

5.7 Newton's laws

Name: _____ Class: _____ Date: _____

Total: 26 marks

KEY WORDS Inertia

Objective

State and apply Newton's three laws, use $F = ma$, and describe RP7's method and graphs. Original questions for spec statements 4.5.6.2.1–4.5.6.2.3.

1 Key knowledge and worked examples

First law: resultant force zero $\rightarrow$ a stationary object stays stationary; a moving object keeps the same velocity. Straight-line motion at steady speed means driving force = resistive forces. (HT) **Inertia** is the tendency to resist change of motion.

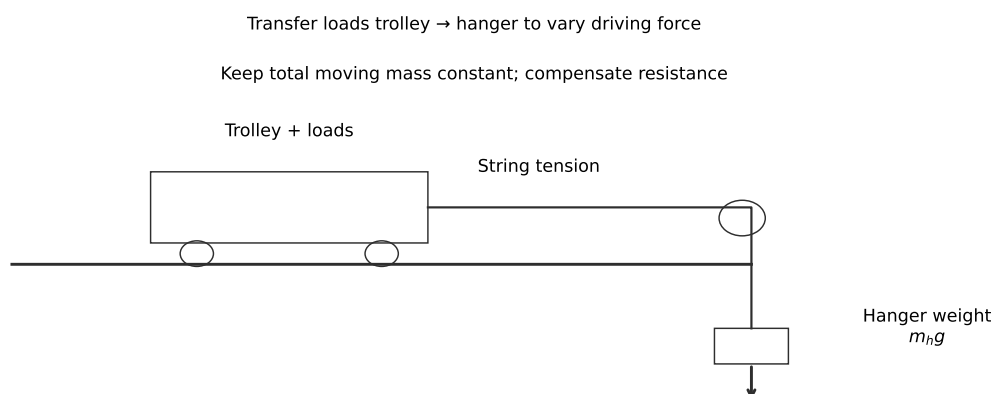
Second law: $a \propto F$ and $a \propto 1/m$, so:

$$F = ma$$

(HT) **Inertial mass** = F/a – how hard it is to change an object's velocity.

Third law: when two objects interact they exert **equal and opposite forces on each other** – same type, opposite directions, acting on different objects. (A book pushes down on the table; the table pushes up on the book.)

RP7 (force and mass effect on acceleration):



Compensate for friction by tilting the runway first.

- Set-up: trolley on a runway, thread over a pulley to a mass hanger, light gates (or ticker timer) measuring acceleration.
- **Part 1:** keep the **total moving mass** constant by moving masses from the trolley to the hanger; measure a for each driving force $F = m_h g$ on the combined trolley–hanger system, with resistance compensated or negligible; plot a against F – a straight line through the origin ($a \propto F$).
- **Part 2:** keep the **force** constant; add masses to the trolley; plot a against $1/m$ using the total moving mass – a straight line through the origin ($a \propto 1/m$).
- Controls: compensate friction (tilt until the trolley just runs steadily); same hanger mass in part 2; repeats and means.

Worked example. A 1500 kg car accelerates at 2.5 m/s^2 .

$$F = ma = 1500 \times 2.5 = 3750 \text{ N}$$

2 Practice

2.1 State Newton's first law for a moving object. [1]

2.2 A resultant force of 48 N acts on a 12 kg trolley. Calculate the acceleration. [2]

2.3 State Newton's third law and give one example with names on both objects. [2]

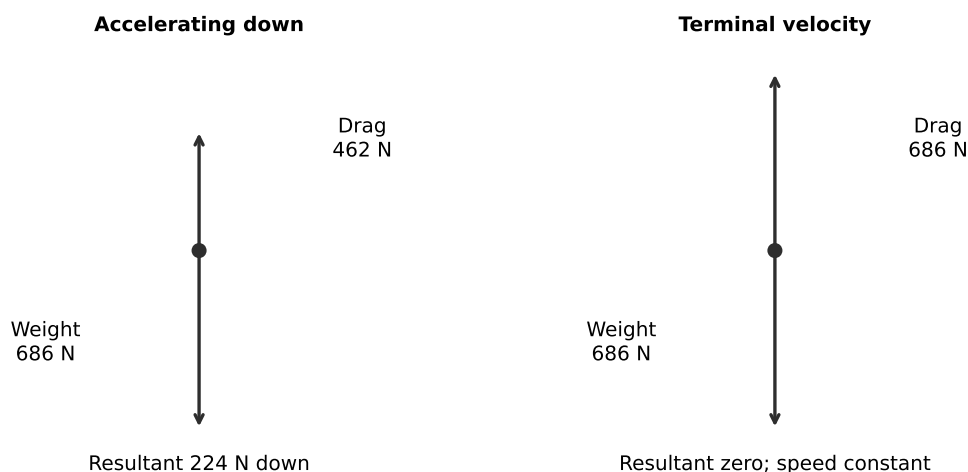
3 Exam-style questions

3.1 A student investigates how the driving force on a trolley–hanger system affects its acceleration, keeping the total moving mass constant and resistance negligible or compensated.

- (a) State the independent and dependent variables and one control. [3]
- (b) Describe how the student obtains the force and the acceleration values. [3]
- (c) The a – F graph is a straight line through the origin. State the relationship. [1]

3.2 A skydiver of mass 70 kg falls with acceleration 3.2 m/s^2 ($g = 9.8 \text{ N/kg}$).

- (a) Calculate the skydiver's weight. [2]
- (b) Calculate the resultant force. [2]
- (c) Calculate the drag force. [2]



3.3 A 1400 kg car travelling at 18 m/s brakes with constant deceleration and stops in a braking distance of 25 m.

- (a) Calculate the deceleration using $v^2 - u^2 = 2as$. [3]
- (b) Calculate the braking force. [2]

(c) (HT) State Newton's third-law pair for the braking force on the car, and explain why the two forces do not cancel out. [3]

Solutions

2.1 With zero resultant force, a moving object continues at the same velocity (same speed and direction).

2.2

$$a = F/m = 48/12 = \mathbf{4.0 \text{ m/s}^2}$$

(C1, A1)

2.3 Two interacting objects exert equal and opposite forces on each other; e.g. the foot pushes the ground backwards and the ground pushes the foot forwards (both named, B1).

3.1 (a) Independent: the pulling force (masses on the hanger); dependent: the acceleration; control: total mass of the system (or friction compensation / runway angle). (b) Driving force on the combined system: $F = m_h g$ using the mass of the hanger and its loads; do not call this the tension on the trolley; acceleration: light gates measure velocities at two points and $a = (v_2 - v_1)/t$ – or ticker-tape spacing; repeat each force and average. (c) Acceleration is directly proportional to the force.

3.2 (a) $F_W = mg = 70 \times 9.8 = \mathbf{686 \text{ N}}$ (C1, A1). (b) $F = ma = 70 \times 3.2 = \mathbf{224 \text{ N}}$ down (C1, A1). (c) Drag = weight – resultant = $686 - 224 = \mathbf{462 \text{ N}}$ up (C1, A1).

3.3 (a)

$$a = \frac{v^2 - u^2}{2s} = \frac{0 - 18^2}{2 \times 25} = \mathbf{-6.5 \text{ m/s}^2}$$

(substitution C1, rearrangement C1, answer A1) (b) $F = ma = 1400 \times 6.48 = \mathbf{9072 \approx 9100 \text{ N}}$ (2 s.f.) (C1, A1). (c) The third-law pair is: the car exerts a forward force on the road surface, and the road exerts an equal backward friction force on the tyres. They act on **different objects** (road vs car), so neither balances the other on the car – the backward friction on the tyres is what decelerates it.