8 **(a)** State Newton's Second Law.

.....

.....

[2]

.....

(b) A toy truck of mass 1.0 kg is moving in a straight line on a horizontal surface as shown in Fig. 8.1. The toy truck has a cargo compartment at the back with an open top.

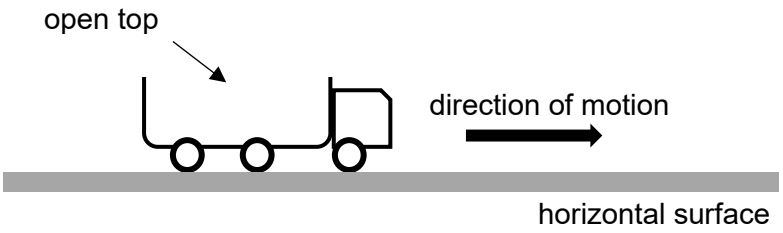

Fig. 8.1

Air resistance is negligible.

(i) If the engine of the toy truck delivers a constant driving force of 0.0050 N, calculate the impulse of the driving force for a duration of 30 s.

impulse = ... N s [1]

(ii) The toy truck was moving with a speed of 0.20 m s^{-1} when it started to rain. The rain droplets fall vertically and collect in the cargo compartment.

Show that the horizontal momentum of the truck and the rain droplets collected 30 s after the rain started is 0.35 N s.

horizontal momentum = ... N s [1]

(iii) The rain droplets collect in the cargo compartment at a rate of 0.0325 kg s^{-1}.

1. Calculate the total mass of the toy truck and the droplets collected at the end of the 30 s duration.

total mass = ... kg [1]

2. Using your answer in **(b)(ii)**, show that the final speed of the truck is 0.177 m s^{-1}.

[1]

3. Hence, state and explain the direction of the average acceleration of the toy truck.

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[2]

.....

4. By considering the forces acting on the toy truck, explain why it slows down despite a forward driving force.

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.....

.....

[3]

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(c) An oscillating system, whereby a sphere is attached to the top of a spring, is fitted into the cargo compartment of the toy truck, as shown in Fig. 8.2.

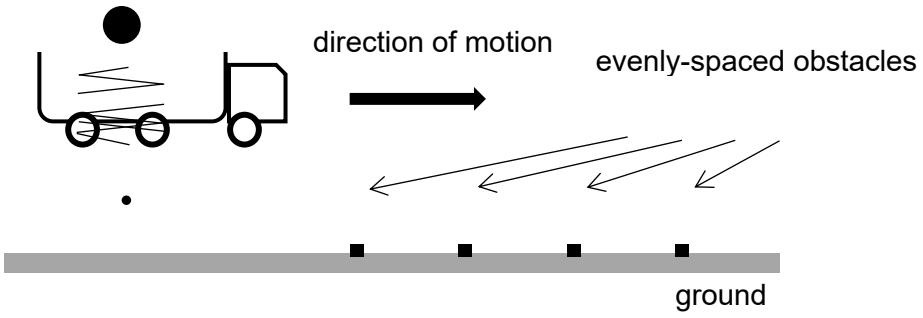

Fig. 8.2

The toy truck moves over evenly-spaced obstacles placed on the ground, causing the sphere to oscillate in the vertical direction.

The mass m of the sphere is 0.10 kg. The force constant k of the spring is 2.0 N m^{-1}.

(i) The equilibrium position of the sphere is defined as the position where the sphere experiences no net force.

1. Write down an equation for the net force acting on the sphere in terms of its vertical displacement x from the equilibrium position and the force constant k of the spring.

[1]

2. Using Newton's Second Law, show that the acceleration a of the sphere and its displacement x from the equilibrium position are related by

$$a = -\omega^2 x ,$$

where

$$\omega = \sqrt{\frac{k}{m}}$$

is called the angular frequency of the oscillation.

[1]

3. Explain the meaning of the negative sign in the equation $a = -\omega^2 x$.

[1]

.....

(ii) Calculate the natural frequency of the oscillating system.

natural frequency = ... Hz [2]

(iii) When the toy truck is moving across the obstacles at a constant velocity of 5.0 m s^{-1}, the sphere oscillates with maximum amplitude.

Calculate the distance between consecutive obstacles.

distance = ... m [2]

(iv) As the toy truck continues to move over the obstacle at the same speed, it starts to drizzle and the sphere absorbs rainwater.

State and explain the effect of the absorbed rainwater on the oscillation of the system.

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[2]

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[Total: 20]