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Question 1

A forty-three tonne glider (18 marks)

Thunderstorms can produce lightning bolts with an average 1.00×10^9 V carrying a current of 1.00×10^5 A. Most pilots are not seriously concerned about lightning, as the outer skin of most aircraft is made primarily of aluminium. When lightning strikes the skin, charge flows from the contact point to the back of the aircraft, where it is discharged into the air.

In 1988, a new Boeing 737 aircraft with 45 people on board was coming in to land at New Orleans when it passed through a thunderstorm. At an altitude of about 5000 m, the aircraft suddenly lost thrust in both engines and all electrical power. The aircraft was now a 43-tonne glider.

With only three minutes to find a place to land, the pilot had the choice of a crowded freeway or a waterway. New Orleans is surrounded by waterways enclosed in levees (permanent grass-covered banks), which are designed to prevent the water from flooding the city. If he landed the aircraft on the freeway, many more people could die. The pilot then spotted a grass-covered levee to the right of a waterway. While the levee was shorter and narrower than a runway, it was solid, and safer than the water.

Lining up with the levee was difficult, but was successfully achieved. Despite having neither engine thrust nor brakes, a successful landing was made on the levee. The landing was hard and, as one passenger described, their seatbelts prevented them from shooting forward and crashing into the seat in front of them.

Investigators arrived within hours. They decided to replace one engine and the aircraft flew off the levee to New Orleans. The take-off speed for a Boeing 737 is 250 km h^{-1} and this speed was reached in 360 m during the take-off from the levee.

(a) Lightning can be five times hotter than the surface of the Sun, but as it strikes an aircraft for only about 4.00×10^{-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)

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

(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)

(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)

(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)

(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)

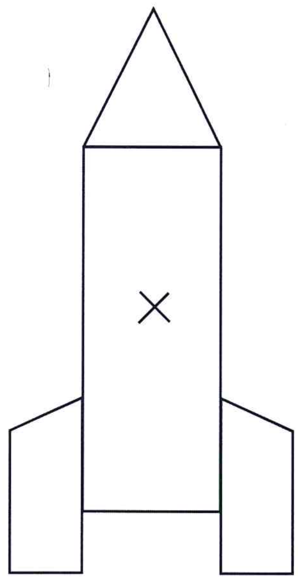
(g) Using the information given in the passage, calculate the acceleration of the aircraft when it took off from the levee. (3 marks)

Question 2

(18 marks)

A toy rocket with a mass of 0.650 kg is fired straight upward. The chemical engine provides 8.50 N of thrust for 1.80 s with negligible loss of mass. The engine works for 1.80 s.

(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)



(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)

(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)

(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)

(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.)

Question 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)

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

(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)

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Question 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)

(b) What is the magnitude of the resultant force acting on the car under these conditions? (3 marks)