Mark schemes

1 (a) (i) (moment = 520 x 0.26) = 140 (135.2) ✓

Nm ✓

2

(ii) **180 x 0.41** and **0.63 X** seen ✓

135.2 = 180 x 0.41 + 0.63 X ✓ ecf from (a)(i)

(X = (135.2 – 73.8) / 0.63)

= 97 ✓ (N) (97.46) allow 105 from use of 140Nm ecf from (a)(i)

3

(iii) (520 – (180 + 97.46))

= 240 ✓ (242.5 N) ecf (or from correct moments calculation)

1

(b) (i) ($v^2 = u^2 + 2as$)

9.3^2 = 2 x a x 35 OR 9.3^2=70a OR a = $v^2/2s$
OR $9.3^2/70$ ✓

OR correct alternative approach

1.2 (1.2356) ✓ (m s^{-2})

2

(ii) *(m = W/g)* = 520/9.81 (= 53.0) ✓ (kg)

F = *ma* = 53 × 3bi (1.2356) = 65 (N) (65.49) ✓

accept use of 1.2 giving 64(63.6) , allow 53 x 124 = 65.7

2

[10]

2 (a) (sum of) clockwise moment(s) = (sum of) anticlockwise moment(s) ✓
sum of clockwise moment **s** = **sum of** anticlockwise moment **s** (about any given point) ✓
(for a system in) equilibrium ✓ allow 'balanced'

third mark depends upon the first
Don't allow references to 'forces' being balanced.
Don't allow 'stationary'.
Allow 'total', etc instead of sum
Ignore definitions of moment

3

(b) (i) 35 × 110 (×10^{-3}) ✓
(= 3.85) = 3.9 (or 3.8) ✓
allow 4 or 3.90 but not 4.0

(3.9) **Nm** / allow (3850, 3900) **Nmm** ✓ don't allow nm, NM
unit must match answer

3

(ii) 3.85 = T × 25 (×10^{-3}) ✓ ecf from (bi)
Correct answer with no working gets 2 out of three.

T = 3.85 / 25 (×10^{-3}) = 0.150 (×10^{3}) ✓ ecf
Allow 156 (160) N from rounding error

= 150 (154 N) ✓

3

(c) *(P = Fv , F = P / v)*
= 2.8(× 10^{3}) / 15 ✓
= 190 (186.7 N) ✓

2

[11]

3 (a) (i) $m = W / g)$
(3.4 × 10^{4} / 9.81 =) 3500 (3466 kg) ✓
Allow use of g = 10

1

(ii) (moment = 34 000 × 5.0) = 1.7 × 10^{5} ✓ (Nm)
Nm ✓ do not allow NM \ nM etc
allow in words

2

(iii) 170 000 = T x 12 OR T = 170 000 / 12 ✓ ecf aii
= 1.4(167) × 10^{4} ✓ (N)

2

(iv) (component of T perpendicular to lever) = T cos 24 **OR** 14 167 × 0.9135 **OR**
12942 (N) ✓ ecf aiii allow 2.5cos24 × T

(12942) × 2.5 = **F** × 8.0
OR F = ((12942) × 2.5) / 8.0 ✓ ecf for incorrect component of T or T on its own
F = 4000 (N) ✓ (4044) ecf for incorrect component of T or T on its own

allow 4100 for use of 14 200 (4054)
Some working required for full marks. Correct answer only gets 2
Failure to find component of T is max 2 (4400 N)

3

[8]

4 (a) (moment =) Force x perpendicular distance ✓
between line of action (of force) and pivot / point ✓

both marks need to be clear − avoid bod
if the force is named specifically (e.g. weight) mark the work but give a maximum of 1 mark
ignore extra material such as law of moments

2

(b) (i) moment = 250 × 0.048 = 12 ✓ (allow 12000 for this mark)

only allow answers in other units if consistent e.g. 1200 N cm

N m ✓ (stand alone mark if no number is present but only for N mm, N cm and N m)

no working shown can gain full marks if answer and unit are consistent
newton should be upper case if a symbol and metre should be in lower case (but only penalise if it is very obviously wrong)

2

(ii) $Y \times 0.027 = 12$ OR $Y = 12 / 0.027$ ✓
(allow use of 12 and 27 for this mark)
= 440 (N) ✓ (444.4 N) CE from (i)

Y = (i) / 0.027

treat power of 10 error as an AE

note 450 N is wrong

1 sig fig is not acceptable

2

(iii) *($k = F / \Delta L$)*
= 444.4 / 0.015 ✓ CE from (ii)
= 3.0×10^4 (Nm^{-1}) ✓ (29630 Nm^{-1})

k = (ii) / 0.015

treat power of 10 error as an AE

using 440 gives 2.9×10^4 (Nm^{-1})

1 sig fig is not acceptable

2

(iv) W (= ½ $F\ \Delta L$) = ½ × 444.4 × 0.015
Or
W (= ½ $k\ \Delta L^2$) = ½ × 29630 × 0.015^2 ✓
(give this mark for seeing the digits only ie ignore powers of 10 and allow CE from (ii) or (iii) as appropriate
= 3.3 (J) ✓ (3.333 J)

W = ½ × (ii) × 0.015

W = ½ × (iii) × 0.015^2

treat power of 10 error as an AE

if either equation misses out the ½ no marks

common CE is to use F = 250 N which can be

used giving W = 1.9 J

2

[10]

5 (a) a (resultant) force directed through the centre of mass of an object will not give it a moment / will not cause the object to rotate owtte
or all the mass of the object appears to be concentrated at the centre of mass owtte
or point at which all the (object's) weight acts ✓ owtte

We are not distinguishing between c of g and c of m. So allow point at which all the mass acts.

If a balance idea is given the situation described must be achievable.

Don't allow answers like:

Where mass is most concentrated It has the same mass on both sides All forces act through this point

1

(b) (moment of plank from the bank = $mg \times d$) = 32 × 9.81 × 2.0 or 32 × g × 2.0 ✓
this moment is balanced by F × 3.2 giving F = 200 (N) ✓ (196 N)

Award 2 marks if 196 (N) is seen but 200 (N) only gains 1 mark with the second mark available if working is shown

9.8m s^2 *is ok for g.*

2

(c) (At the point of tipping) there is no (reaction) force from the bank ✓ (This point must be in words not implied from a calculation)

Taking moments about the rock

LHS = 1.2 × 32 × g = 38.4 × g = 380 (Nm) ✓ (377 N m)

RHS = 0.80 × 46 × g = 36.8 × g = 360 (Nm) ✓ (361 N m)

Or show a moment calculation that gives the maximum boy's weight that can be supported (471 N)

Or show a moment calculation that gives the maximum distance the boy can be from the rock without tipping (0.83 m) Score any two of the above marks

(Therefore) plank will not tilt ✓ (to score this mark the answer must be justified)

NB the first 3 marking points score a maximum of 2 marks.

The last mark makes up the total to 3 marks

Note it is the RHS mark that has the alternative approaches

Condone missing 'g' provided it is cancelled / missed out in both moment calulations.

The last mark can come from an ecf as long as the reason is clearly stated in terms of the answers given earlier

3

[6]

6 (a) use of $V = \frac{4}{3}\pi r^3$ to give $V = \frac{4}{3}\pi(2.5 \times 10^{-2})^3$ ✓ = 6.5 × 10^{-5} m^3

use of $\rho = \frac{m}{V}$ to give $m = \rho V$ = 8030 × 6.5 × 10^{-5} ✓ = 0.53 kg

use of $W = mg$ to give W = 0.53 × 9.81 = 5.2 (N) ✓

the first mark is for making some attempt to calculate the volume; ignore power of ten errors.

the second mark is for the correct substitution or for the calculation of mass

the third mark is for going on to calculate the weight

allow ce for incorrect volume or mass but 2 errors = 0/3

no sf penalty but g = 10 N kg^{-1} loses mark

3

(b) distance of line of action of weight to pivot = (0.120 + 0.025) = 0.145 m ✓

moment = force × distance = 5.2 × 0.145 = 0.75 ✓

unit Nm ✓

the first mark is for identifying that the weight of the ball will act through its centre; use of 0.12 m loses this mark

the second is for correctly calculating the moment; allow ce for wrong distance; condone force = 5 N (which leads to 0.725)

allow suitable unit consistent with calculation, eg N cm

reject 'nm' or 'NM' etc

3

(c) taking moments about the pivot
clockwise moment from spring = anticlockwise moment from ball
$F \times 0.080 = 0.75$ ✓
$F = 9.4$ N ✓
use of $F = kx$ to give $x = \frac{F}{k} = \frac{9.4}{100}$ = 0.094 m ✓

allow ce from (b)

the first mark is for the use of the moment equation

the second mark is for calculating the force on the spring; condone 9.35 and 9.3

the third mark is for calculating the extension; allow calculation in cm

allow ce from the second mark ie use of wrong force; condone 1 sf 0.09 m if (1 sf) 5 N used in (b)

3

(d) the line / pen (initially) moves up; ignore subsequent motion ✓
(the downwards acceleration of the ball is much less than that of the frame and) the ball does not move (very far in the time taken for the frame to move down) ✓

the first mark is for stating the correct direction of the line / pen; allow 'diagonally up', 'up then down' but reject 'up and down'

the second mark is for an explanation which shows some understanding of the relative displacement of the ball and frame; this mark is consequential on the first being correct; condone 'ball has inertia'

2

[11]

7 (a) Distance to centre of mass of counterweight from pivot = 2.9 m ✓

Moment = (f ×d = 50×2.9 =)145 (N m) ✓

No credit for use of 3.2 m (or 2.6 m) here, but maybe ecf later

2

(b) mass of water = 0.08 × 1000 (= 80 kg)✓

total weight of bucket + water = 80g + 120 (= 905 N)✓

moment of bucket + water = 905 × 1.4 = 1270 (N m)✓

905 × 1.4 = 145 + F×3.2 ✓

350 (N)✓

No credit for 1000 × 1.6 here

Allow ecf from any mass

Ecf from part ***(a)***

5

(c) Weight of beam acts to right of the pivot / centre of mass is to the right of the pivot ✓

provides an additional **clockwise moment** ✓

Therefore the value calculated in part **(b)** would be less to have equilibrium ✓

Need "moment" and some sense of direction

No credit for unsubstantiated statement of change of force.

3

[10]

8 (a) Sum of / total clockwise <u>moments</u> = sum of / total anticlockwise <u>moments</u>✓

<u>For a body in equilibrium</u>✓

2

(b) Clockwise moments = 2.0 × 9.81 × 0.25 + 0.65 × 9.81 × 0.45

= 7.77 (N m)✓

Anticlockwise moments = Tsin30 × 0.3✓

Tsin30 × 0.3 = 7.77 or T = 7.77/(sin30 × 0.3) ✓

T = 52.0 (N) ✓

First mark for clockwise moments, workings or correct answer.

Second mark for anticlockwise moments.

Third mark for equating clockwise and anticlockwise moments.

Fourth mark for correct answer.

4

(c) tensile stress = 52.0/(7.8 × 10^{-7}) = 6.6 × 10^{7} ✓

tensile strain = 6.6 × 10^{7}/(180 × 10^{9})= 3.7 × 10^{-4} ✓

2

[8]

9 (a) force is at right angles / horizontal to wall (and so no component along the wall) ✓

1

(b) arrow drawn upwards from point of contact with ground ✓ between ladder and vertical which when extended would pass through 'on ladder' part of label ✓

Must be vertical or pointing to right for first mark

1
1

(c) *(use of sum of clockwise moments = sum of anticlockwise moments)*
EITHER
F × 8.0sin 60
OR
390 × 4.0 cos60 ✓
F = 390 × 4.0 cos60/8.0sin 60= 110 (113) N ✓

Either moment correct gets first mark (does not have to be evaluated)

1
1

(c) **ANY 3**
(vertical reaction) force from ground increases ✓
direction of arrow of resultant force from ground changes (as ladder is ascended) ✓
friction force / horizontal component of G between ladder and ground would increase ✓
the (reaction) force from the wall increases ✓
weight (of system) / load on ladder increases ✓
as person climbs they exert a force along the ladder ✓

MAX 3

[8]

Examiner reports

1 For part (a)(i) most students successfully gained the unit mark here, but a few put Nm^{-1}, N/m, NM or Nm^{-2}. In part (a)(ii) students fared better on this moments problem than we have seen on previous papers. However, there were still plenty of problems. In particular, some students are unable to identify clockwise and anticlockwise moments. It is perhaps surprising how many AS physics students do not understand the concept of a moment and are unable to identify the direction of rotation that it would cause about a given point if no other forces acted. One possible strategy is get students to identify the clockwise and anticlockwise moments in many situations before teaching them how to use the law of moments. There were also a lot of mathematical errors by those who had equated the moments correctly and then could not rearrange correctly. Many rounded 97.46 to 97.5 and then rounded again to 98. For part (a)(iii) most were successful. Very few resorted to an unnecessary moments calculation for this one and many picked up the mark for an error carried forward if their previous answer had been wrong.

In part (b)(i) nearly all students were successful here though some used s rather than 2s. In part (b)(ii) a significant number of students used 520 N as the mass, not realising it was necessary to divide the weight by 9.81 to get the mass. Some multiplied by 9.81 instead of dividing. However, this was an easy two marks for most.

2 (b) (i) Most candidates got this correct. Only a few dropped a mark for the unit, e.g. with N / m rather than Nm.

(ii) A very large number of candidates thought that $W = F\cos\theta$ had to be used and needlessly multiplied by cos25.

(iii) This tended to be 3 marks or zero. Some lost marks due to errors in the powers of ten. Other than that, a large number didn't know how to do a simple moments calculation.

(c) The majority were very successful on this question.

3 (a) Most candidates were successful on this one but a few divided by 9.81 rather than multiply.

(b) There was significant use of mass rather than weight for this moment calculation and 12 m was occasionally used rather than 5 m.

Incorrect units were often seen. Nm^{-1} and NM being the most common errors.

(c) Most candidates got this one right but a few attempted to use trigonometry to resolve the weight of the ship. A few used a distance of 12 − 5 = 7 m, perhaps thinking the pivot was at the centre of mass.

(d) Quite a few candidates did not attempt to resolve T and did 2.5 × T = 8.0 × F, but nearly all had a correct moments equation, which was credited.

4 The moments component of this question was answered relatively well but students ran into difficulties in calculating the work done on a spring. The definition required in (a) split the students into three equal groups. The weakest group could get as far as saying that a moment is a force times a distance. The next group made the addition that it is the perpendicular distance to the pivot without defining what the line is perpendicular to. The last group got the whole definition correct by adding in the line of action of the force.

A vast majority got (b)(i) correct. Even the small cohort who chose to work in non-SI units did so without error. The most significant error seen was to give the unit of moment as N m^{-1} rather than Nm.

(b)(ii) was again answered well. Weaker students had issues in a number of ways. Some wanted to use a force of 250 N taken from the diagram. Again, using the diagram, others wanted to incorporate the 45 degree angle in some trigonometrical expression. The final group had issues over powers of 10. Students who did not work in SI units tended to feature more in this group.

Students performed well on (b)(iii) but (b)(iv) highlighted cracks in their knowledge. Most did not appreciate that the average force on a spring being squeezed is half the maximum force. Most used the equation work done equals force times distance and left out the factor of one half. The other problem encountered was students inability to choose the correct data to substitute from previous sections of the question.

5 (a) Very few students could distinguish between centre of mass and centre of gravity. On this matter the marking was made lenient. So the main issue was lack of clarity in answers such as, 'The point that has no turning' or 'the point where most of the mass is' etc.

(b) A majority of students tackled the question using moments very well. A minority became unstuck over their use of 'g' because some of the data was given in kg but the question asked for a force.

(c) The ability to show a logical approach that could be seen through to the end was a major requirement to achieve a good mark. The question itself had half a dozen acceptable approaches, some more involved than others. About half the students scored full marks, with the majority using the easiest option of taking moments about the rock. The most common error was to take moments about the bank and not take the reaction force from the rock into consideration. As usual in these calculations, there were a number of students who simply gave a number of calculations almost in a random order without introduction.

6 This question required students to apply their knowledge and understanding of physics to a simple seismometer. Although the diagram contained a lot of information, and there was a relatively long stem to the question, there was no evidence to suggest that students found the context particularly demanding.

(a) This was a multi-step calculation that most students found fairly straight forward. The common errors seen were wrong substitution of diameter (or use of a wrong formula for volume) and power of ten errors arising from calculation of volume in cm^3. Students who have difficulty converting between cm^3 and m^3 would be better advised to work in m from the outset. Generally "show that" questions are used to provide unsuccessful students the data they would need to complete further parts of the question. Students should be reminded to provide at least 1 sf more than the "show that" value, and they should be discouraged from trying to calculate an answer backwards. Another error is forcing their answer to be near the "show that" value: many students were denied consequential error marks when, having made an error, they attempted to manipulate their answer to obtain a numerical value near 5. For example, students who used 5 cm for the radius could obtain a value of 4.2 kg for the mass. Many would then miss out the step (multiplying by g) to determine the weight, as they had already reached a value near to 5 perhaps. Many modern calculators generate results as fractions or surds. No credit is given for final answers given in such a form or with recurring notation but there is no penalty for this with intermediate results. However students should be discouraged from doing this because it makes the work less transparent and inhibits error-checking. The rounding down of intermediate results compromises the chance of full credit; any rounding down, e.g. to the same significant figures as that of the least accurate data should not be done until the final stage is complete.

(b) There were two potential errors in answers that often led students to lose at least one mark. Many students did not take the centre of mass of the ball into account, and therefore did not include the radius when calculating the distance to the pivot. Some students worked through their answers in cm, but wrote the moment unit as Nm.

(c) Many good answers were seen to this multi-step calculation and this was a good discriminator. Some students were unable to suggest much beyond picking $F = 5\ N$ and rearranging $F = k\Delta l$ (given on the data sheet) to produce $\Delta l = 0.05$ m. Spotting that this was a 3 mark question may have led some of them to realise that a more complicated calculation was needed. Others tried to calculate the extension by dividing turning moment by stiffness or by multiplying distance from the pivot by stiffness. A number of students did not attempt this question.

(d) This was a fairly demanding question that aimed to get students to think about the reason for having the heavy ball in the seismometer. Successful answers were able suggest that, in the very short length of time involved, the ball would barely move and therefore the arm holding the pen would pivot about the ball, causing the upwards line. Many incorrect answers were seen: some students were convinced there was a third law or conservation of momentum explanation while others said the spring, having become compressed, then pulled the arm up. It seemed that many felt that the downwards accelerating seismometer took the ball with it and so the line went downwards. No credit was earned for saying the pen or the arm did not move, likewise any suggestion of an 'up and down' motion of the pen (although 'up then down' could earn a mark).

9 Responses to this question on statics proved to be quite patchy.

Question (a) was generally well answered, with the majority appreciating that friction was negligible because the resultant force was a right angle to the wall.

Question (b) was less well done: very few students appreciated that the arrow for force G, the weight and the resultant force from the wall when extended would intersect at one point. G was often drawn vertically upwards or along the ladder; this did score 1 mark providing the arrow started from the point of contact with the ground. The calculation caused problems for over half of the students because they did not appreciate that they had to apply the principle of moments. The last part of the question generated some very good answers with some quite detailed analysis seen. Three-quarters of students were awarded at least two marks. There were some misconceptions such as that the force G decreases as the person climbs the ladder or that the resultant force from the wall only increases when the person is over half-way up the ladder.