

(iv) Sketch a graph to show how the **vertical** component of the force **on the bar** varies with the angle rotated through by the gymnast during the manoeuvre. Assume that a downward force is positive.

Include the values for the initial force and the maximum force on the bar.

Only show the general shape between these values.



(2)

(b) The bones in each forearm have a length of 0.25 m. The total cross-sectional area of the bones in both forearms is 1.2×10^{-3} m^2 . The Young modulus of bone in compression is 1.6×10^{10} Pa.

Assuming that the bones carry all the weight of the gymnast, calculate the reduction in length of the forearm bones when the gymnast is in the start position shown in **Figure 1**.

(3)
(Total 11 marks)

4 (a) **Figure 1** and **Figure 2** each show a car travelling in a horizontal circular path.

(i) Draw and label on **Figure 1** and **Figure 2** arrows to indicate the other forces acting on the cars.

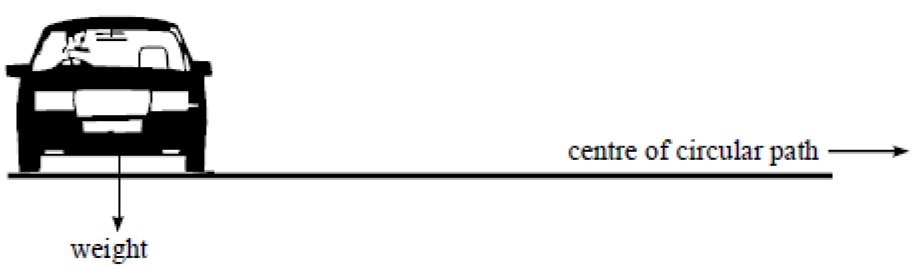


Figure 1

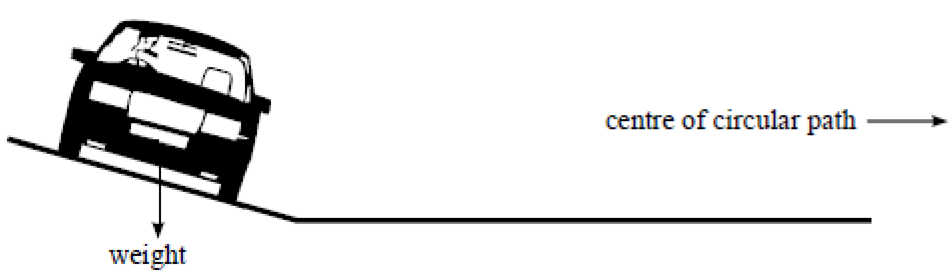


Figure 2

(2)

(ii) State the possible origins of the centripetal force on the car in **Figure 2**.

(4)

(b) **Figure 3** shows a motorcycle stunt rider travelling around a track in a vertical circle of radius 5.2 m. At position **Q**, when the speed is the minimum necessary to keep the motorcycle in contact with the track, the centripetal force is supplied by the weight of the motorcycle and rider. The combined mass of the motorcycle and rider is 220 kg.

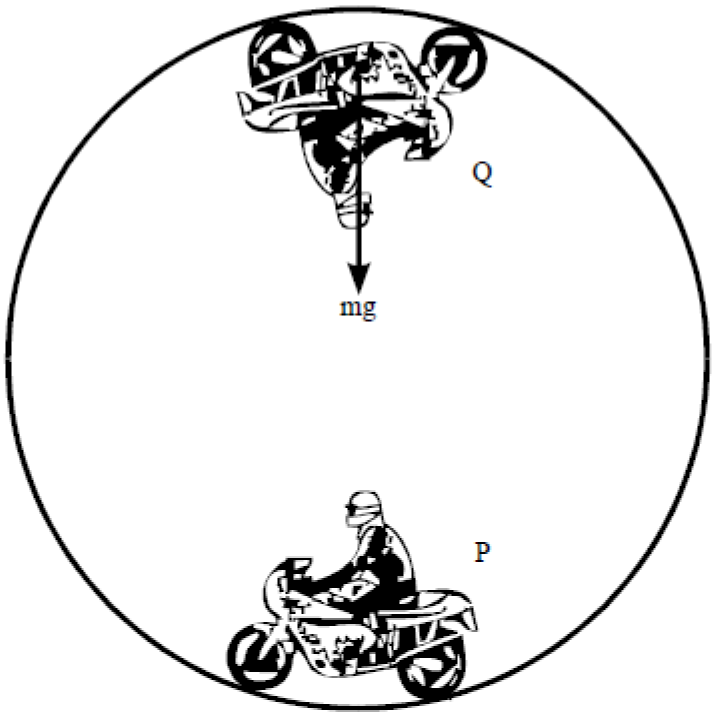


Figure 3

Calculate the minimum speed which will keep the motorcycle in contact with the track at position **Q**. The acceleration due to gravity, g, is 9.8 m s^{-2}.

(3)
(Total 9 marks)

5 **Figure 1** shows an apparatus for investigating forced vibrations and resonance of a mass-spring system. **Figure 2** shows the displacement-time graph when the system is resonating.

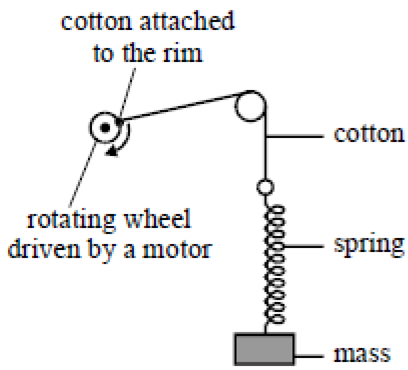


Figure 1

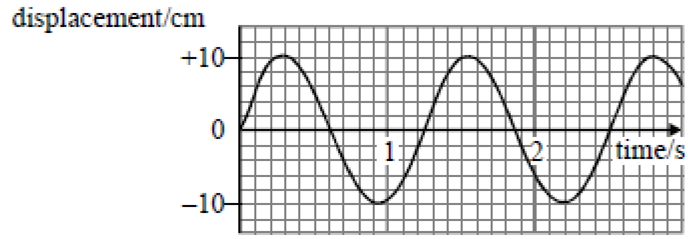


Figure 2

(a) (i) State what is meant by a forced vibration.

(1)

(ii) Under what condition will resonance occur in the system shown in **Figure 1**?

(1)

(b) The spring constant of the spring used in the experiment was 9.0 N m^{-1}. Using information from **Figure 2**, determine the value of the mass suspended from the spring.

(3)

(c) When the rotating wheel stops, **Figure 3** shows how the amplitude of the oscillations of the mass subsequently varies with time.

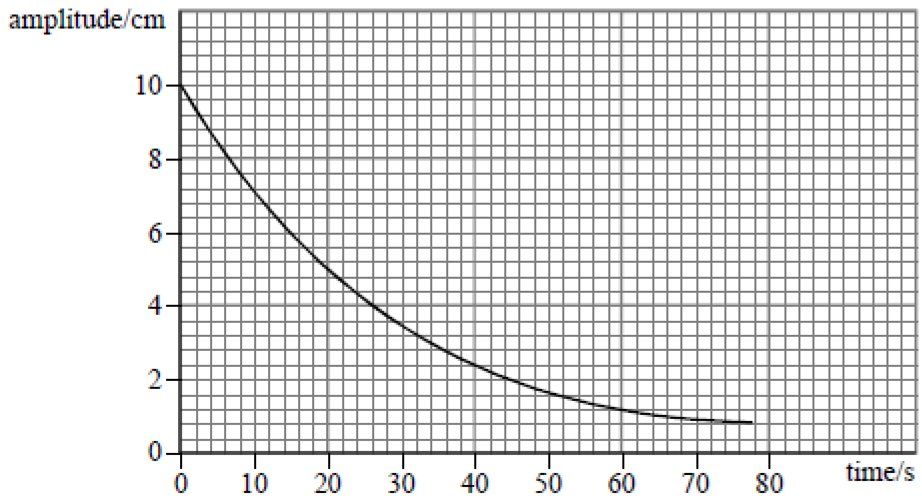


Figure 3

(i) Explain whether the graph supports the suggestion that the amplitude of the damped oscillations varies exponentially with time. Show your reasoning clearly.

____

____

____

____

____

____

(3)

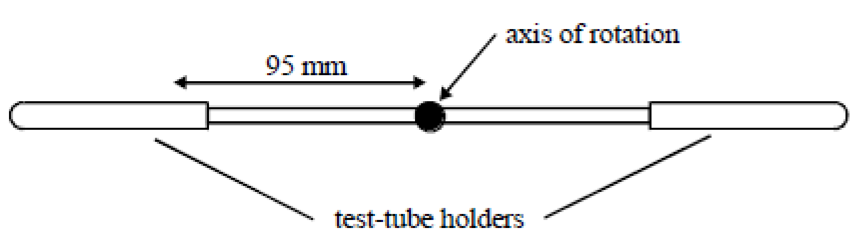
(ii) Determine the ratio:

$$\frac{\text{energy of the oscillator after twenty oscillations}}{\text{energy of the oscillator at time } t = 0}$$

(2)

(Total 10 marks)

6 A chemical centrifuge consists of two test-tube holders which can be spun round in a horizontal circular path at very high speed as shown. The centrifuge runs at a steady speed of 3000 revolutions per minute and the test-tube holders are horizontal.



(a) Calculate the angular speed of the centrifuge in rad s^{-1}.

(b) Calculate the magnitude of the acceleration at a point on the centrifuge 95 mm from the axis of rotation.

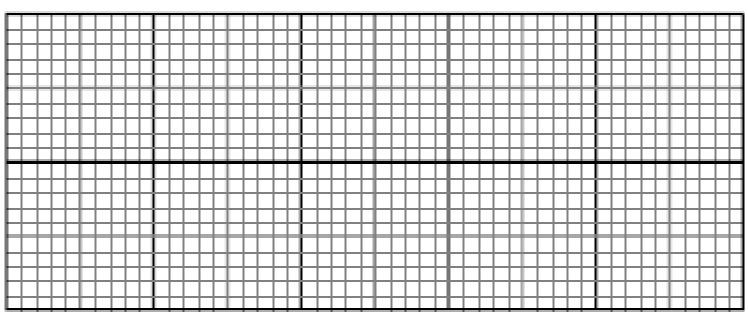
(c) State the direction of the acceleration in part (ii).

(Total 5 marks)

7 A spring, which obeys Hooke's law, hangs vertically from a fixed support and requires a force of 2.0 N to produce an extension of 50 mm. A mass of 0.50 kg is attached to the lower end of the spring. The mass is pulled down a distance of 20 mm from the equilibrium position and then released.

(a) (i) Show that the time period of the simple harmonic vibrations is 0.70 s.

(ii) Sketch the displacement of the mass against time, starting from the moment of release and continuing for two oscillations. Show appropriate time and distance scales on the axes.



(5)

(b) The mass-spring system described in part (a) is attached to a support which can be made to vibrate vertically with a small amplitude. Describe the motion of the mass-spring system with reference to frequency and amplitude when the support is driven at a frequency of

(i) 0.5 Hz,

(ii) 1.4 Hz.

____

____

____

(3)

(Total 8 marks)

8 The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

(a) Calculate the angular speed of the Hubble telescope, stating an appropriate unit.

answer = ________________________

(3)

(b) (i) Calculate the radius of the orbit of the Hubble telescope.

answer = ________________________ m

(3)

(ii) The mass of the Hubble telescope is 1.1×10^4 kg. Calculate the magnitude of the centripetal force that acts on it.

answer = ________________________ N

(2)

(Total 8 marks)

9 A simple pendulum has a time period of 1.42 s on Earth. The gravitational field strength at the surface of Mars is 0.37 times that at the surface of the Earth.
What is the time period of the pendulum on Mars?

A 0.53 s

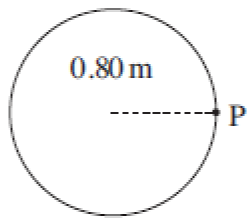
B 0.86 s

C 2.33 s

D 3.84 s

(Total 1 mark)

10 A model car moves in a circular path of radius 0.80 m at an angular speed of $\frac{\pi}{2}$ rad s^{-1}.



What is its displacement from point P 6.0 s after passing P?

A zero

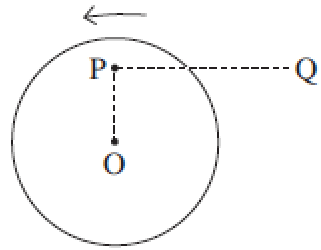
B 0.4π m

C 1.6 m

D 1.6π m

(Total 1 mark)

11 A small mass is placed at P on a horizontal disc which has its centre at O. The disc rotates anti-clockwise about a vertical axis through O with constant angular speed.



Which one of the following describes the force which keeps the mass at rest relative to the disc when in the position shown?

A the weight of the mass

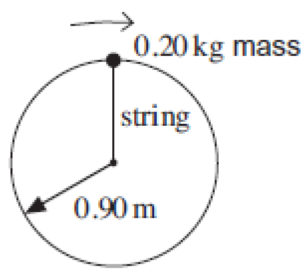
B a frictional force from P to Q

C a frictional force directed away from O

D a frictional force directed towards O

(Total 1 mark)

12 A 0.20 kg mass is whirled round in a vertical circle on the end of a light string of length 0.90 m.



At the top point of the circle the speed of the mass is 8.2 m s^{-1}. What is the tension in the string at this point?

A 10 N

B 13 N

C 17 N

D 20 N

(Total 1 mark)

13 Which line, **A** to **D**, in the table gives the amplitude and frequency of a body performing simple harmonic motion whose displacement x at time t is given by the equation $x = P \cos Qt$?

	Amplitude	**Frequency**
A	$\frac{P}{2}$	$\frac{Q}{2\pi}$
B	P	$2\pi Q$
C	P	$\frac{Q}{2\pi}$
D	$2P$	$\frac{Q}{2\pi}$

(Total 1 mark)

Mark schemes

1 (a) Time for one cycle

M1

One cycle defined correctly in terms of diagram, can be on diagram

A1

2

(b) B

B1

Mention of air resistance, allow drag OR bob faster in centre of motion

B1

Links two ideas

B1

3

[5]

2 (a) (i) 15 rev / s = 30π rad / s **or** v = 51 / 52 m s^{-1} [could appear in subst]

Bl

$F = mw^2r$ [or mv^2 / r & $v = \omega r$]

Bl

appropriate sub leading to 7.33 kN [2+sf evaluation mandatory]

Bl

(ii) to centre of rotor OWTTE

Bl

(iii) *stress* = F / A

Bl

correct substitution from ai

Bl

(iv) $0.55 \times 2.09 \times 10^7 / 6 \times 10^{10}$ [or $\varepsilon = 3.3 \times 10^{-4}$]

Cl

= 0.192 mm

Al

(v) $\frac{1}{2} \times 7.32 \times 10^3 \times 1.92 \times 10^{-4}$ [ecf]

C1

$= 0.702$ J

A1

(b) (i) volume pushed down [per second] = Av [mass = ρ × volume]

B1

Change of momentum [per second] = mass pushed down per second × v

B1

(ii) Upward force = 900 N OWTTE [penalise use of 900g]
OR area swept out by blades = $\pi \times 0.55^2$

C1

$900 = (0.55)^2\, \pi 1.3 v^2$

C1

$= 27$ m s^{-1}

A1

[15]

3 (a) (i) loss of PE = gain of KE or $mgh = \frac{1}{2}mv^2$

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)

8.9×10^{-6} – 9.1×10^{-6} m **A1**

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

(3)

[11]

4 (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 $g = v^2 r$, centripetal force = mv^2 / r

C1

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

C1

7.1 m s^{-1}

A1

(3)

[9]

5 (a) (i) system made to oscillate by a periodic external force / energy source
or system made to oscillate by another oscillator it is connected to
or another oscillator forcing the system to vibrate
or an oscillator forcing another oscillator to vibrate
due to its own vibrations

A1

(1)

not made to oscillate by an external force
not when its vibrations are not at its natural frequency
not when it is made to oscillate by another system

(ii) frequency of wheel (motor)= natural frequency of system
condone 'fundamental or resonant frequency' of the system
or rotating wheel rotates at the resonant / fundamental
frequency of the system

must be reference to the wheel or motor or driver oscillator
not just when it vibrates at its natural frequency

B1

(3)

(b) T = 1.25 s

B1

$T = 2\pi(m / k)^{1/2}$ **or** numerical substitution

C1

0.36 kg
allow e.c.f. for T; 0.6 s gives 0.82 kg

A1

(1)

(c) (i) correct process using ratios
(eg times to halve marked on the graph)

B1

three amplitudes read correctly
or
two times to halve read correctly

B1

ratios determined and conclusion drawn that it is exponential
or
a clear statement that the time to halve is the same for points indicated and conclusion that it is exponential

B1

(3)

(ii) amplitude correct for 25 s , i.e. 4 to 4.2 cm
or energy proportional to A^2 (allow 0.5 kA^2 or 0.5 kx^2)

C1

allow e.c.f. from (b); T = 0.6 s leads to amplitude = 6.8 cm ; ratio = 0.46

0.16-0.19 or 17/100 (2 s.f. only)

A1

(3)

[10]

6

(a) $f = \frac{3000}{60}$ = 50 (Hz) **(1)**

ω (= $2\pi f$) = 314 (rad s^{-1}) **(1)**

(b) $\alpha = (r\omega^2) = 95 \times 10^{-3} \times 314^2 = 9.4 \times 10^3$ m s^{-2} **(1)**

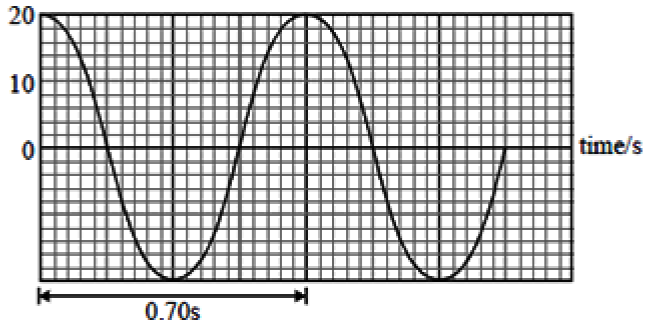
(c) (inwards) towards axis of rotation **(1)**

[5]

7

(a) (i) $k = \frac{2.0}{50 \times 10^{-3}}$ **(1)** $T = 2\pi\sqrt{\frac{0.5}{40}}$ **(1)** = 0.70 s

(ii)



a correct (= 20mm) **(1)**

x = ±20 mm at t = 0 **(1)**

T correct (= 0.70 s)**(1)**

(5)

(b) (i) vibrates at 0.5 Hz with low amplitude **(1)**

(ii) vibrates with high amplitude **(1)**
at natural frequency **(1)**
resonates **(1)**

(max 3)

[8]

8 (a) $\omega \left(= \frac{2\pi}{T}\right) = \frac{2\pi}{97 \times 60}$ [or $\omega \left(= \frac{360}{T}\right) = \frac{360}{97 \times 60}$]

$= 1.1 \times 10^{-3}$ (1.08×10^{-3}) **(1)** [= 6.2 (6.19) $\times 10^{-2}$]

rad s^{-1} [accept s^{-1}] **(1)** [degree s^{-1}]

3

(b) (i) $\frac{GMm}{r^2} = m\omega^2 r$ **or** $r^3 = \frac{GM}{\omega^2}$ **(1)**

gives $r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.08 \times 10^{-3})^2}$ **(1)**

$\therefore r = 6.99 \times 10^6$ (m) **(1)**

3

(ii) $F\ (= m\omega^2 r) = 1.1 \times 10^4 \times (1.08 \times 10^{-3})^2 \times 6.99 \times 10^6$ **(1)**

$= 9.0 \times 10^4\ (8.97 \times 10^4)$ (N) **(1)**

[**or** $F\left(= \frac{GMm}{r^2}\right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 1.1 \times 10^4}{(6.99 \times 10^6)^2}$ **(1)**

$= 9.0 \times 10^4\ (8.98 \times 10^4)$ (N) **(1)**]

2

[8]

9 C

[1]

10 C

[1]

11 D

[1]

12 B

[1]

13 C

[1]

Examiner reports

1 (a) This was well answered, but there were still too many candidates whose descriptions were so imprecise as to be worthless. The phrase '*how long*..' when referring to a time is simply unacceptable at this level of examination. Other candidates failed to give clear descriptions *in terms of the positions shown on the diagram*.

(b) There were many misunderstandings shown in the answers. Although candidates often recognised that damping depends on speed, some were at sea when recognising how speed varies in a simple pendulum. Far too many stated that the speed is a maximum at the extremes of the motion. Other scripts stated that the maximum damping is '*where the bob has stopped*.

2 (a) (i) Candidates here (and elsewhere in the paper) must recognise that questions beginning with the words '*Show that*...' demand a clear and well-explained exposition of the calculation or proof. Examiners are not satisfied with muddled and incomplete answers or answers that simply re-state the question. Explicitly, in this part, candidates were expected to quote their answer to *more than* the one significant figure in the question. They were also expected to show how they converted 15 revolutions per second into a value that could be used in their equation. Failures to convince often lead to loss of marks.

(ii) Although examiners were generous here, the common answer 'to the centre' is not adequate for a candidate at A2 level in a physics examination; the centre of what? Strong candidates often illustrated the answer on a labelled diagram of the helicopter itself *and drew the examiner's attention to this amendment* . Candidates should take every opportunity to make their answers clear.

(iii) Again, a 'show that' which often did not. Those who quote the equation $p = F / A$ for 'stress' without defining their symbols must not be surprised if the examiner assumes that p stands for 'pressure'. The safest route is to supply a word equation in cases like this.

(iv) There were many good answers here, but solutions were frequently marred by arithmetic errors and by negligent candidates who calculated the strain and then omitted to go on to evaluate the required change in length.

(v) Again, this was well done by many, but there was a significant number of candidates who attempted to go via the route
strain energy per unit volume = ½ stress × strain.
This is indeed a possible method, but these candidates too often failed to multiply in the volume of the helicopter blade.

(b) (i) Only a few candidates were able to prove this simple relationship. Those who did stated clearly the volume of air being forced downwards every second, could use this to evaluate the mass of air being forced down, and could go on to show the change in momentum of this air. Otherwise candidates simply floundered around trying unsuccessfully to 'spot' a relationship that would yield the result they needed.

(ii) To the examiners' surprise very many found the evaluation of the air speed beyond them. Although many recognised that the change in momentum per unit time has to equal the weight of the helicopter, candidates still turned the weight of the aircraft back to mass, and failed to spot the squared velocity term. This was a disappointing failure by many candidates.

3 (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!

4 (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.

5 (a) (i) It was necessary to state that the force producing the oscillations has to be a periodic force. Many candidates stated only that an external force was needed. Some stated explicitly that applying a force and then releasing it so that oscillations took place would be a forced oscillation.

(ii) Many candidates gave a general statement of the condition (i.e. external frequency equal to the natural frequency). This was accepted but an answer that actually referred to the context in which the question was set was preferred. Simply stating that the oscillating body oscillated at its natural or resonant frequency was inadequate.

(b) Careless reading of data from the graph led to many incorrect answers but most candidates used the correct equation.

(c) (i) The communication of the process used to test for the exponential was often not clear. Some candidates simply stated that there was a constant 'half life' without showing any evidence of data having been taken from the graph. This was the preferred method of most candidates; checking for a constant ratio for other time periods was rare. Some candidates thought that exponential meant that the amplitude would be inversely proportional to the time. Weaker candidates thought it adequate to say that the graph never touches the time axis or that the gradient of the graph decreases as time increases.

(ii) Candidates could gain credit either for obtaining the correct amplitude after 20 oscillations or for knowing that energy of an oscillator is proportional to the amplitude squared. Those who gained one of the two marks usually gained it for the first of these. Only a small proportion of the candidates obtained both marks. Some of those who could have gained full marks spoiled their answer by the use of too many significant figures.

6 This question on circular motion involving angular velocity caused less confusion than similar questions have done recently. A significant number of candidates, over a range of ability levels, were able to arrive at a correct answer. There was the usual confusion between orbital speed and angular velocity, but this was certainly not a major problem. The units for acceleration in part (ii) caused a few problems, with some of the better candidates giving the unit rad s^{-2}

Most candidates could say no more than "a polymer is a long chain molecule". The mention of monomers or cross-linking was quite rare.

7 Part (a) was done well by the majority of candidates. Although some omitted the units on the graph axes, the only error of significance was to start the graph from the displacement origin.

The quality of answers given to part (b) varied widely. A small minority of candidates gave excellent and concise answers which showed a clear understanding of amplitude, natural frequency and resonance. Unfortunately, most answers were so badly expressed that it was difficult to award marks.

8 This question as a whole was very rewarding for the candidates who were sufficiently familiar with the principles of gravitation to understand the mathematical conditions for a satellite in stable orbit, as required in part (b) (i). These candidates made good progress with all parts of the question, whereas many other candidates were only able to score well on parts (a) and (b) (ii). In part (a), the correct conversion of the orbital time of the Hubble satellite into seconds followed by correct use of $\omega = 2\pi/T$, with a correct unit for angular speed, brought full marks for the majority of the candidates. Confusion of angular speed ω with linear speed v continues to be a problem, and giving the unit of ω as m s^{-1} inevitably caused the loss of one mark.

Part (b) (i) required candidates to appreciate that the radius of the orbit of a satellite can be found from the orbit equation $GMm/r^2 = m\omega^2 r$. The angular speed ω had been determined in part (a), whilst the values for G and the Earth's mass M could be taken from the *Data and Formulae Booklet*. Because the question had indicated that the Hubble telescope is in orbit close to the Earth, some candidates assumed that the radius of its orbit would be that of the Earth, 6.37×10^6 m.

Another common unsuccessful response was to attempt to determine the answer using the orbit relationship T^2/r^3 = constant, incorrectly treating the surface of the Earth as a satellite orbit and using T = 24 hours and r = 6.37×10^6 m.

Candidates who used $F = m\omega^2 r$, or $F = GMm/r^2$, had very little difficulty in part (b) (ii), where both marks were still accessible to those who had worked out wrong values for ω and/or r in the earlier parts of the question. Attempts at this part using $F = mv^2/r$ were often incorrect because of inability to correctly work out the linear speed, v.

9 This question required the application of $T = 2\pi\sqrt{l/g}$ to a simple pendulum which had been taken to Mars. Just over three-quarters of the students gave the correct answer.

10 This question had a facility of 65%, up from 59% when used previously. Its subject was angular speed and its effect on the linear displacement of a model car moving around a circle. In 6.0 s, the car would travel through an angular displacement of 3π radians, taking it round the circle 1½ times and therefore to the opposite end of a diameter. An incorrect answer of 2.4π m (the distance travelled) would have been understandable, but it was not on the list of distractors. The common incorrect answers were distractors B (the distance travelled after 1.0 s) and D (the distance travelled after 4.0 s).

11 In this question most students realised that the centripetal force on the mass acts towards the centre of the circle in which it moves, and very few were distracted by the weight of the mass. 73% of the responses were correct. This question had been used in a 2010 examination, when 9% fewer students chose the correct answer.

12 This question, on circular motion in a vertical circle, produced correct responses form almost 70% of the students. The most popular incorrect choice was distractor C, made by 26%. This error follows from the wrong resolution of forces when applying $F_{res} = ma$. $T = mg + mv^2 / r$ leads to T = 17N whereas $T + mg = mv^2 / r$ gives T = 13N.

13 This question concerned the equations of simple harmonic motion. In this question, the selection of the correct algebraic terms for amplitude and frequency from the equation $x = P \cos Qt$ was carried out correctly by three-quarters of the students. Difficulties with algebra are likely to have caused 17% to select distractor B (where frequency = $2\pi Q$ instead of $Q / 2\pi$).