

QQQ – Further Mechanics 1 – Chapter 2 – Work, Energy & Power (Version 1)

Total Marks: 22

(22 = Platinum, 20 = Gold, 18 = Silver, 15 = Bronze)

1. A parcel of mass 2.5 kg is moving in a straight line on a smooth horizontal floor. Initially the parcel is moving with speed 8 m s^{-1} . The parcel is brought to rest in a distance of 20 m by a constant horizontal force of magnitude R newtons. Modelling the parcel as a particle, find

(a) the kinetic energy lost by the parcel in coming to rest, (2)

(b) the value of R . (3)

(Total 5 marks)

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2. A car of mass 1000 kg moves along a straight horizontal road at a constant speed $U \text{ m s}^{-1}$. The engine of the car is working at a rate of 20 kW.

The total resistance to the motion of the car is modelled as a constant force of magnitude 1600 N.

Using the model,

(a) find the value of U . (3)

Later on, the car moves down a straight road which is inclined to the horizontal at an angle α ,

where $\sin \alpha = \frac{1}{49}$

The total resistance to the motion of the car is again modelled as a constant force of magnitude 1600 N.

At the instant when the engine of the car is working at a rate of 20 kW and the speed of the car is 8 m s^{-1} , the acceleration of the car is $a \text{ m s}^{-2}$

Using the model,

(b) find the value of a . (4)

(c) State one improvement to the model that would make it more realistic. (1)

(Total 8 marks)

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3.

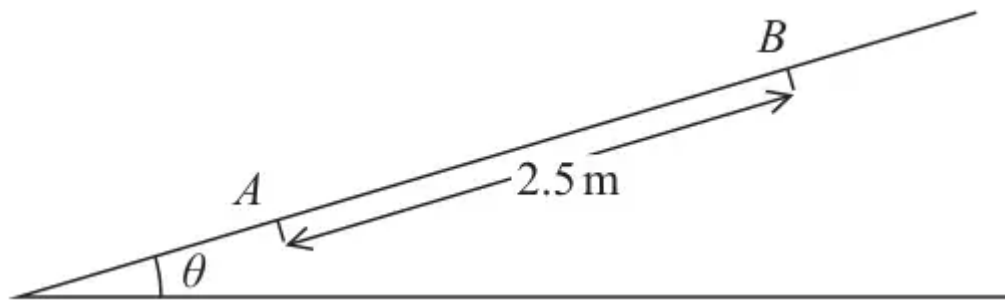


Figure 1

Figure 1 shows a ramp inclined at an angle θ to the horizontal, where $\sin \theta = \frac{2}{7}$

A parcel of mass 4 kg is projected, with speed 5 m s^{-1} , from a point A on the ramp.

The parcel moves up a line of greatest slope of the ramp and first comes to instantaneous rest at the point B , where $AB = 2.5 \text{ m}$.

The parcel is modelled as a particle.

The total resistance to the motion of the parcel from non-gravitational forces is modelled as a constant force of magnitude R newtons.

(a) Use the work-energy principle to show that $R = 8.8$ (4)

After coming to instantaneous rest at B , the parcel slides back down the ramp. The total resistance to the motion of the particle is modelled as a constant force of magnitude 8.8 N.

(b) Find the speed of the parcel at the instant it returns to A . (3)

(c) Suggest two improvements that could be made to the model. (2)

(Total 9 marks)

Solutions

1.

Mark scheme (a)

Scheme	Marks
KE lost is $\frac{1}{2} \times 2.5 \times 8^2 = 80 \text{ (J)}$	M1 A1
	(2)

Mark scheme (b)

Scheme	Marks
Work energy $80 = R \times 20$ ft their (a)	M1 A1 ft
$R = 4$	A1
	(3)
	(5 marks)

Alternative to (b)

$0^2 = 8^2 - 2 \times a \times 20 \Rightarrow a = (-)1.6$	
N2L $R = 2.5 \times 1.6$ ft their a	M1 A1ft
$= 4$	A1

(3)

2.

Mark scheme (a)

Scheme	Marks	AO
Equation of motion	M1	3.4
$\frac{20000}{U} - 1600 = 0$	A1	1.1b
$U = 12.5$	A1	1.1b
	(3)	

Notes

M1: Allow $F - 1600 = 0$ or $F = 1600$

A1: Correct equation in U only.

A1: Allow 13

N.B. A correct answer only, with no working, can score all 3 marks.

Mark scheme (b)

Scheme	Marks	AO
$\frac{20000}{8} = F$, the driving force	B1	3.3
Equation of motion	M1	3.1b
$F + 1000g \sin \alpha - 1600 = 1000a$	A1	1.1b
$a = 1.1$	A1	1.1b
	(4)	

Notes

B1: Seen or implied. Allow 20 instead of 20000.

B0 if they use $\frac{20000}{8}$ as the resultant force not the driving force.

M1: Correct no. of terms, condone sign errors and sin/cos confusion.

A1: Correct equation.

A1: cao

Mark scheme (c)

Scheme	Marks	AO
E.g. Make the resistance dependent on the speed. Make the resistance variable (not constant)	B1	3.5c
B0: Anything which is not related to the model i.e. to the total resistance being constant. e.g. Model the road as rough, include friction, include air resistance, unevenness of the road, more accurate value of g , make air resistance dependent on the speed.		

N.B. If there is more than one answer, penalise incorrect extras once e.g. one correct, one incorrect is B0.		
	(1)	
	(8 marks)	

Notes

B1: Accept 'make resistance non-constant' oe

3.

Mark scheme (a)

Scheme	Marks	AO
Work-energy equation: KE lost = PE gained + Work Done	M1	2.1
$\frac{1}{2} \times 4 \times 5^2 - 4 \times g \times 2.5 \times \sin \theta = 2.5R$	A1	1.1b
$\frac{1}{2} \times 4 \times 5^2 - 4 \times g \times 2.5 \times \frac{2}{7} = 2.5R$	A1	1.1b
$2.5R = 22 \Rightarrow R = 8.8 *$	A1*	1.1b
	(4)	

Notes

M1: A complete method to obtain R . The question requires the use of work-energy. Need to consider all three terms with no duplication. Condone sign error and sin/cos confusion.

A1: Unsimplified equation with at most one error

A1: Correct unsimplified

A1*: Correct answer with sufficient working shown to justify **given answer**

Mark scheme (b)

Scheme	Marks	AO
Work-energy equation: KE after = initial KE - 2 (Work Done)	M1	3.3
$\frac{1}{2} \times 4 \times v^2 = \frac{1}{2} \times 4 \times 25 - 2 \times 8.8 \times 2.5$	A1	1.1b
$\Rightarrow 2v^2 = 6, v = 1.7 \text{ (m s}^{-1}\text{)}$	A1	1.1b

	(3)	
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Notes

M1: Work-energy equation considering $A \rightarrow A$ or $B \rightarrow A$. Requires all relevant terms with no duplication. Condone sign errors and sin/cos confusion

A1: Correct unsimplified equation

A1: Accept 1.7 or 1.73 (answer depends on use of g). Not $\sqrt{3}$

Alternative (b)

Scheme	Marks	AO
Work-energy equation: KE at A = PE lost – Work Done	M1	
$\frac{1}{2} \times 4 \times v^2 = 4 \times 9.8 \times \frac{2}{7} \times 2.5 - 8.8 \times 2.5$	A1	
$\Rightarrow 2v^2 = 6, v = 1.7 \text{ (m s}^{-1}\text{)}$	A1	
	(3)	

(corrected from the printed mark scheme: “KE at B ”, but the kinetic energy found is at A ; the parcel is at rest at B)

Alternative (b)

Scheme	Marks	AO
Equation of motion and <i>suvat</i> : $4g \sin \theta - 8.8 = 4a$ ($a = 0.6$)	M1	
$v^2 = 2 \times a \times 2.5$	A1	
$v = 1.7 \text{ (m s}^{-1}\text{)}$	A1	
	(3)	

M1: Complete method to find v or v^2 .

A1: Correct unsimplified expression for v or v^2 .

A1: Accept 1.7 or 1.73 (answer depends on use of g)

Mark scheme (c)

Scheme	Marks	AO
A valid improvement	B1	3.5c
A second valid, distinct, improvement	B1	3.5c
	(2)	

	(9 marks)	
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Notes

B1: it has assumed a constant resistance - have variable resistance

-have air resistance proportional to speed

B1: Do not model the parcel as a particle

- so can consider the possibility that the parcel rotates as it moves up/down the slope

- consider the dimensions of the parcel

The comments need to relate to the 2 modelling assumptions in the question. Air resistance and friction are already included in "non-gravitational forces".