Q1.

2 (a) (i) distance from a (fixed point) in a specified direction ........................................... M1

(Allow 1 mark for 'distance in a given direction')

(ii) (displacement from start is zero if) car at its starting position .... B1 [3]

(b) (i)1 \( v^2 = u^2 + 2as \)
\[ 28^2 = 2 \times a \times 450 \] (use of component of 450 scores no marks) .... C1
\[ a = 0.87 \text{ m s}^{-2} \] ................................................. A1 [2]
(-1 for 1 sig. fig. but once only in the question)

(i)2 \( v = u + at \) or any appropriate equation
\[ 28 = 0.87t \] or appropriate substitution ................................................. C1
\[ t = 32 \text{ s} \] ................................................. A1 [2]

(i)3 \( E_k = \frac{1}{2}mv^2 \) ................................................. C1
\[ = \frac{1}{2} \times 800 \times 28^2 \]
\[ = 3.14 \times 10^3 \text{ J} \] ................................................. A1 [2]

(i)4 \( E_p = mgh \) ................................................. C1
\[ = 800 \times 9.8 \times 450 \sin 5 \] ................................................. C1
\[ = 3.07 \times 10^4 \text{ J} \] ................................................. A1 [3]

(ii) power = energy/time ................................................. C1
\[ = \frac{(6.21 \times 10^4)}{32.2} \] ................................................. C1
\[ = 1.93 \times 10^3 \text{ W} \] ................................................. A1 [3]

(power = \( Fv \) with \( F = mg \sin \theta \) scores no marks)

(iii) some work also done against friction forces ................................................. M1
location of frictional forces identified ................................................. A1 [2]

(allow reasonable alternatives)

Q2.

5 (a) (i) distance = \( 2\pi r \) ................................................. B1

(ii) work done = \( F \times 2\pi r \) (accept e.c.f.) ................................................. B1 [2]

(b) total work done = \( 2 \times F \times 2\pi r \)
but torque \( T = 2Fr \)
hence work done = \( T \times 2\pi r \) ................................................. B1 [2]

(c) power = work done/time (= \( 470 \times 2\pi \times 2400 \)/60)
\[ = 1.2 \times 10^5 \text{ W} \] ................................................. A1 [2]

Total ................................................. [6]

Q3.
3 (a) (i) \[ \Delta E = mg \Delta h \]
= \(0.602 \times 9.8 \times 0.086\)
= 0.51 J

(do not allow \(g = 10\), \(m = 0.600\) or answer 0.50 J)

(ii) \[ v^2 = (2gh) = 2 \times 9.8 \times 0.086 \text{ or } (2 \times 0.51)/0.602 \]
\[ v = 1.3 \text{ m s}^{-1} \]

(b) \[ 2 \times V = 602 \times 1.3 \text{ (allow 600)} \]
\[ V = 390 \text{ m s}^{-1} \]

(c) (i) \[ E_k = \frac{1}{2}mv^2 \]
= \(\frac{1}{2} \times 0.002 \times 390^2\)
= 152 J or 153 J or 150 J

(ii) \(E_k\) not the same/changes
or \(E_k\) before impact > \(E_k\) after/\(E_k\) after
so must be inelastic collision

(allow 1 mark for ‘bullet embeds itself in block’ etc.)

Q4.

4 (a) (i) (change in) potential energy = \(mgh\)
= \(0.056 \times 9.8 \times 16\)
= 8.78 J
(allow 8.8)

(ii) (initial) kinetic energy = \(\frac{1}{2}mv^2\)
= \(\frac{1}{2} \times 0.056 \times 18^2\)
= 9.07 J
(allow 9.1)

total kinetic energy = 8.78 + 9.07 = 17.9 J

(b) kinetic energy = \(\frac{1}{2}mv^2\)

17.9 = \(\frac{1}{2} \times 0.056 \times v^2\) and \(v = 25(\ldots) \text{ m s}^{-1}\)

(c) horizontal velocity = 18 m s\(^{-1}\)

(d) (i) correct shape of diagram
(two sides of right-angled triangle with correct orientation)

(ii) angle = 41° \(\rightarrow\) 48° (allow trip. solution based on diagram)
(for angle 38° \(\rightarrow\) 41° or 48° \(\rightarrow\) 51°, allow 1 mark)

Q5.
Q6.

2 (a) work done is the force \( \times \) the distance moved / displacement in the direction of the force
or
work is done when a force moves in the direction of the force ................................. B1 [1]

(b) component of weight = 850 \( \times \) 9.81 \( \times \) sin 7.5°
\[ = 1090 \text{ N} \]
(use of incorrect trigonometric function, 0/2) ................................. C1 [2] A1

(c) (i) \( \Sigma F = 4600 - 1090 = 3510 \)
deceleration = 3510 / 850
\[ = 4.1 \text{ m/s}^2 \]
M1 A1 [2]

(ii) \( v^2 = u^2 + 2as \)
\[ 0 = 25 + 2 \times -4.1 \times s \]
\[ s = 225 / 8.2 \]
\[ = 27.8 \text{ m} \]
(allow full credit for calculation of time (6.05 s) & then s) ................................. C1 A1 [2]

(iii) 1. kinetic energy = \( \frac{1}{2} mv^2 \)
\[ = 0.5 \times 850 \times 25^2 \]
\[ = 2.7 \times 10^5 \text{ J} \]
C1 A1 [2]

2. work done = 4600 \( \times \) 75.7
\[ = 3.5 \times 10^5 \text{ J} \]
A1 [1]

(iv) difference is the loss in potential energy (owitte) ................................. B1 [1]

Q7.
3 (a) evidence of use of area below the line
   distance = 39 m (allow ±0.5 m)
   (if > ±0.5 m but ≤ 1.0 m, then allow 1 mark)
   B1
   A2 [3]

(b) (i) 1 \( E_k = \frac{1}{2}mv^2 \)
   \( \Delta E_k = \frac{1}{2} \times 92 \times (6^2 - 3^2) \)
   = 1240 J
   C1
   A1 [2]

   2 \( E_p = mgh \)
   \( \Delta E_p = 92 \times 9.8 \times 1.3 \)
   = 1170 J
   C1
   A1 [2]

   (ii) \( E = Pt \)
   \( E = 75 \times 8 \)
   = 600 J
   C1
   A1 [2]

(c) (i) energy = (1240 + 600) - 1170
   = 670 J
   M1
   A0 [1]

   (ii) force = 670/39 = 17 N
   A1 [1]

(d) frictional forces include air resistance
   air resistance decreases with decrease of speed
   B1
   B1 [2]

Q8.

3 (a) (i) work done equals force \times distance moved / displacement in the direction of
   the force
   B1 [1]

   (ii) power is the rate of doing work / work done per unit time
   B1 [1]

(b) (i) kinetic energy = \( \frac{1}{2} mv^2 \)
   = 0.5 \times 600 \times (9.5)^2
   = 27075 (J) = 27 kJ
   C1
   C1
   A1 [3]

   (ii) potential energy = \( mgh \)
   = 600 \times 9.81 \times 4.1
   = 24132 (J)
   = 24 kJ
   M1
   A1
   A0 [2]

   (iii) work done = 27 - 24 = 3.0 kJ
   A1 [1]

   (iv) resistive force = 3000 / 8.2 (distance along slope = 4.1 / sin 30°)
   = 368 N
   C1
   A1 [2]

Q9.
2 (a) (i) \[ v^2 = u^2 + 2as \]
\[ = (8.4)^2 + 2 \times 9.81 \times 5 \]
\[ = 12.99 \text{ ms}^{-1} \] (allow 13 to 2.5 s.f. but not 12.9)

(ii) \[ t = \frac{v - u}{a} \text{ or } s = ut + \frac{1}{2}at^2 \]
\[ = (12.99 - 8.4) / 9.81 \text{ or } s = 8.4t + \frac{1}{2} \times 9.81t^2 \]
\[ t = 0.468 \text{ s} \]  

(b) reasonable shape
suitable scale
correctly plotted 1st and last points at (0,8.4) and (0.88 – 0.96,0)
with non-vertical line at 0.47 s

(c) (i) kinetic energy at end is zero so \( \Delta KE = \frac{1}{2} mv^2 \text{ or } \Delta KE = \frac{1}{2} mu^2 - \frac{1}{2} mv^2 \)
\[ \frac{1}{2} \times 0.05 \times (8.4)^2 \]
\[ = (-) 1.8 \text{ J} \]

2. final maximum height \( \frac{(4.2)^2}{2 \times 9.8} = (0.9 \text{ m}) \)
change in PE = \( mgh_2 - mgh \)
\[ = 0.05 \times 9.8 \times (0.9 - 5) \]
\[ = (-) 2.0 \text{ J} \]

(iii) change is \(-8.8 \text{ J}\)
energy lost to ground (on impact) / energy of deformation of the ball / thermal energy in ball

Q10.

3 (a) loss in potential energy due to decrease in height (as P.E. = mgh)
gain in kinetic energy due to increase in speed (as K.E. = \( \frac{1}{2} mv^2 \))
special case 'as PE decreases KE increases' (1/2)
increase in thermal energy due to work done against air resistance
loss in P.E. equals gain in K.E. and thermal energy
max. 3

(b) (i) kinetic energy \( \frac{1}{2} mv^2 \)
\[ \frac{1}{2} \times 0.150 \times (25)^2 \]
\[ = 46.875 = 47 \text{ J} \]

(ii) 1. potential energy \( = mgh \) = 0.150 \times 9.81 \times 21
loss = KE – mgh = 46.875 – (30.9)
\[ = 15.97 = 16 \text{ J} \]

2. work done = 16 J
work done = force \times distance
\[ F = 16 / 21 = 0.76 \text{ N} \]

Q11.
4 (a) force \times distance moved ........................................... M1  
in the direction of the force ........................................ A1 [2]

(b) weight / force = mg .................................................. M1  
\Delta E_p = mg \times \Delta h ............................................... A1 [2]  
(no marks for quote of mg\Delta h)

Q12.

8 (a) product of force and distance moved in the direction of the force ........................................ M1  
                              ............................................... A1 [2]

(b) (i) falls from rest decreasing acceleration reaches a constant speed ........................................... B1  
                              ............................................... B1 [3]

(ii) straight line with negative gradient v-axis intercept above maximum \text{E}_k reasonable gradient (same magnitude as that for \text{E}_k initially) ........................................... B1  
                              ............................................... B1 [3]

Q13.

1 (a) (i) product of force and distance moved (by force) in the direction of the force ........................................ M1  
                              ............................................... A1 [2]

(ii) work (done) per unit time (idea of ratio needed) ........................................... B1 [1]

(b) either work/time or power = (force \times distance)/time to give power = force \times velocity ......................... M1  
                              ............................................... A1 [2]

(c) (i) kinetic energy (= \frac{1}{2}mv^2) = \frac{1}{2} \times 1900 \times 27^2 
power = 692550 / 8.1 = 8.55 \times 10^3 \text{ W} ........................................... C1  
                              ............................................... A1 [2]

(ii) either for equal increments of speed, increments of \text{E}_k are different so longer time (to increase speed) at high speeds  
or air resistance increases with speed (M1) so driving force (and acceleration) reduced (A1)  
or \text{P} (= Fv) = mv \text{a} (M1) (P and m constant) so when v increases, a decreases (A1)

Q14.
3. (a) (i) potential energy: stored energy available to do work  
(ii) gravitational: due to height/position of mass OR distance from mass  
OR moving mass from one point to another  
es elastic: due to deformation/stretching/compressing

4. (b) (i) height raised = \((61 \cdot \cos 18°) = 30 \text{ cm}\)  
energy = \((mg \cdot h = 0.051 \times 9.8 \times 0.030 = 1.5 \times 10^{-2} \text{ J})\)  

(b) (i) moment = force \times \text{perpendicular distance}  
\(= 0.051 \times 9.8 \times 0.61 \times \sin 18°\)  
\(= 0.094 \text{ N m}\)

Q15.

4. (a) electrical potential energy (stored) when charge moved and gravitational potential energy (stored) when mass moved  
and work done in electric field and work done in gravitational field

(b) work done = force \times \text{distance moved (in direction of force)}  
and force = \(mg\)  
\(mg \times h \text{ or } mg \times \Delta h\)

(c) (i) \(0.1 \times mgh = \frac{1}{2} m v^2\)  
\(0.1 \times m \times 9.81 \times 120 = 0.5 \times m \times v^2\)  
\(v = 15.3 \text{ m/s}\)

(ii) \(P = 0.5 m v^2 / t\)  
\(m \times t = 110 \times 10^3 / [0.25 \times 0.5 \times (15.3)^2]\)  
= 3740 \text{ kJ/s}^{-1}

Q16.
3 (a) (i) power = work done per unit time / energy transferred per unit time / rate of work done

   B1 [1]

   (ii) Young modulus = stress / strain

   B1 [1]

   (b) (i) \[ E = \frac{T}{A \times \text{strain}} \] (allow strain = \( \epsilon \))

   \[ T = E \times A \times \text{strain} = 2.4 \times 10^{11} \times 1.3 \times 10^{-4} \times 0.001 \]

   \[ = 3.12 \times 10^4 \text{N} \]

   C1

   \[ W = ma \]

   \[ [3.12 \times 10^4 - 1800 \times 9.81] = 1800a \]

   \[ a = 7.52 \text{ ms}^{-2} \]

   C1

   A1 [3]

   (ii) \[ T = 1800 \times 9.81 = 1.8 \times 10^4 \text{N} \]

   A1 [1]

   2. potential energy gain = \( mgh \)

   \[ = 1800 \times 9.81 \times 15 \]

   \[ = 2.7 \times 10^5 \text{J} \]

   A1 [2]

   (iii) \[ P = Fv \]

   \[ = 1800 \times 9.81 \times 0.55 \]

   input power = \( 9712 \times (100/30) = 32.4 \times 10^5 \text{W} \)

   A1 [3]

Q17.

3 (a) \( \text{work = } \) force \( \times \) distance moved / displacement in the direction of the force

OR when a force moves in the direction of the force work is done

B1 [1]

(b) kinetic energy = \( \frac{1}{2} m v^2 \)

\[ = \frac{1}{2} 0.4 (2.5)^2 = 1.25 \text{ / } 1.3 \text{ J} \]

C1

A1 [2]

(c) (i) area under graph is work done / work done = \( \frac{1}{2} Fx \)

\[ 1.25 = (14 \times x) / 2 \]

\[ x = 0.18 \text{ (0.179) m} \] [allow \( x = 0.19 \text{ m using kinetic energy = 1.3 J} \]

C1

A1 [3]

(ii) smooth curve from \( v = 2.5 \text{ at } x = 0 \) to \( v = 0 \) at \( Q \)

M1

A1 [2]

Q18.
4 (a) gravitational PE is energy of a mass due to its position in a gravitational field. 
   Elastic PE energy stored (in an object) due to (a force) changing its shape / deformation / being compressed / stretched / strained. 

(b) (i) 1. kinetic energy = \( \frac{1}{2} mv^2 \)  
         = \( \frac{1}{2} \times 0.065 \times 16^2 \) = 8.3(2) J 

2. \( v^2 = 2gh \) OR \( PE = mgh \)  
   \( h = 16^2 / (2 \times 9.81) = 13(0.05) \) m

(ii) speed at \( t = \frac{1}{2} \) total time = 8 (ms\(^{-1}\))  
     or total \( t = 1.63 \) or \( t_{1/2} = 0.815 \) s  
     KE is \( \frac{1}{2} \)  
     or \( h \) at \( t_{1/2} = 9.78 \) (m)  
     and PE is \( \frac{3}{4} \) of max  
     ratio = 3  
     or \( \frac{9.78}{3.26} = 3 \)  

(iii) time is less because (average) acceleration is greater OR average force is greater