Unit Review 2 Q and A

Motion

Q1

- A block of mass 2 kg has a constant velocity when it is pushed along a table by a force of 5 N. When the push is increased to 9 N what is a) the resultant force,
- b) the acceleration?

- When the block moves with constant velocity the forces acting on it are balanced. The force of friction opposing its motion must therefore be 5 N.
- a When the push is increased to 9 N the resultant (unbalanced) force F on the block is (9 − 5) N = 4 N (since the frictional force is still 5 N).
- b The acceleration a is obtained from F = ma where F = 4 N and m = 2 kg.

$$\therefore \quad a = \frac{F}{m} = \frac{4\,\text{N}}{2\,\text{kg}} = \frac{4\,\text{kg m/s}^2}{2\,\text{kg}} = 2\,\text{m/s}^2$$

Q2

- A ball is projected vertically upwards with an initial velocity of 30 m/s. Find a its maximum height and b the time taken to return to its starting point. Neglect air resistance and take g = 10 m/s2.

a We have $u = 30\,\mathrm{m/s}$, $a = -10\,\mathrm{m/s^2}$ (a deceleration) and $v = 0$ since the ball is momentarily at rest at its highest point. Substituting in $v^2 = u^2 + 2as$,

$$0 = 30^2\,\mathrm{m^2/s^2} + 2(-10\,\mathrm{m/s^2}) \times s$$

or

$$-900\,\mathrm{m^2/s^2} = -s \times 20\,\mathrm{m/s^2}$$

$$\therefore \quad s = \frac{-900\,\mathrm{m^2/s^2}}{-20\,\mathrm{m/s^2}} = 45\,\mathrm{m}$$

b If t is the time to reach the highest point, we have, from $v = u + at$,

$$0 = 30\,\mathrm{m/s} + (-10\,\mathrm{m/s^2}) \times t$$

or

$$-30\,\mathrm{m/s} = -t \times 10\,\mathrm{m/s^2}$$

$$\therefore \quad t = \frac{-30\,\mathrm{m/s}}{-10\,\mathrm{m/s^2}} = 3\,\mathrm{s}$$

The downward trip takes exactly the same time as the upward one and so the answer is 6 s.

Q3

- A sprint cyclist starts from rest and accelerates at 1 m/s2 for 20 seconds. He then travels at a constant speed for 1 minute and finally decelerates at 2 m/s2 until he stops. Find his maximum speed in km/h and the total distance covered in metres.

$u = 0 \quad a = 1\,\text{m/s}^2 \quad t = 20\,\text{s}$

$$v = u + at = 0 + 1\,\text{m/s}^2 \times 20\,\text{s}$$
$$= 20\,\text{m/s}$$
$$= \frac{20}{1000} \times 60 \times 60 = 72\ \text{km/h}$$

The distance s moved in the first stage is given by

$$s = ut + \frac{1}{2}at^2 = 0 \times 20\,\text{s} + \frac{1}{2} \times 1\,\text{m/s}^2 \times 20^2\,\text{s}^2$$
$$= \frac{1}{2} \times 1\,\text{m/s}^2 \times 400\,\text{s}^2 = 200\,\text{m}$$

Second stage

$u = 20\,\text{m/s}$ (constant) $\quad t = 60\,\text{s}$

$$\text{distance moved} = \text{speed} \times \text{time} = 20\,\text{m/s} \times 60\,\text{s}$$
$$= 1200\,\text{m}$$

Third stage

$u = 20\,\text{m/s} \quad v = 0 \quad a = -2\,\text{m/s}^2$ (a deceleration)

We have

$$v^2 = u^2 + 2as$$
$$\therefore \quad s = \frac{v^2 - u^2}{2a} = \frac{0 - 20^2\,\text{m}^2/\text{s}^2}{2 \times (-2)\,\text{m/s}^2} = \frac{-400\,\text{m}^2/\text{s}^2}{-4\,\text{m/s}^2}$$
$$= 100\,\text{m}$$

Maximum speed = 72 km/h
Total distance covered = 200 m + 1200 m + 100 m
= 1500 m

Q4

- A boulder of mass 4 kg rolls over a cliff and reaches the beach below with a velocity of 20 m/s.
- Find: a) the kinetic energy of the boulder as it lands; b) the potential energy of the boulder when it was at the top of the cliff and c) the height of the cliff.

a Mass of boulder = m = 4 kg

Velocity of boulder as it lands = v = 20 m/s

$$\therefore \quad \text{k.e. of boulder as it lands} = E_k = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 4\text{ kg} \times (20)^2\text{ m}^2/\text{s}^2$$

$$= 800\text{ kg m/s}^2 \times \text{m}$$

$$= 800\text{ N m}$$

$$= 800\text{ J}$$

p.e. of boulder on cliff = k.e. as it lands

$$\therefore \quad \Delta E_p = E_k = 800\text{ J}$$

c If h is the height of the cliff,

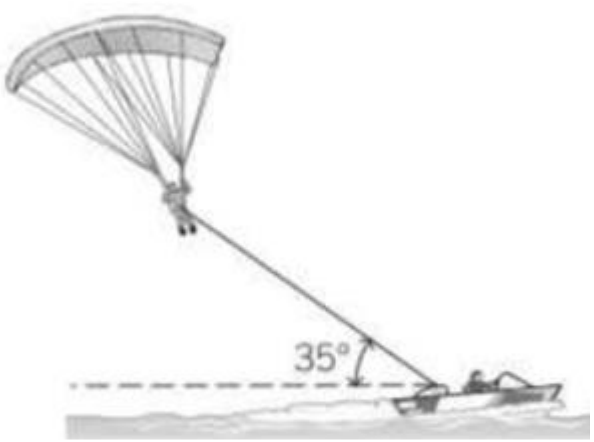
$$\Delta E_p = mgh$$

$$\therefore \quad h = \frac{\Delta E_p}{mg} = \frac{800\text{ J}}{4\text{ kg} \times 10\text{ m/s}^2} = \frac{800\text{ N m}}{40\text{ kg m/s}^2}$$

$$= \frac{800\text{ kg m/s}^2 \times \text{m}}{40\text{ kg m/s}^2} = 20\text{ m}$$

Q5

- A paraglider is pulled along at constant height at steady speed by a cable attached to a speedboat as shown in. The cable pulls on the paraglider with a force of 500N at an angle of 35° to the horizontal. Calculate the horizontal and vertical components of this force.



- Because the force on rhe paraglider is at an angle of 35° below the horizontal, the horizontal and vertical components of this force are
- 500 cos35° = 410N horizontally to the right
- 500 sin 35° = 287 N vertically downwards.

Q6

- The driver of a vehicle travelling at 8m s- 1 applies the brakes for 30 s and reduces the velocity of the vehicle to 2m s- 1• Calculate the deceleration of the vehicle during this time.

$$u = 8\,\mathrm{m\,s^{-1}},\ v = 2\,\mathrm{m\,s^{-1}},\ t = 30\ \mathrm{s}$$

$$a = \frac{v - u}{t} = \frac{2 - 8}{30} = \frac{-6}{30} = -0.2\,\mathrm{m\,s^{-2}}$$

Q7

- A driver of a vehicle travelling at a speed of 30 m s- on a motorway brakes sharply to a standstill in a distance of 100 m. Calculate the deceleration of the vehicle.

$u = 30\,\text{m}\,\text{s}^{-1}$, $v = 0$, $s = 100$ m, $a = ?$

To find a, use $v^2 = u^2 + 2as$

Therefore $0 = u^2 + 2as$ because $v = 0$

Rearranging this equation gives

$2as = -u^2$

$$a = -\frac{u^2}{2s} = -\frac{30^2}{2 \times 100} = -4.5\,\text{m}\,\text{s}^{-2}$$

Q8

In an American football match, the stationary quarterback is tackled by a defender who dives through the air at 4 m s^{-1} and, in mid-air, grabs the quarterback and the two fly backwards together. Ignoring any friction effects, calculate how fast the two will fly back if the tackler has a mass of 140 kg and the stationary player has a mass of 95 kg. Consider the entire situation to be happening horizontally.

Before:

Quarterback stationary so zero momentum

$p_{tackler} = mv = 140 \times 4 = 560$

momentum before = 560 kg m s^{-1}

After:

momentum after = momentum before = 560 kg m s^{-1}

$p_{both} = m_{both} \times v_{both}$

$$v_{both} = \frac{p_{both}}{m_{both}} = \frac{560}{(140 + 95)} = \frac{560}{235}$$

$v_{both} = 2.4$ m s^{-1}

Q9

If the boy has a mass of 55 kg and steps forward at a speed of 1.5 m s^{-1}, what will happen to the boat which has a mass of 36 kg? (Ignore friction effects.)

This situation is an explosion, so:

total momentum before = total momentum after = zero

$\therefore \quad p_{boat} + p_{boy} = 0$

$\therefore \quad p_{boat} = -p_{boy}$

So when the two are added up, the total momentum is still zero.

$\therefore \quad p_{boat} = -(55 \times 1.5) = -82.5\ \text{kg m s}^{-1}$

$m_{boat} \times v_{boat} = -82.5\ \text{kg m s}^{-1}$

$$v_{boat} = \frac{-82.5}{m_{boat}} = \frac{-82.5}{36}$$

$v_{boat} = -2.3\ \text{m s}^{-1}$

boat moves at 2.3 m s^{-1} in the opposite direction to the boy.

Q10

An athletics hammer has a mass of 7.26 kg (men's competition standard) and can be released at speeds in excess of 25 m s^{-1}. Its momentum at 25.0 m s^{-1} would be:

$$p = m \times v$$
$$p = 7.26 \times 25.0$$
$$p = 182 \text{ kg m s}^{-1}$$

A bullet can have a mass of 4.50 grams and can be fired at a speed of 925 m s^{-1}. The momentum of this example bullet would be:

$$p = m \times v$$
$$p = 4.5 \times 10^{-3} \times 925$$
$$p = 4.16 \text{ kg m s}^{-1}$$

Q11

If the forklift truck referred to above lifted the crate when supplied with electrical energy from its battery at a rate of 3000 joules per second, what is its efficiency?

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

$$\text{efficiency} = \frac{1470}{3000}$$

$$\text{efficiency} = 0.49 = 49\,\%$$

Q12

At what speed would Liam's watch hit the ground if he dropped it from a height of 52m.

$$v = \sqrt{2g\Delta h}$$

$$v = \sqrt{2(9.81 \times 52)} = \sqrt{1020}$$

$$v = 31.9\,\mathrm{m\,s^{-1}}$$

How high would water from a fountain rise if it were ejected vertically upwards from a spout at 13m/s

$$\Delta h = \frac{v^2}{2g}$$

$$\Delta h = \frac{13.5^2}{2(9.81)} = \frac{182.25}{19.62}$$

$$\Delta h = 9.29\,\mathrm{m}$$

Q13

A space vehicle moving towards a docking station at a velocity of 2.5 m s^{-1} is 26 m from the docking station when its reverse thrust motors are switched on to slow it down and stop it when it reaches the station. The vehicle decelerates uniformly until it comes to rest at the docking station when its motors are switched off.

Calculate **a** its deceleration, **b** how long it takes to stop.

Let the + direction represent motion towards the docking station and – represent motion away from the station.

Initial velocity $u = +2.5\,\mathrm{m\,s^{-1}}$, final velocity $v = 0$, displacement $s = +26\,\mathrm{m}$.

a To find its deceleration, a, use $v^2 = u^2 + 2as$

$$0 = 2.5^2 + 2a \times 26 \qquad \text{so } -52a = 2.5^2$$

$$a = \frac{2.5^2}{52} = -0.12\,\mathrm{m\,s^{-2}}$$

b To find the time taken, use $v = u + at$

$$0 = 2.5 - 0.12t \qquad \text{so } 0.12t = 2.5$$

$$t = \frac{2.5}{0.12} = 21\,\mathrm{s}$$

Q14

A driver of a vehicle travelling at a speed of $30\,\text{m}\,\text{s}^{-1}$ on a motorway brakes sharply to a standstill in a distance of 100 m. Calculate the deceleration of the vehicle.

$u = 30\,\text{m}\,\text{s}^{-1}$, $v = 0$, $s = 100$ m, $a = ?$

To find a, use $v^2 = u^2 + 2as$

Therefore $0 = u^2 + 2as$ because $v = 0$

Rearranging this equation gives

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