1. A car of mass 1000 kg is towing a trailer of mass 1500 kg along a straight horizontal road. The tow-bar joining the car to the trailer is modelled as a light rod parallel to the road. The total resistance to motion of the car is modelled as having constant magnitude 750 N. The total resistance to motion of the trailer is modelled as of magnitude R newtons, where R is a constant. When the engine of the car is working at a rate of 50 kW, the car and the trailer travel at a constant speed of 25 m s^{-1}.

(a) Show that $R = 1250$.

(3)

When travelling at 25 m s^{-1} the driver of the car disengages the engine and applies the brakes. The brakes provide a constant braking force of magnitude 1500 N to the car. The resisting forces of magnitude 750 N and 1250 N are assumed to remain unchanged. Calculate

(b) the deceleration of the car while braking,

(3)

(c) the thrust in the tow-bar while braking,

(2)

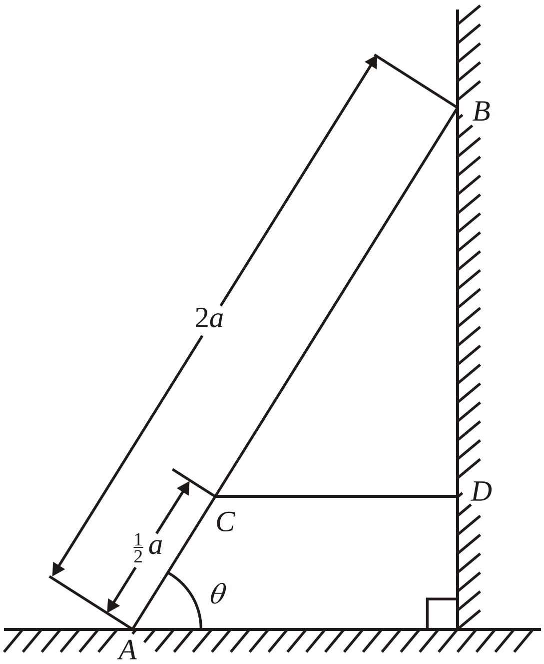
(d) the work done, in kJ, by the braking force in bringing the car and the trailer to rest.

(4)

(e) Suggest how the modelling assumption that the resistances to motion are constant could be refined to be more realistic.

(1)
(Total 13 marks)

2.



A uniform ladder, of weight W and length $2a$, rests in equilibrium with one end A on a smooth horizontal floor and the other end B on a rough vertical wall. The ladder is in a vertical plane perpendicular to the wall. The coefficient of friction between the wall and the ladder is μ. The ladder makes an angle θ with the floor, where $\tan\theta = 2$. A horizontal light inextensible string CD is attached to the ladder at the point C, where $AC = \frac{1}{2}a$. The string is attached to the wall at the point D, with BD vertical, as shown in the diagram above. The tension in the string is $\frac{1}{4}W$. By modelling the ladder as a rod,

(a) find the magnitude of the force of the floor on the ladder,

(5)

(b) show that $\mu \geq \frac{1}{2}$.

(4)

(c) State how you have used the modelling assumption that the ladder is a rod.

(1)
(Total 10 marks)

1.	(a)	$50\,000 = F \times 25$ ($F = 2000$) *or equivalent*	M1	
		$\to F = R + 750$	M1	
		$R = 1250$ (*) *cso*	A1	3
	(b)	N2L $1500 + 2000 = 2500a$ *ignore sign of a*	M1 A1	
		$a = 1.4$ (ms^{-2}) *cao*	A1	3
	(c)	Trailer: $T + R = 1500 \times 1.4$ *or* Car: $T - 1500 - 750 = 1000 \times -1.4$	M1	
		$T = 850$ (N)	A1	2
	(d)	$25^2 = 2 \times 1.4 \times s$ ($s = 223.2$)	M1	
		$W = 1500 \times s$ *ft their s*	M1 A1ft	
		$= 335$ (kJ) *accept 330*	A1	4
	(e)	Resistances <u>vary</u> with <u>speeds</u>	B1	1

[13]

2.	(a)	$M(B)$, $N\,2a\cos\theta = \text{W}\,a\cos\theta + \frac{1}{4}W\,\frac{3a}{2}\,\sin\theta$	M1 A2 (–1 e.e.)	
		$N = \frac{7W}{8}$	dep. M1 A1	5
	(b)	$R = \frac{1}{4}W$; $F + N = W$	B1; B1	
		$F \le \mu R$ or $F = \mu R$	M1	
		$\frac{1}{2} \le \mu$ * (exact)	A1 c.s.o.	4
	(c)	It does not bend or has negligible thickness	B1	1

[10]

1. Part (a) was well done but later parts of the question proved very discriminating. In part (b), the quickest method is to consider the whole system, but many who gave only one equation used a mass of 1000 kg or 1500 kg. If the car or the trailer is considered separately, then a pair of equations is needed and this was very rarely seen. Another source of error was treating the tractive force of 2000 N as still applying to the system. Part (c) was not understood by the majority of candidates; thrust often being confused with impulse or linear momentum. Thrust, along with tension, does appear in the M1 specification and can be tested on the M2 paper. In part (d), many thought that the work done was just the change in kinetic energy or made the equivalent error of, having found the distance moved in coming to rest, multiplying by 3500 N instead of 1500 N. Candidates did not seem to be expecting to be asked the work done by a specific force in a situation where there were three forces acting. A few used ratios and correctly, as all three forces have been acting over the same distance, calculated $\frac{3}{7}$ of the energy loss. In part (e), the majority knew that, in practice, resistance varies with speed.

2. This question was generally well done by the better candidates, with 8 or 9 marks a common score but the weaker ones, many of whom were not clear about the difference between resolving and taking moments, found it very difficult.A substantial number of candidates failed to draw a diagram, leaving examiners to guess the meaning and direction of R, S etc. Few candidates scored full marks. A handful of candidates had friction at the floor and not at the wall.

Even fewer had friction at both the wall and the floor. The two most common errors were to have friction pointing down (not one candidate explained the resulting negative friction) and, most common of all, to use *Wg* as the weight. Some candidates found angle *è* and so introduced errors into their work. One or two candidates failed to realise that $T = \frac{1}{4}W$.

Generally the moments equation was done well in part (a). Most candidates correctly resolved ? And ? (at the beginning of (a)) and the majority correctly used *f* = *ìr* or *f* ≤*ìr* in part (b). Very few correctly worked through with the inequality. Roughly half the candidates answered part (c) correctly. Weight at the centre was the most common wrong answer.