Mark schemes

1. (a) (Work done = lost KE = ½ mv^2 =) 0.019 (J) ✓

1

(b) Use of $W = Fs$✓

(F =) 0.66 (N) ✓

Condone POT error in substitution

ECF from ***(a)***

Alternative:

Use of an appropriate suvat equation **and** *use of $F = ma$* ✓

(t = 9.8 x 10^{-6} s)

(a = 6.0 x 10^{8} m s^{-2})

Condone POT error in substitution

No ECF from 3.1 this route (F =) 0.66 (N) ✓

2

(c) Use of Volume = Thickness x area of cross-section✓

Condone POT errors apart from final answer (V =) $8 \times 10^{-4} \times 0.03$
Or (V =) 2.4×10^{-5}

(Average density =) $\frac{50+5}{2} = 27.5$ ✓

Use of density = $\frac{\text{mass}}{\text{volume}}$ ✓

Condone use of their density and volume

(mass =) 6.6×10^{-4} (kg) ✓ c.a.o

Alternative:

Use of Volume = Thickness x area of cross-section✓

Condone POT errors apart from final answer

(V =) $8 \times 10^{-4} \times 0.03$ Or (V =) 2.4×10^{-5}

Use of density = $\frac{\text{mass}}{\text{volume}}$ / (mass =) 1.2×10^{-3} or 1.2×10^{-4}✓

(Average mass =) $\frac{1.2\times10^{-3}+1.2\times10^{-4}}{2}$ ✓

= 6.6×10^{-4} (kg) ✓ c.a.o

Condone use of their density and volume (50 kg m^{-3} =1.2×10^{-3})

(5 kg m^{-3} =1.2×10^{-4})

Alternative:

Condone POT errors apart from final answer

Attempts to determine the area under the graph:

Formula for area of a rectangle added to the formula for area of a triangle seen / formula for the area of trapezium seen✓

$5 \times 0.03 + \frac{(50-5)\times0.03}{2} = 0.825\ (kg\ m^{-2})$
$or\ \frac{50+5}{2} \times 0.03 = 0.825\ (kg\ m^{-2})$ ✓

Multiplies their area by 8×10^{-4}✓

Mass = 6.6×10^{-4} (kg) ✓ c.a.o

4

(d) **Q** has a larger volume (for the same mass and KE) /

Q has a larger surface area (for the same mass and KE) ✓

Q will experience a greater resistive force (at any given speed) / **Q** will displace more matter per unit distance✓

Q will do more work per unit distance / **Q** will transfer more of its kinetic energy per unit distance / **Q** will experience a greater deceleration✓

*Must have **Q** will travel a shorter distance for all 3 marks.*

3

[10]

2. B

$\sqrt{2}v$

[1]

3. D

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

[1]

4. D

Only total momentum is conserved.

[1]

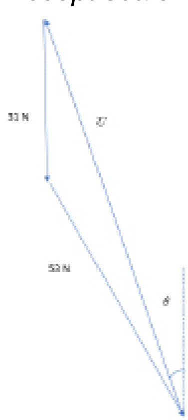
5. (a) Closed triangle of forces drawn ✓

Appropriate scale ✓

θ = 23 to 27 (°) ✓

U = 77 to 81 (N) ✓

Accept scale where 10 N is represented by at least 1 cm.



Treat each marking point independently.

Do not accept answers for U and θ without a scale diagram.

Maximum of 3 marks for a free-body diagram where forces have been drawn to scale. (Check figure 8)

4

(b) V is vertical / Force at **Y** is now vertical / V does not have a horizontal component / $V = S + 31$ / V is perpendicular to the pole / V is of greater magnitude than U / Force at **Y** has increased in magnitude✓

(Because) S and weight (or mg) are both vertical (in **Fig 3**)✓

(Because) greater moment of weight (about **Y**) in **Fig 3** / smaller moment of weight (about **Y**) in **Fig 1** / (Because) S is larger in magnitude than D (to produce a greater moment (about **Y** because they are equal distances from Y)✓

3

[7]

6. (a) Use of $p = mv$ **or** estimates walking speed = 1 or 2 m/s✓

Allow use of where m has been made the subject and p has been substituted.

Accept any answer in range 2×10^6 to 10×10^6 (kg) ✓

Range on answer:

(Using speeds in range 0.5 ms^{-1} to 2.5 ms^{-1})

Accept 1 significant figure answer

2

(b) **Max 4**

There is a force on the water (from the propeller) and this produces an equal force on the propeller (from the water in the opposite direction) ✓
Correctly links to Newton's 3 rd law ✓

This force on the ship equals the drag force on the ship✓ Correctly links to Newton's 1st law ✓

Force is needed to change the water's momentum ✓ Correctly links to Newton's 2nd law✓

Must link correct law to at least one correct statement for all 4 marks

4

(c) (When system is enabled,) drag decreases by more than thrust

Or

(When system is enabled,) decrease in work done (per second) against drag (at any speed) is greater than the decrease in the work done by the propeller (at any rotational speed)✓

Work done (per second) by drag decreases and work done (per second) by propeller decreases (at any rotational speed) ✓

To maintain constant momentum then drag must equal thrust✓

Propeller can operate at lower rotational speed so that thrust again equals drag

Or

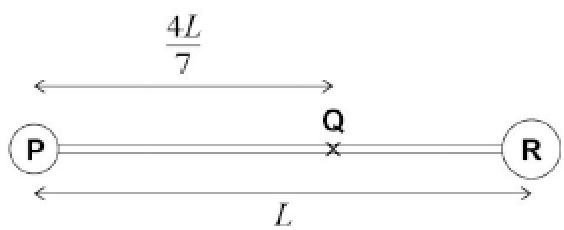
Engine does less work (and less fuel needs burnt) ✓

3rd MP: Accept answer in terms of power = Fv

3

[9]

7. C



[1]

8. B

190 m

[1]

9. (a) arrow between block and belt pointing upwards along the belt

1

(b) (F =) 19$g$sin23° to give 72.8 (N) ✓

Allow 2 sf answer.

1

(c) uses $F = \frac{\Delta(mv)}{\Delta t}$

Allow for MP1 use of appropriate kinematic equation for a ***AND*** *use of* $F = ma$

F = 12 (N) ✓

their (b) + 12 (N) ✓

Expect 82 or 85 (N)

3

(d) uses V and I to get total input power or energy ✓

P_{input} of motor = 110 × 5.0 = 550 W

$E_{input} = 550 \times \frac{8.0}{0.32} = 13\,750$ J

uses efficiency equation ✓

P_{useful} to belt = 550 × 0.28 = 150 W

E_{useful} = 3850 J, from $154 \times \frac{8.0}{0.32}$, or 13 750 × 0.28

determines power or energy to move one block ✓

P_{block} = 22 or 23 W

E_{block} = 560 or 580 J

divides (total) useful power or energy by individual power or energy to give answer of 6 blocks ✓

Allow ecf for MP4 only for their (c)

4

[9]

10. D

moving up with a decreasing velocity.

[1]

11. C

80 m s^{-1}

[1]

12. C

*The acceleration of **X** is the same as that of **Y**.*

[1]

13. C

*The terminal speed of **Y** is greater than that of **Z**.*

[1]

14. (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 $t = \dfrac{12.9 \pm \sqrt{(-12.9)^2 - 4 \times 4.91 \times 3.00}}{2 \times 4.91}$

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

(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

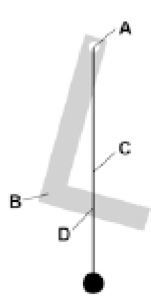
[14]

15. D

9.6 N

[1]

16. C



[1]

17. C

G F

[1]

18. C

250 J

[1]

19. A

the acceleration of the car increases.

[1]

20. (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

(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 <u>greater than the weight</u> 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

(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]

21. (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

(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]

22. **A**

[1]

23. **C**

[1]

24. **D**

[1]

25. **C** **[1]**

26. **B** **[1]**

27. **D** **[1]**

28. **A** **[1]**

29. **B** **[1]**

30. (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

(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

(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]

31. (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 3.7×10^4 cos20 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. $½ \times 3.7 \times 10^4 \times 13.2 = 2.44 \times 10^5$ (J) ✓

4.9×10^5 (J) ✓

4

(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 $½ \times 1.2 \times 10^3 \times (\text{their } v)^2$ ✓

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]

32. (a) 0.56 (N) ✓

1

(b) Definition of couple as two equal 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

(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]

33. (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

(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]

34. **B**

[1]

35. (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

(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 ✓

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]

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

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

$(= 7(.2) \times 10^5)$

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) ✓

$= 4.4 \times 10^4$ ✓

For unit <u>only</u> 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($= ½ \times 1.5 \times 10^3 \times 28.7^2$) = 618 kJ ✓

Change = 700 – 618 ✓ (= 82 kJ)

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 ✓

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]

37. **D** **[1]**

38. **D** **[1]**

39. **A** **[1]**

40. **A** **[1]**