Solution 1

(18 marks)

(a) Lightning can be five times hotter than the surface of the Sun, but as it strikes an aircraft for only about 4.0×10^{-7} s, this is not usually a problem.

Using the data given in the article, calculate the average energy of one lightning strike on an aircraft. (3 marks)

Description	Marks
Energy = W = VIt = $1 \times 10^9 \times 1 \times 10^5 \times 4.0 \times 10^{-7}$	1–2
Energy = 4.00×10^7 J	1
Total	**3**

(b) Calculate the total charge in coulombs involved in one average lightning strike. (2 marks)

Description	Marks
Total charge is $q = It = 1 \times 10^5 \times 4.0 \times 10^{-7}$	1
Total q = 0.0400 C	1
Total	**2**

(c) Using the charge on one electron from the Formulae and Data Booklet, calculate the number of electrons that would enter the aircraft during a 4.00×10^{-7} s strike. Assume that all the charge in the lightning strike is carried by electrons. (2 marks)

Description	Marks
Number of electrons = total charge / charge on an electron $= 0.04 / 1.6 \times 10^{-19}$	1
Number of electrons = 2.50×10^{17} electrons	1
Total	**2**

(d) As well as electricity, heat can be conducted along an aircraft. Explain the process of heat conduction in metals such as aluminium. (3 marks)

Description	Marks
Heat energy causes the kinetic energy of the particles to increase	1
Increase in kinetic energy results in an increase in vibrations	1
Vibrations passed along from atom to atom increasing average kinetic energy (and temperature) along the metal or reference to mobile electrons.	1
Total	**3**

(e) Part of the air conditioning process in an aircraft involves compressed air being squirted into an expansion chamber, which causes the air to cool rapidly as it expands. Explain why this occurs. (2 marks)

Description	Marks
When particles move apart they gain potential energy	1
This energy is taken from the surroundings thus cooling them	1
Total	**2**

Solution 1 cont

(f) State Newton's first law of motion and then, using your understanding of this law, explain why seatbelts help to prevent injury. (3 marks)

Description	Marks
Objects remain in their state of motion unless acted on by a net external force	1
As the aircraft comes into land the people are moving at the same speed as the aircraft	1
The seatbelts hold the people against their seats as the aircraft stops quickly and prevents them from continuing forward	1
Total	**3**

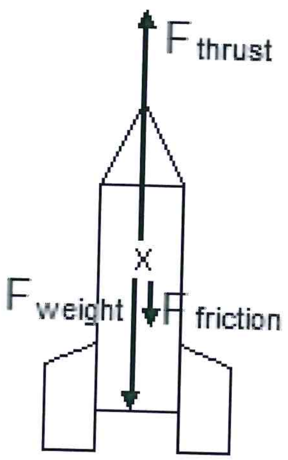
(g) Using the information given in the passage, calculate the acceleration of the aircraft when it took off from the levee. (3 marks)

Description	Marks
$v = 250\ km\ h^{-1} = 69.4\ m\ s^{-1}$	1
$v^2 = u^2 + 2as$ $69.4^2 = 2 \times a \times 360$ $4823 = 720a$	1
$a = 6.70\ m\ s^{-2}$	1
Total	**3**

Solution 2

(18 marks)

(a) Draw labelled vector arrows from point X on the rocket to show all the forces acting on the rocket in the first 1.80 s of flight. Include any frictional forces. The length of each arrow should represent the approximate magnitude of the force acting. (5 marks)



Description	Marks
F thrust upwards	1
F friction downwards	1
F weight downwards	1
Length upwards arrow longer than combined length of downward arrows.	1
Appropriate labels	1
Total	**5**

(b) The net acceleration of the rocket is affected by the thrust of the engine and the force of gravity. Calculate the acceleration of the rocket just before its engine stops working. Ignore any other forces acting on the rocket, and show **all** workings. (4 marks)

Description	Marks
$a_{rocket} = F_{engine} \div m_{rocket}$ $= 8.50 \div 0.650$	1
$a_{rocket} = 13.08$	1
Acceleration up subtract gravity down 13.1 – 9.8	1
3.28	1
Total	**4**

(c) Calculate the height, in metres, reached by the rocket at the moment when the engine stops working. If you were unable to calculate an answer to Part (b), use an acceleration value of 3.00 m s^{-2}. (2 marks)

Description	Marks
$s = ut + ½at^2$ but as $u = 0$ $s = ½at^2$ $s = 0.5 \times 3.28 \times 1.80^2$	1
s = 5.31	1
Alternative answer 4.86	
Total	**2**

(d) Calculate the velocity in metres per second of the rocket, 1.80 s after the engine starts. If you could not calculate an answer to Part (b), use an acceleration of 3.00 m s^{-2} upward. Show **all** workings. (3 marks)

Description		Marks
Let up be positive. $v^2 = u^2 + 2as$ $v^2 = 0 + (2 \times 3.28 \times 5.31)$ $= 34.83$	Alternative answer Let up be positive. $v^2 = u^2 + 2as$ $v^2 = 0 + (2 \times 3.00 \times 4.86)$ $= 29.16$	1–3
v = 5.90	v = 5.40	
Total		**3**

(e) Calculate the maximum height, in metres, reached by the rocket. Show **all** workings. (4 marks)

(Hint: When calculating the displacement of the rocket after the engine stops working, use the velocity you calculated in Part (d) above as an initial velocity.)

Description	Marks
$v^2 = u^2 + 2as$ $0 = (5.91)^2 + (2 \times -9.8 \times s)$ $0 = 34.83 + (-19.6s)$ $34.83 = 19.6s$	1–2
s = 1.78 m	1
s total = 5.35 + 1.78 = 7.13	1
Total	**4**

Solution 3

(10 marks)

A flea's jump is one of the most impressive examples of acceleration in the animal kingdom. By pushing its legs against the ground, the flea can attain an initial upward velocity of 1.00 m s^{-1} in 10.0 milliseconds.

Calculate:

(a) the flea's average acceleration over this time (that is, while leaving the ground). (3 marks)

Description	Marks
$a = \frac{(v - u)}{t}$	1
$a = \frac{1}{0.01}$	1
a = 100 m s^{-2}	1
	Total 3

(b) the force acting on the flea during this time if it has a mass of 2.00 mg. (4 marks)

Description	Marks
F = ma	1
$F = 2 \times 10^{-6} \times 100$	1–2
$F = 2 \times 10^{-4}$ N	1
	Total 4

(c) the maximum height that the flea can reach if its initial velocity is vertically upward. Hint: once the flea leaves the ground, it is affected only by gravity. (3 marks)

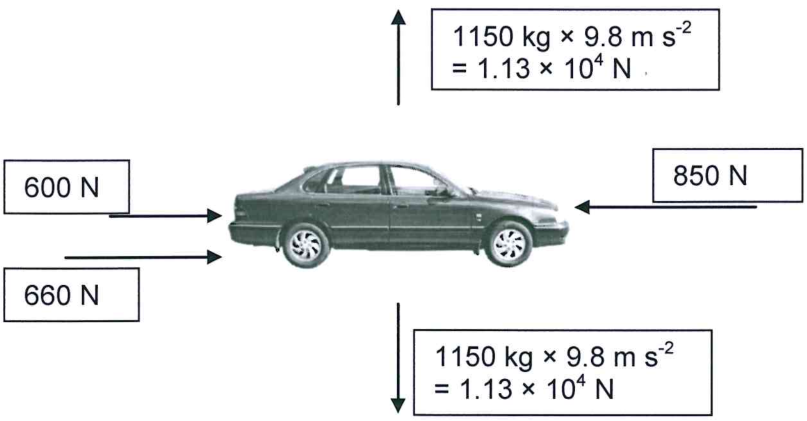
Description	Marks
$s = \frac{(v^2 - u^2)}{2a}$	1
$s = \frac{-1}{-19.6}$	1
s = 0.051 m	1
	Total 3

Solution 4

(6 marks)

Sam and Henry run out of petrol not far from a service station and decide to push their car to the service station to refuel it. Sam is able to exert a force of 600 N and Henry a force of 660 N. The mass of the car is 1150 kg and there is a frictional force of 850 N. Both boys push from the rear of the car in the same direction.

(a) Using the picture below, show all of the forces, with their magnitudes, acting on the car under these conditions. (3 marks)



Description	Marks
1 mark subtracted for each error on force diagram to a max of 3	1–3

Solution 4 cont

(b) What is the magnitude of the resultant force acting on the car under these conditions?

(3 marks)

Description	Marks
600+660=1260	1
F_r^2= (1260 – 850)	1
= 410 N	1
	Total 3