inkPhysics

ANSWER BOOK

Newton's laws and the resultant force

Mechanics · Year 12

AQA 3.4.1.5 · CIE 3.1.2, 3.1.5 · OCR A 3.2.1(a), 3.2.1(d), 3.2.1(e), 3.2.1(f), 3.5.1(a)

19 questions · 60 marks

NAVY EDITION

SECTION A · Warm-up

A1 An object stays at rest, or continues at constant velocity (1), unless acted on by a resultant external force (1). [2]

A2 $F = ma = 2.0 \times 3.0$ (1) [2]
$F = 6$ N (1)

A3 The resultant force is the single force equivalent to all the individual forces acting on the object (1); it is their vector sum (1). [2]

A4 Zero: at constant velocity there is no resultant force (Newton's first law). (1) [1]

A5 Mass = 0.250 kg (1). $F = ma = 0.250 \times 12 = 3.0$ N. (1) [2]

A6 When body A exerts a force on body B, body B exerts a force on body A that is equal in magnitude and opposite in direction (1); the two forces are of the same type and act on different bodies. (1) [2]

SECTION B · Standard

B1 Resultant = 12 - 4.0 = 8 N to the right (1) [3]
$a = F/m = 8/4.0$ (1)
$a = 2.0\ \text{m s}^{-2}$ (1)

B2 (a) $W = mg = 70 \times 9.81$ (1) [4]
$W = 686.7$ N (1)
(b) $N - mg = ma$, so $N = m(g + a) = 70 \times (9.81 + 2.0)$ (1)
$N = 826.7$ N (1)

B3 (a) $a = F/(\text{total mass}) = 10/5.0$ (1) [4]
$a = 2.0\ \text{m s}^{-2}$ (1)
(b) Contact force = 2.0×2.0 (1)
Contact force = 4.0 N (1)

B4 The third-law pair is the book pushing down on the table with an equal and opposite force (1). The weight is not the pair because it is a gravitational force from the Earth (1), a different type of force acting on the same object (1). [3]

B5 Resultant force = $T - mg = 3650 - 350 \times 9.81 = 216.5$ N upwards (1). $a = F/m$ (1) $= 216.5/350 = 0.62\ \text{m s}^{-2}$ upwards. (1) [3]

B6 $a = \Delta v/\Delta t = (18 - 12)/4.0 = 1.5\ m\ s^{-2}$ (1). $F = ma = 0.160 \times 1.5$ (1) $= 0.24$ N, directed opposite to the motion. (1) [3]

B7 The swimmer's hands and feet push backwards on the water (1). By Newton's third law the water exerts an equal and opposite force forwards on the swimmer (1). This forward force gives a resultant force on the swimmer, so they accelerate ($F = ma$). (1) [3]

SECTION C · Stretch

C1 Component of weight down the slope = $mg \sin\theta$ (1) [3]
$a = g \sin 30° = 9.81 \times 0.5$ (1)
$a = 4.9\ m\ s^{-2}$ (2 s.f.) (1)

C2 (a) For the system: $a = m_1 g/(m_1 + m_2)$ (1) [5]
$a = 3.0 \times 9.81/5.0$ (1)
$a = 5.89\ m\ s^{-2}$ (1)
(b) For the table mass: $T = m_2 a = 2.0 \times 5.89$ (1)
$T = 11.8$ N (1)

C3 The person pushes down on the ground; the third-law pair is the ground pushing up on the person with an equal and opposite (normal contact) force (1). That upward force and the person's weight both act on the person, so they are not a third-law pair (1). They are equal in magnitude, so the resultant force on the person is zero and they remain in equilibrium (1). [3]

C4 Component of weight down the slope = $mg \sin\theta$ (1) $= 12 \times 9.81 \times \sin 25° = 49.8$ N (1). This is less than the 55 N maximum frictional force available (1), so friction can balance it: the resultant force is zero and the crate remains at rest. (1) [4]

C5 Force from the scales $N = 56.5 \times 9.81 = 554$ N (1). Newton's second law (up positive): $N - mg = ma$ (1), so $a = (554.3 - 62.0 \times 9.81)/62.0 = -0.87$, i.e. $0.87\ m\ s^{-2}$ (1) directed downwards (1). The lift could be moving upwards and slowing down, or moving downwards and speeding up: the reading fixes the acceleration, not the velocity. (1) [5]

C6 The pull on the cart and the pull on the horse act on different bodies, so they can never cancel: each body's motion depends only on the forces acting on that body (1). Forces on the cart: the forward pull from the horse and backward resistive forces (1). The cart accelerates when the horse's pull exceeds the resistance, giving a resultant force ($F = ma$) (1). The horse's hooves push backwards on the ground (1); by the third law the ground pushes forwards on the horse, and when this exceeds the backward pull of the cart plus resistance the horse accelerates too (1). So both accelerate together: third-law pairs act on different bodies and never cancel within one body's free-body diagram. (1) [6]