AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 2

SCORE	PERCENTAGE
/203	%

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Mark schemes

1. B

[1]

2. D

[1]

3. A

[1]

4. B

[1]

5. D

[1]

6. (a) Conversion of 110 km h^{-1} to 31 m s^{-1} ✓

= ½ × 1.5 × 10^3 × *their conversion*^{2} with a consistent answer ✓

(= 7(.2) × 10^5)

Allow ecf for incorrect or failure to carry out speed conversion
Expect answer to be calculated correctly and to 2+ sf.
Accept 700 kJ as 2 sf

2

(b) Component of velocity = 31 × cos (20)

OR

evidence of using momentum = mass × velocity (eg 1.5 × 10^3 × a velocity) ✓

= 4.4 × 10^4 ✓

For unit only accept kg m s^{-1} **OR** N s ✓

Allow ecf for speed from part (a)
Accept 4.65 × 10^4 kg m s^{-1} for max 2
Use of 30.6 m s^{-1} gives 43 kN s

3

(c) (KE before collision = 700 kJ)

Speed (parallel to barrier) after (= 31 × cos 20) = 28.7 m s^{-1} ✓

KE after(= ½ × 1.5 × 10^3 × 28.7^2) = 618 kJ ✓

Change = 700 – 618 ✓ (= 82 kJ)

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OR

Speed (perpendicular to barrier) after = 31 × sin 20 (= 10.5 m s^{-1}) ✓

Loss of KE (= ½ × 1.5 × 10^3 × 10.5^2) = 82 kJ ✓

Justification that total KE = KE due to speed parallel to barrier + KE due to speed perpendicular to barrier ✓

Allow ecf for speed from part (a)

Use of KE = $p^2/2m$ can gain full credit.

Allow ecf for momentum in part (b)

Final answer depends on extent to which candidate has rounded in earlier parts. Allow correctly evaluated solutions for full credit.

In this question, do not insist on final answer to 2+ sf.

If there is a suggestion that KE is a vector or can be resolved, do not award MP3.

3

(d) Evidence of work done = force × distance

Eg Force = 82 000 / 1.5 OR their value for part (c) ÷ part (a) ✓

Allow 80 kJ for energy

= 5.5 × 10^4 N✓

This is less than braking force – so yes. ✓

OR energy approach

- work done by barrier = 60 kN × 1.5 m ✓
- 90 kJ ✓
- which is > E_k of vehicle, so yes ✓

OR impulse argument

- evaluate time taken to stop, 0.26 s ✓
- impulse value leading to distance or force ✓
- conclusion consistent with correct method of calculation ✓

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OR use of F = ma and suvat :

- F = ma leading to a = (-)40 m s^{-2} ✓
- suvat leads to 1.37 m ✓
- which is < 1.5 m, so yes ✓

General scheme for alternatives and reverse arguments is:

- *first step calculation*
- *subsequent calculation(s) leading to comparative value. Allow ecf for error in first step.*
- *conclusion consistent with correct method of calculation*

Alternative suvat method:

- *uses suvat to get a = 36.5 m s^{-2}*
- *uses F = ma*
- *which is <60 kN, so yes*

3

(e) (Steel barrier is better because)

Increase time of contact as material deforms ✓

Reference to impulse (= change in momentum = Ft) implies smaller force (on dummy) ✓

OR

Increasing stopping distance as material deforms ✓

Reference to work done (= Fs) implies smaller force (on dummy) ✓

Allow correct discussion leading to concrete barrier is worse.

Alternative second mark for either alternative can be awarded for correct reference to F = ma

2

[13]

7. (a) The centre of mass of the beam and box is at the pivot ✓

Idea that moments balance / sum of the moments is zero at this position ✓

OR

The anticlockwise moment (of weight of the beam) = clockwise moment (of weight of the box) ✓

Links pivot position to a consideration of moments ✓

Accept one route or the other, do not accept points from both.

Allow max 1 for "the pivot is to the right of the centre (of mass) of the beam"

'pivot' on its own does not get the first mark

Award 2 for 1.25 × weight of beam = 1.5 × weight of empty box

Confusion of moments with eg work done/forces = max 1

2

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(b) Clockwise moment = 610 × 9.81 × 1.5 (= 8976 N m) ✓

Anticlockwise moment = 250 × 4 + T sin 50 × 4.0 (N m)✓

Use of clockwise = anticlockwise✓

Use of T sin 50° seen / relates vertical component to tension✓

T (= 1994/sin 50°) = 2600 (N)✓

Credit any evidence to work out a moment with one mark

Condone cos 50 in MP2.

Allow ecf for clockwise moment

Allow ecf for anticlockwise moment

Use of g = 10 N kg^{-1} gives 2990 N Omission of 4.0 m (g = 9.8) gives 10410 N. Use of cos 50 (g = 9.8) gives 3100 N

Allow max 4 for use of g = 10 N kg^{-1}.

5

(c) 7.5 = ½ g t^2 ✓

(t = 1.2 s)

(calculate distance)

s (= ut = 18 × 1.2) = 22 (m)✓

Allow ecf from incorrect t for MP2

2

(d) **(Range will be greater:)**

component of velocity upwards ✓

rock will spend longer in the air ✓

greater t ✓

therefore the range is greater ✓

OR

(Range will be smaller)

Counterweight will fall less far before projectile released ✓

Less energy transferred to rock ✓

Initial speed of rock less/horizontal velocity reduced ✓

therefore the range is smaller ✓

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OR

(balanced arguments)

therefore the range is unchanged / answer is indeterminate ✓

Candidates can argue from both lists to reach a balanced view suggesting that there is no change.

Full credit can be obtained from 2 deductions from one list ✓ ✓+ consistent conclusion ✓

1 deduction from each list ✓ ✓+ consistent conclusion ✓

Do not allow an unsupported conclusion.

*Conclusion must be consistent with **correct** statements.*

Treat incorrect statements as neutral.

Do not reward arguments based on a longer time of flight.

MAX 3

[12]

8. D

[1]

9. C

[1]

10. B

[1]

11. C

[1]

12. D

[1]

13. C

[1]

14. B

[1]

15. B

[1]

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16. (a) **Method 1:**

Attempts to determine area under curve / by counting squares $_1$✓

Multiplies their (total) area (or charge) by 24 (V) $_2$✓

240 (J) $_3$✓

Allow POT error on area of square in $_1$✓ and $_2$✓

*Evidence seen by calculations **or** from counting squares **or** from division of area into **at least two** recognisable geometrical shapes (triangles, rectangles, trapezia)*

answer in range 220 J to 264 J

Method 2:

Attempt to determine average current (over first 200 ms in range 45 A to 55 A) $_1$✓

Use of $E = I \times V \times t$ $_2$✓

240 (J) $_3$✓

Substitutes current value (or Δ current) with t = 200 ms and V = 24 V. Condone POT

Allow as two stage Q=It and E=QV

*Or $P = VI$ **and** $E = Pt$*

answer in range 220 J to 264 J

3

(b) (KE (gained) =) 65(.0) (J) **or**

(PE (gained) =) 58(.3) (J) $_1$✓

Use of efficiency = $\frac{\text{an output energy}}{\text{ans from part 04.1}}$

Allow output energy = 65 /58/ 120 /123 or candidate ke + pe

or (total output = 65 + 58 =) 123 (J) $_2$✓

Allow ecf from (a) for all 3 marks.

(Efficiency =) 0.51 or 51% $_3$✓

Answer to at least 2 sf. Range is 0.467 to 0.56 (46.7 % to 56 %)

3

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(c) Heating occurs / temperature increases when there is a current (in the thermistor) (due to I^2R) $_1$✓

(When the temperature increases) the resistance of thermistor decreases (whereas fixed resistor remains high) $_2$✓

(Lower resistance from thermistor means) less wasted power $_3$✓

OR

(Lower resistance from thermistor means) more pd dropped across the motor (less wasted voltage) $_3$✓

Alternatively: (Lower resistance from the thermistor means) less voltage drop across thermistor $_3$✓

3

[9]

17. A

[1]

18. (a) Neutron number increases by one **and** proton number decreases by one $_1$✓

Or

A proton changes/decays to a neutron $_1$✓

(because) up (quark) changes to a down (quark) $_2$✓

Allow use of symbols: N increases by one and Z decreases by one

Allow this expressed as an equation symbols for proton and neutron.

Allow u (quark) changes to d (quark)

Allow uud → dud

Where decay equation is attempted, condone incorrect leptons (quarks must be correct).

2

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(b) Conversion of 0.52 MeV to eV seen $_1$✓

Or

Conversion of 0.52 MeV to J $_1$✓

Or

Use of $p = \frac{E}{c}$ $_1$✓

(p =) 2.77 × 10^{-22} or 2.8 × 10^{-22} $_2$✓ **c.a.o**

5.2 × 10^5 (eV) seen for MP1

Condone POT error in conversion to joule

Expect to see: 8.32 × 10^{-14} (J) for MP2

With substitution of student's value for E (where conversion hasn't been completed or completed incorrectly)

2

(c) Shades detector opposite **P** ✓

The leader line from label 'patient's head' passes through a box.

Expect to see shaded the box below the 'leader line' box.

Allow either of the boxes adjacent to expected box.

Penalise more than one box shaded.

1

(d) 2 photons (are produced) / Photons must move off in opposite directions (along the same line)$_1$✓

The photons must have equal and opposite momentum / must conserve momentum $_2$✓

2

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(e) Use of $(\text{gradient}=)\frac{\Delta v}{\Delta t}$ $_1$✓

Condone power of ten errors and leaving time in hours (or incorrect conversion to seconds)

Correct read off; condone errors in read off that lead to ± 1mm s^{-1} in Δv and ±0.02 h in Δt.

For 1 mark expect to see

(79-60) ÷ 1.18

(65-60) ÷ 0.3

(70-60) ÷ 0.6

(75-60) ÷ 0.92

(76-60) ÷ 1

***Max 1** for answer where there is failure to notice false origin. MP2 is available in this case where there is only the false origin error.*

4.5(1) × 10^{-6} (m s^{-2}) $_2$✓

Range = 4.40 × 10^{-6} ≤ accepted value < 4.65 × 10^{-6}

2

(f) Acceleration increases$_1$✓

Condone correct acceleration statement linked to incorrect explanation.

Larger change in momentum (because more photons are reversing direction of motion) <u>therefore</u> a larger force on solar sail $_2$✓

Or

More momentum gained per second (from the photons) $_2$✓

Or

Larger force on photons <u>therefore</u> larger force on sail $_2$✓

2

[11]

19. (a) 0.56 (N) ✓

1

(b) Definition of couple as two <u>equal</u> forces acting in opposite directions ✓

Moment of a couple is independent of the point about which moments are taken ✓

Forces (are equal but) don't act in opposite directions, therefore it is not correct ✓

Combined moment of the two forces depends on the point about which moments are taken, therefore not correct. ✓

2

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(c) Use of total upward force = total downward force

1 mark for any attempt to equate upward and downward forces.
Response may be on diagram.

eg 0.87 + 0.62 = 1.12 + W ✓

0.32 (N) ✓

Attempt to use Principle of Moments ✓

0.14 (m) ✓

Allow MP4 if (their W) × (their d) = 0.0448

4

(d) Readings (on A and B) would be the same/1.44 (N) ✓

(Because) total downwards force/weight is same

OR

All (perpendicular) distances affected by the same factor

(cos θ) ✓

2

[9]

20. B

[1]

21. B

[1]

22. C

[1]

23. C

[1]

24. A

[1]

25. B

[1]

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26. (a) Evidence of distance travelled = area under graph = 1755 + 1440 + 1620 = 4815 ✓

Full marks can be credited for use of suvat.

Average speed = total distance/time taken = 4815/240

= 20.1 m s^{-1} ✓ (at least 3sf)

Which is less than (speed) limit, (and therefore the answer is No). ✓

Allow ecf for distance in MP2

Only award MP3 for incorrect speed if attempt made to calculate distance correctly e.g. area under graph OR a.e. in distance or speed

Alternative for MP2 and MP3

Calculation of distance travelled at speed limit = 5280 m ✓

Which is greater than distance travelled (so no). ✓

Alternative for MP1 and MP2:

Total area = 80.25 m s^{-1} min ✓

Time = 4 min

Average = 20.1 m s^{-1} ✓

3

(b) Using reaction time of 2.0 s ✓

1

Use of distance = speed × time = 62 m.

62 m (would be appropriate). ✓

Award MP2 if 1.6 s (to give 50 m) or 1.8 s (to give 56 m) or 1.7 s (to give 53 m) or average of two distances used

Allow 60 m.

1

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(c) Use of F = ma to calculate acceleration.

a = 6800/1200 ✓ = 5.7 m s^{-2}

evidence of use of suvat to calculate s or t, ✓

to give t = 5.5 s ✓

s = 85 m. ✓

If no other mark given, allow 1 mark for

mv = 1200 × 31 (= 37200)

Alternative for MP1 and MP2

$t = \frac{mv-mu}{F}$

Allow ce for a.

Allow ce for either incorrect s or t.

4

(d) (It is assumed that) the car in front would take the same time/travel the same distance as the car behind when braking/ only difference is reaction time of the driver of car behind. ✓
Or
Car in front cannot stop instantaneously (so car behind will have time/distance to bring car to rest).or words to that effect

Alternative:
suggestion that total stopping distance is too large (drivers would ignore it/inefficient use of motorway)

1

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(e) Correct use of cos (5) ✓

E.g.

$mg = N$ cos (5)

Correct use of sin (5) ✓

E.g.

N sin (5) (= mv^2/r)

So

mv^2/r seen ✓

And $v = (rg \tan(5))^{½}$

Gives $v = (200 \times 9.81 \times \tan(5))^{½} = 13$

So speed limit = 13 m s^{-1} ✓

May see cos (85) for sin (5)

Alternative for MP1 and MP2: Evidence of mg tan (5)

fourth mark is for answer and suggesting this as the speed limit.

Max 3 if mg = N used

4

[14]

27. C

[1]

28. C

[1]

29. B

[1]

30. B

[1]

31. A

[1]

32. D

[1]

33. D

[1]

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34. (a) Attempt to resolve **A** or **B** eg 430 × cos35° or T_B × cos12° ✓

360 (N) ✓

If no other mark given, allow 430 × sin35° = T_B × sin12° to give 1190 N for 1 mark.

2

(b) Substitution of *F* and *A* into Young modulus or stress equation ✓

4.4×10^{-2} (m) ✓

Condone POT error for Young modulus

2

(c) Angle of **A** decreases or angle of **B** increases ✓

Accept references to 35º or 12º

Any correct application of trig or geometry to the situation

*(*eg $T_B/T_A = \cos\theta_A/\cos\theta_B$ so as θ_A decreases, $\cos\theta_A$ increases, $\cos\theta_B$ decreases, so T_B/T_A increases)

OR

eventually θ_B will equal 35º, θ_A = 12º so forces will be reversed (as system is symmetrical)

OR

sum of vertical components remains unchanged and vertical component of tension becomes less as angle **A** decreases ✓

*Allow idea that more of the weight is supported by **B***

T_A decreases, following some relevant discussion ✓

3

(d) Greater rate occurs when pulses are shorter (in time)/less modal dispersion ✓

Allow reverse arguments

Smaller diameter (leads to less modal dispersion) means smaller range of path lengths ✓

Accept idea of fewer reflections

X is more suitable because narrower core leads to lower modal dispersion or reduced pulse broadening ✓

3

[10]

35. B

[1]

36. A

[1]

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37. C

[1]

38. D

[1]

39. C

[1]

40. (a) Use of an appropriate equation of motion ✓

Where $v^2 = u^2 + 2as$ is correctly stated, condone one error in substitution e.g. sign of a

Where other equations are used it must be clear that v can be determined.

Must see v as subject and an attempt to determine t.

(v =) 0.35 (m s^{-1}) ✓

Allow more than 2 sf where correct.

2

(b) Use of tan 35 = u_v / 8.8

Or

Use of u cos 35 = 8.8 and u_v = u sin 35

and

6.2 or 6.16 with supporting a calculation ✓

Alternative: credit use of sine rule

Must see answer to at least two significant figures

1

(c) Use of an appropriate equation of motion ✓ ECF

Condone their incorrect value of u in this substitution.

Condone errors in signs in substitution Where other equations are used it must be clear how t can be determined.

Must see t as subject and an attempt to determine s.

(t=) 0.63 (s) ✓ ECF

0.61 (s) for use of u = 6 m s^{-1}

*For MP2, where their value of u is used, the answer must be consistent with this value. **Only** allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1}*

Condone 1 significant figure answer where U is 1 sig fig.

2

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(d) Use of an appropriate equation of motion ✓ ECF

Where equation is correctly stated, condone one error in substitution e.g. ***one error on sign*** *of a substituted value* ***or*** *one incorrect value substituted (of course, ecf is acceptable)*

(h =) 1.9 (m) ✓ ECF

h = 1.83 m for use of u = 6 m s^{-1} allow ecf on t (check (c))

For MP2, where their value of u is used, the answer must be consistent with this value. ***Only*** *allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1}*

allow reverse calculation where u=0 and v = 6 m s^{-1}

2

(e) Smooth curve with maximum turning point seen, curve starts at the ball and finishes at **X** ✓

Curve should be approximately parabolic in shape.

Curve must start below the label 'golf ball' and ends within 5mm of the ball or the label ***X****. Curve must have a maximum turning point.*

1

(f) (Increase the angle to horizontal so) the ball must go higher (and increases its time in the air)

Or

(Increase the angle to horizontal so) the ball must have a greater (initial) vertical velocity ✓

(Covers the same horizontal distance over) a longer time in the air (so has a smaller horizontal velocity) ✓

Alternative:

Increased angle (to horizontal of projection) so smaller horizontal velocity ✓

must be falling towards ground to land at **X** ✓

(Increase the angle to horizontal so that) the vertical velocity greater than the horizontal / increase the vertical decreases the horizontal

2

[10]

41. (a) Use of $E_k = ½ mv^2$ ✓

(Kinetic energy =) 9.2×10^9 (J) ✓

Condone POT error on 1st MP

Allow use where v where has been converted from 5.5 km h^{-1}

An answer to 2 significant figures (with some working) ✓

Significant figure mark requires evidence of some relevant working.

3

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(b) **Why force on the gas:**

The gas's momentum is changing ✓

This require a force according to **Newton's 2 nd law** ✓

Or

The gas is being accelerated ✓

This require a force according to **Newton's 2 nd law** ✓

Max 3 *for* ***why there is a force on the gas*** *and* ***why there is a resistive force on the system***

Must have ***why the system decelerates*** *to obtain all* ***4 marks****.*

The reason why the resultant force causes the deceleration rather than the acceleration.

Why (resistive) force on system:

The gas exerts a force on the parachute (with an equal magnitude and opposite direction force) / there is air resistance (on the system) / there is drag (on the system) / there is a resistive force (on the system) ✓

(because) the Parachute exerts a force on the gas according to **Newton's 3 rd law** ✓

Allow statement that is equivalent to N1 / N2 / N3.

Allow: air resistance (or drag) increases.

Allow: there is an upward force

must have a clear action-reaction pair for this ***N3*** *mark.*

Why system decelerates:

The resistive force is greater than the weight so there is a resultant force

Or

The **resultant** force is acting in the opposite direction (to its motion). ✓

acceleration in same direction as resultant force according to **Newton's 2 nd law** ✓

allow the ***resultant*** *force is vertically upwards*

Or

Links *to violation for conditions of Newton's 1 st law and therefore cannot continue at constant velocity.*

4

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(c) Attempt at determining difference = 3.3 (× 10^5) − 2.2 (× 10^5) or difference = 1.1 (× 10^5) ✓

1st mark: Credit an application of conservation of energy (allow written statement, or equation without substitution)

Ignore signs on difference and answer.

MP2 allow their energy in a substitution that is, otherwise correct.

Condone an answer = 18.4 (m s^{-2}) is worth 2 marks.

Use of $E_p = mgh$ ✓

(g =) 3.7 (m s^{-2}) ✓

Condone mgh = ½ mv^2 where rearranged to make g subject.

Condone 610 x g x 49 = ***their energy***

Alternative:

- *Attempt to use appropriate equations of motion to determine acceleration*

$v^2=u^2$ +2as rearranged to make a the subject (condone use of their values for v and u and / or g = a)

- *Attempt to use W=Fs to determine the air resistance F_D (or F_D= 6734(.7) (N) seen)*
- *Attempt to determine g from the deceleration of the system*

$$g = \frac{F_D - ma}{m}$$

3

(d) More mass to **displace** / more particles to **collide with** / more gas / dust to displace ✓

Must have some interaction with parachute-spacecraft.

N/E to say there are more particles / gas / dust /mass

(at any given speed)
Greater (rate of) change of momentum / More work done (per unit distance) / Greater (resistive) force / more kinetic energy transferred (per unit distance) ✓

Greater **resultant** force **on** the system (therefore greater deceleration) / greater loss of velocity per second (therefore greater deceleration) ✓

3rd MP for greater resultant force: allow the idea that the difference between the drag and weight has increased

3rd MP
Allow clear statement that links:

- *rate of change of momentum of gas / dust to rate of change of momentum of system*
- *rate of work done on gas / dust to rate of work done by system*

3

[13]

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42. D

[1]

43. B

[1]

44. D

[1]

45. C

[1]

46. C

[1]

47. C

[1]

48. B

[1]

49. B

[1]

50. C

[1]

51. A

[1]

52. B

[1]

53. C

[1]

54. C

[1]

55. (a) Centripetal force acts inwards / towards the centre of rotation ✓

Links reaction force to centripetal force ✓

2

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(b) Equates forces AND states **either** centripetal force with correct symbols✓

$F = m_A r\omega^2$

$F = m_B (L - r)\omega^2$

In MP1 condone: equations containing v; use of ω_A and ω_B for the angular velocities.

cancelling ω✓

$m_A r\omega^2 = m_B (L - r)\omega^2$

$r = \frac{m_B L}{m_A + m_B}$

E.g.

In MP2 it must be clear that the angular velocity and not the velocity.

2

(c) The angular speed is the same for A & B or

Rotational radius for B less than that for A ✓

Both of these points AND $v = r\omega$ so velocity of A is greater.✓

Alternative for MP2:

Both of points in MP1 AND

A travels greater distance in the same time.

2

(d) Use of safety factor e.g. maximum stress << 0.300 GPa ✓

$F = ma$ = 1.32 × 10^6 × 3.7✓ (= 4.9 × 10^6 N)

$A = \frac{F}{\sigma}$ valid substitution ✓

$\sqrt{\frac{4A}{\pi}}$ ✓ (expect > 0.144 m)

Valid justification for selection of maximum stress used e.g. using a stress that is from the linear / elastic section of the graph or reference to either safety factor or trying to limit weight of cable. ✓

Alternative for MP1: they can work through for a stress of 0.3 GPa and then increase the diameter, if justified as a safety factor. Do not allow use of stress ≈0.3 GPa for full marks.

Allow ecf for stress and force

5

[11]

56. D

[1]

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57. (a) horizontal velocity = 20 cos 40° = 15.3 ✓ (m s^{-1})

Needs minimum 3 sf

For MP1 it must be clear that the horizontal velocity has been determined.

horizontal velocity (is constant) / minimum when vertical velocity = 0 ✓

2

(b) (vertical velocity) v = 20 sin 40° (= 12.9) ✓ (m s^{-1})

$s = ut + \frac{1}{2}at^2$

$-3 = -12.9t + \frac{1}{2} \times 9.81t^2$ or $3 = 12.9t - \frac{1}{2} \times 9.81t^2$ ✓

($4.91t^2 - 12.9t + 3.00 = 0$)

For second mark both suvat equation and substitution must be shown. Equation may be rearranged before substitution

2

(c) Use of quadratic formulae with +, − or ± ✓

eg $t = \frac{12.9 \pm \sqrt{(-12.9)^2 - 4 \times 4.91 \times 3.00}}{2 \times 4.91}$

0.258 s and 2.37 s✓

Two correct answers alone scores first 2 marks.

Time to reach 3 m once on the way up and once on the way down (OWTTE)✓

Larger value ✓

ecf available for last 2 marks

4

(d) $s = vt$ = 20 cos 40° × 2.37 = 36.3 m so no✓

ecf from ***(c)***

Calculation must be seen

1

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(e) Gradient is the acceleration **AND**

area under graph = <u>vertical</u> distance travelled✓$_1$

Without air resistance:
comment about gradient✓$_2$
comment about area✓$_3$

With air resistance
comment about gradient✓$_4$
comment about area✓$_5$

For each comment on the graph a reason must be given not just a description.

e.g for ✓$_2$

• constant gradient = g or 9.81 m s^{-1}

e.g. for ✓$_4$

• initially steeper gradient since air resistance in same direction as weight (so $a > g$)

• when line crosses time axis, gradient = g /9.81 / gradient without air resistance as air resistance = 0 when v = 0 /

• After crossing time axis, gradient decreases as air resistance increases with speed

E.g. for ✓$_3$ or ✓$_5$

• total area under graph = 0 since ball starts and finishes on ground

• area between graph and axis is max height/ ***vertical*** *distance*

• without air resistance reaches a higher height as area greater

statement referring to area under both graphs gains ✓$_3$ and ✓$_5$

5

[14]

58. A

[1]

59. (a) 37.8 ✓

CAO

1

(b) <u>random</u> (error)

condone 'statistical' ✓

the following are neutral:

'parallax' / 'human (error)' / '(some) results are anomalous'

1

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(c) advantage (of using thinner beam):

(same load produces) larger (values of) s or wtte 1✓

so

the percentage uncertainty / error (in s) is reduced 2✓

for 1✓ accept 'beam bends / deflects more'

'beam extends more' / 'easier to bend' are neutral

for 2✓ the following are neutral:

'easier to make readings' / 'values (of s) are more accurate' / 'more precise' / 'less mass needed' / 'wider range of readings'

disadvantage (of beam bending more):

idea that beam may undergo plastic deformation 3✓

so

the graph will be non-linear / curve or wtte 4✓

or

beam 'may break' / 'slip off knife edges' **and** relevant comment about safety / health / hazard / 'cannot get unload data'

or

reduces range of m or wtte **and** relevant comment about the effect on the graph, eg increase scatter 34✓ = 1 MAX

for 3✓ accept / 'beam may become permanently deformed' or wtte / 'necking may occur' / 'hysteresis may occur' / 'beam can reach (go past) elastic limit'

the following are neutral:

'causes systematic error' / 'beam may go past limit of proportionality' / 'need to increase height of supports' / 'beam may bend under own weight'

MAX 3

(d) $E \approx 10^9$

or

1.14×10^9 seen 1✓

for 1✓ accept 10^9 seen in working

1

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correct manipulation seen in **body of answer** of $s = \frac{\eta m}{E}$ 2✓

for 2✓ ***either***

substitution of their E and data from ***Figure 8***
leaving η as only unknown: allow POT in s but not in m

eg $\eta = \frac{\text{their } E \times 25.5 \left(\times 10^{-3}\right)}{0.25}$ **or**

substitution of their E and result of a gradient calculation: allow POT in Δs but not in Δm

eg $\eta = 1.14 \times 10^{9} \times 1.02 (\times 10^{-1})$ ***or***

calculation involving orders of magnitude (expect 10^{-1} but allow 10^{2} for gradient)

eg $\eta \approx 10^{9} \times 10^{-1}$

2

correct raw result (allow POT in E) 3✓

for 3✓ expect 1.16×10^{8} but allow 1 sf gradient eg leading to 1.14×10^{8}

(on answer line) order of magnitude consistent with their raw result 4✓

for 4✓ $\eta = 10^{8}$ or 8 only; allow use of their E

award 34✓ = 1 MAX for use of gradient ≈ 100
leading to order of magnitude = 10^{11} or 11 only

1

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(e) identifies that s and L are linked by a power law ✓

accept any correct expression (unless there is talk-out) with s or log s as the subject;

treat any quantities other than s and L as constant except E and η

possible answers are:

$s \propto L^n$

allow $s \propto L^m$ if m identified as constant

$s \propto L^3$

$s = kL^n$

log s = n log L + (log) k

log s = 3 log L + (log) k

log s = log L^3 + (log) k

reject

$s = L^n$

log s = n log L

log $s \propto n$ log L

$10^s \propto 10^L$

's and L are linked logarithmically'

's is directly proportional to L'

1

(f) (log L =) −0.097 seen

for 1✓ accept any log L rounding to −0.097;

1

or

working on **Figure 5** confirming a value of log L between −0.095 and −0.100 1✓

uses **Figure 5** to obtain s in range 2.9 to 3.1 × 10^{-2} (m) 2✓

working can be suitable ruled line or mark on the best-fit line / on graph axes

for 2✓ accept 29, 30 or 31 mm etc

reject 1sf 3 × 10^{-2} (m)

1

use of wrong base

ln L = −0.22(3);

uses **Figure 5** to obtain s in range 1.49 to 1.51 × 10^{-1} or 1.5 × 10^{-1} (m) 12✓

accept 15 cm etc

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(g) use of **Figure 4** to determine M ✓

*their (final answer to) (f) × gradient of **Figure 4** (9.8 ± 2.5%)*

minimum 2sf

condone use of 1sf s

1

[13]

60. (a) Attempt to calculate weight of cage
eg $1.2 \times 10^3 \times 9.81$ or 1.18×10^4 seen ✓

Attempt to find vertical component of tension T_V in one rope
eg $3.7 \times 10^4 \cos 20$ or 3.5×10^4 seen ✓

Uses F = twice their tension – their weight ✓

If weight not calculated, allow MP3 for doubling their tension or their resolved component

5.8×10^4 (N) ✓

4

(b) Use of F = ma with 6×10^4 N or their (a) ✓
50 (m s^{-2}) ✓

Allow 48 (m s^{-2}).

2

(c) Calculation of length of rope
eg 35/cos20 or 37.2 seen ✓

Allow methods using $F = k\Delta L$ and E = ½ $k\Delta L^2$

Calculation of extension of one rope or calculation of total extension of both ropes
eg their length–24 or 13.2 or 26.4 seen ✓

Use of E = ½ $F\Delta L$
e.g. ½ × $3.7 \times 10^4 \times 13.2 = 2.44 \times 10^5$ (J) ✓

4.9×10^5 (J) ✓

4

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(d) Use of E lost = ΔE_p
eg $1.2 \times 10^3 \times 9.81 \times h = 5 \times 10^5$ ✓

No credit for use of suvat in either method and MP3 must come from correct Physics.

First method is for calculation of max h and comparison with 50 m.

h = 42 (m) ✓

Allow h from their (c) if it rounds to 5×10^5

42 < 50 (m), so claim not justified ✓

OR

Use of $\Delta E_p = mg\Delta h$ with 50 m
eg $1.2 \times 10^3 \times 9.81 \times 50$ ✓

Second method is for calculation of ΔE_p and comparison with E.

$\Delta E_p = 5.9 \times 10^5$ (J) ✓

$5.9 \times 10^5 > 5 \times 10^5$, so claim not justified ✓

3

(e) 90 km h^{-1} = 25 m s^{-1} ✓

The conversion mark stands alone.

1

Use of $E_k = ½ mv^2$
eg $½ \times 1.2 \times 10^3 \times$ (their v)^2 ✓

3.8×10^5 (J) ✓

ecf for their v

2

(f) If their $E_k > 5 \times 10^5$, claim is unjustified

OR

If their $E_k < 5 \times 10^5$, claim may be justified depending on gain in E_p or losses due to resistive forces ✓

1

[17]

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Examiner reports

5. This question was answered correctly by less than half of the students. By far the most popular distractor was C. Had students chosen to draw a small force diagram, it may have helped them to determine the sign of the different forces in relation to the acceleration and thereby obtain the correct answer.

6. (a) This very straightforward calculation was answered correctly by the vast majority of students. An occasional error was the failure to convert the speed to metres per second.

(b) This calculation was slightly more demanding, with some students attempting to use the energy given to them in the previous calculation. This approach, whilst unnecessarily long, did gain full credit when carried out correctly. One common error was the use of sine rather than cosine when calculating the momentum, or omitting the mass altogether. Another common error was the use of N m for the unit, suggesting some confusion with energy.

(c) Students managed to find some very different approaches to what is essentially a straightforward multi-step calculation. Answers that appeared to be taking a component of the kinetic energy, and therefore treating it as a vector, did not gain full credit.

(d) AO3 questions of the type in question (d) leave students free to choose the approach they wish to take. Each approach was treated on merit and was awarded full marks if correct. The most common, and successful, approach was a consideration of the work done by the barrier and therefore the average force that needed to be applied by the barrier to remove the perpendicular component of the car's velocity. Occasional errors were related to incorrect physics, for example using the wrong *suvat* (kinematic) equation, or errors in algebra and computation. Unfortunately, many students were unable to see a way through this question that gave them any credit. This may have been due to students giving up or to them being unable to achieve the 'show that' values given in previous parts. Students should be encouraged to make use of the 'show that' values in these instances as they are there to allow access to later questions.

(e) This question had several routes to the correct answer, the most popular being the consideration of time and an impulse route, or the consideration of distance and a work done route. Less commonly a route involving Newton's second Law of Motion was seen. A failure to express ideas clearly was the most common reason why students did not achieve full credit here.

7. (a) This question discriminated well. Students who argued in terms of the centre of mass were more likely to gain full credit. Although incorrect equations were not penalised on this occasion, teachers and students should be aware that this may not be the case in future examinations. A common error was the assumption that the centre of mass of the beam was 2.0 m from the pivot, or that the mass of the sling had to be considered, rather than the mass of the beam. A failure to express ideas clearly also cost some students marks.

(b) There were five marks available for this extended calculation and almost half of the students obtained all five. The mark scheme allowed students to make errors in several parts of the calculation without over-penalising them. Common errors included missing *g* from the weight of counterweight stones, or using the incorrect angle for the component of the tension. Occasionally the distance to the rope was missed in the equation for the turning effect of the tension. In multi-step calculations of this kind, students should be encouraged to set out their work logically and make it clear what they are doing at each step so that consequential error marks can still be awarded.

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(c) This two-step calculation was completed correctly by many students, and those who made an error in the calculation of the time still had access to the second mark point.

(d) Despite the fact that this question assessed AO3, a range of good answers were seen. Generally, students realised that the vertical velocity would cause the time of flight to be longer and then linked this to an increase in range. Some answers were less clear, and it was sometimes difficult to understand whether the student was arguing for or against a range increase. Students who suggested that a shorter time of flight would occur did not gain credit.

8. Many students had difficulty in analysing the base units of these quantities. Where working was seen, it often included errors in the use of indices.

9. Less than 40% of students selected the correct response. The most common incorrect answer was D.

10. A significant number of students selected answer A; these students were unaware of the conditions required for collisions to be elastic.

11. Over 60% of students selected the correct answer. The most common incorrect response was D; these students had a limited understanding of the independence of the vertical and horizontal velocities.

12. This question proved to be very challenging. Around 11% of students were able to select the correct answer. The most frequent answer, however, was A; this showed that the students had a very limited appreciation of the situation. They had difficulty in realising that the weight had not been included in the diagram and that the reaction force had to be equal to the sum of the downward forces.

13. Less than half of students were able to perform this calculation correctly. Many have difficulty in resolving forces and dealing with equations in equilibrium situations. The most frequent incorrect answer was A; these students assumed the weight was shared between the tensions but failed to take into account that this was only the vertical component.

14. This was a straightforward recall question and around 88% of students were able to select the correct answer.

15. Students had a good appreciation of the order of magnitude of the energy in this context.

16. (a) One mark was gained by at least 75% of the cohort. This was usually for use of $E = IVt$ with t = 200 ms. Generally, grade A students appreciated that the charge was the area under the curve and determined this to an acceptable level of accuracy.

(b) The most effective answers typically scored at least two marks. Most students who gained 1 mark determined either the potential energy (p.e.) or kinetic energy (k.e.) correctly. Many students did not recognise the sum of the p.e. and k.e. as the useful energy output, often using only p.e. Others didn't realise that the answer to part (a) was the input energy and instead attempted to find some ratio of p.e. to k.e.

(c) Many students gained 1 mark for stating that the resistance of the thermistor would decrease. Only the most successful answers gave an explanation of why this property was useful in this context. The most able students were able to provide quality descriptions that incorporated the potential-divider aspect of the series circuit.

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18.

(a) Almost half of students achieved both marks. However, over 30% scored zero. Students gaining 1 mark did so by correctly identifying this proton–neutron conversion. Students gaining more than 1 went on to describe correctly how the quark character changed. Students scoring zero usually thought that a neutron converted to a proton in beta-plus decay.

(b) Students need to take more care in reading the opening stem to a question. The required equation was provided and any use of this obtained credit. Many students were unable to convert 0.52 MeV to joule. This conversion is a key skill expected of AS physics students and should be treated as such.

(c/d) Over 80% of students were able to select the appropriate detector. They were familiar with the fact that two photons would be produced in the annihilation event. The most effective answers contained detailed explanations supporting the conclusion.

(e) Many students gained some credit for attempting to determine the gradient of the graph. Common mistakes included: failure to appreciate that the velocity axis had a false origin, failure to convert the time from hours correctly, leaving the velocity in mm s^{-1}, and failure to read-off accurately from the graph.

(f) Many students were able to state that the acceleration would increase. Only the most able students were able to provide a good explanation of why this was the case. A significant number of students thought that the acceleration would decrease because *'less of the photon's energy was absorbed'* .

19.

This question required students to have an understanding about systems in equilibrium.

(a) Nearly 70% of students determined the answer by considering the balance of forces.

(b) This question was poorly answered, with over 60% gaining no credit. The definition of a couple was required and this was not well expressed. Only about 12% of students could define a couple and then explain why **A** and **B** could not be a couple. It was very common to read that **A** and **B** were a couple because of the symmetry of the system.

(c) This question proved challenging for many students and barely 20% achieved full marks. Of the remaining cohort, few were competent in selecting an appropriate pivot position for the application of the moments principle.

(d) This question was not answered well. Students could have helped themselves by drawing a diagram of the new situation. Had they then drawn the vertical forces on this diagram, they may well have realised that the readings would be the same. Most students, however, considered the question in terms of moments and drew incorrect conclusions.

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26. Much of the work on motion in this question was relatively straightforward and, in a typical series, students would be expected to score well on it. Although the average scores on most of the question parts were higher than the paper average, a large number of errors in basic understanding were seen. In (a), for example, many students struggled to work out the area, or suggested that the average speed was the average of the speeds of the three sections. In (b), a surprisingly large number of students did not identify the slower response time as the appropriate one for the calculation. Many careless errors in the use of *suvat* equations were also seen in (c). It was pleasing to note in (d) that several students understood the premise of the question and indicated that the chevrons would be too far apart and therefore people would ignore them or that the car in front would also take some distance to come to rest. Very few fully correct answers were seen in (e). Although most students attempted to apply ideas of circular motion, the angle of the slope was largely ignored. Many answers suggesting $N = mg$, or applying the equation of circular motion down the slope rather than horizontally, were seen.

27. The performance of these students on the multiple-choice questions was poorer than in previous years but not quite so poor as their performance in Section A.

Question 29 proved to be the most difficult, with the majority of students choosing option B. Perhaps these students used $\frac{V}{3}$ as the “lost” volts rather than the terminal pd.

There were several other questions where a distractor was more popular than the correct answer. In question 16 the most popular answer was D. Students choosing this possibly failed to understand the difference between a π and a 2π phase difference.

In question 19 the most popular answer was C. The majority of students failed to spot that the angle given was between the two second-order maxima, rather than the central maximum and the second order.

In question 27 the most popular answer was C. Students choosing this distractor probably believed that the resistance of the thermistor increases with temperature.

55. Circular motion is a demanding topic for many students. Answers to these questions indicated the difficulties students commonly have with the ideas of reaction force, centripetal force and angular speed. The multi-step calculation in question (d) proved too difficult for many students, some of whom did little more than work out the Young Modulus, which was not needed. Some of these students made a little progress when they used their calculated Young Modulus to determine a quantity that they could have simply read from the graph. The idea of a safety factor was usually either missed or not understood.

57. Some of the more straightforward calculations in this question were completed successfully by most students and it was pleasing to note how many could successfully solve a quadratic equation. Students generally had more difficulty understanding what the answers represented. Little attempt was made in question (e) to discuss the graph in any detail beyond simple statements about what is represented by the gradient and area. A surprisingly large number of students suggested the graph showed the path of the ball, and made contradictory statements because of this.

59. This question was about the bending of a beam and tested ideas about different types of error, orders of magnitude, and the interpretation of log-log graphs.

In part (a) a popular distractor for the vernier reading was 45.8. Nearly 60% gave the correct answer of 37.8.

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The word '*random*' was supplied by 40% to earn the mark in (b), although just as many preferred '*systematic*'. '*Human error*' is not a term examiners allow or expect students to use.

About 70% of students obtained a mark in (c) for stating that the thinner beam would deflect more. Some went on to identify correctly that this would reduce the percentage uncertainty in s. The third mark could be earned in a variety of ways, e.g. suggesting that the beam could become permanently deformed. We expected students to understand the distinction between elastic limit and limit of proportionality.

Many knew the meaning of the $Giga$ prefix in the value of Young modulus in (d) and could then combine this with data obtained from Figure 4. A common error was failing to notice that s was in millimetres. Many students still do not understand what is required when we ask them to make an order-of-magnitude calculation (specification objective MS 1.4), the majority leaving their raw values for η on the answer line. Only 15% supplied the expected answer 8 or 10^8; we did not accept 1×10^8. A worrying number seemed confused by the unit on the answer line and spoiled a perfectly acceptable result by carrying out some additional mathematical operation.

Part (e) addressed specification objective MS 3.11 which identifies that logarithmic plots are used 'to test power-law variations'. This was the least accessible question on the paper, many claiming that Figure 5 showed an exponential relationship. This question exposed lack of knowledge in the same way as did the question about logarithmic scales from 2019. Successful students, of which there were less than 5%, suggested a mathematical expression such as $s = kL^n$, k being identified as a constant.

In (f), about 75% got as far as identifying $\log L = -0.097$ but some failed to see the next step and used Figure 5 incorrectly.

Part (g) discriminated well in favour of the stronger students, but over 20% did not attempt this part.

60. This contextual question tested the ability to present *'show that'* calculations and fundamental ideas about forces and energy transfers.

(a) In this question, students needed to find the vertical component of the tension, then take into consideration the two ropes and, finally, resolve the weight of the loaded cage. Credit was given to students when they clearly demonstrated these steps. Nearly 40% of students achieved full marks. Answers of a high standard were easy to follow and required little interpretation by the examiner. Students should consider briefly annotating their steps (*'Two ropes so double my tension'*) when giving *'show that'* answers.

(b) This question tested an understanding of Newton's laws. Over 60% of students achieved both marks. Many students understood that they needed to use $F = ma$ but did not appreciate, from Newton's third law, that the force given in (a) was needed. Students should be aware that a *'show that'* question often provides a value that will be used subsequently.

(c) This question proved to be slightly more challenging than (a). Again, students gained credit for showing clear evidence of any of the steps in this calculation. A common error was to use the force from (a) in a Hooke's Law calculation.

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(d) Around one-third of the cohort gained full credit for this question. As a *'deduce'* question, there needed to be a conclusion about the justification of the claim. Over 50% of students gained no marks or did not attempt the question at all. Many did not make the connection with (c) and failed to consider energy transfers. A large number of students applied *suvat* (kinematic) equations but the acceleration is not uniform in this situation.

(e) About 50% of students were able to convert the speed and to use it in the kinetic energy equation. Credit was given for an incorrect or no conversion of the speed so long as the substitution in the kinetic energy equation was fully correct. Mistakes in writing the 'square' exponent or in actually squaring the speed on the calculator were commonly seen.

(f) In this question, students needed to compare their answer to (e) to the *'show that'* value of (c). Even though an error was carried forward, many students struggled to give a relevant conclusion.

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