Page 117 Test yourself on prior knowledge

1 Scalars just have magnitude, vectors have magnitude and direction; velocity includes speed and direction

2 a) 1 N

b) 100 N, but a strong cyclist might exert a force equal to half their weight (so 300–400N).

c) 500N–1000 N; enough to decelerate a 600 kg car at 1 m s^{-2}.

3 Statement c) is true.

4 a) A long handled spanner enables a larger turning moment to be exerted. Moment = F × d

b) Moment = F × d

= 30 N × 0.25 m

= 7.5 N m

Page 118 Test yourself

1 Some examples of scalars: work done, pressure, number of moles.
Some examples of vectors: electric field, magnetic field, turning moment.

2 Vectors: momentum, weight, gravitational field strength.
Scalars: density, volume, electrical resistance, potential difference.

3 a) Distance travelled: 30 km + 10 km = 40 km
Displacement of car: 25 km due east.

b) Average speed of car = distance / time = 40 km / 0.8 h = 50 km h^{-1}
Average velocity of car = displacement / time = 25 km / 0.8 h = 31 km h^{-1} due east.

Page 119 Test yourself

4 a) v = $\{(420)^2 + (90)^2\}^{1/2}$ km h^{-1}

= 430 km h^{-1}

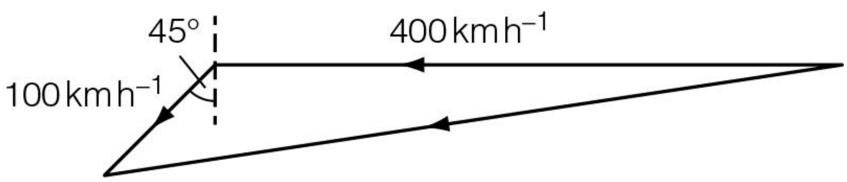
The direction 12^0 west of north. (tan θ = 90/420)

b) time = d/v

= 600 km/430 km h^{-1}

t = 1.39 h or 1 h 24 m

c) velocity = 475 km h^{-1} in a direction 8.5° south of west.



d) t = d/v

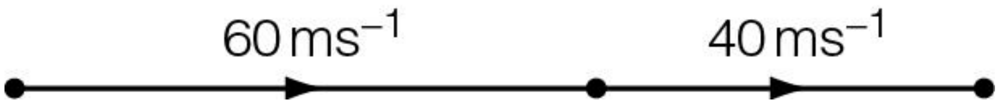
= 600 km/475 km h^{-1}

= 1.26 h or 1 h 16 m

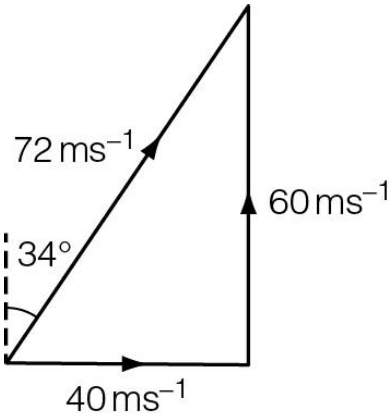
5 F = $\{(15\,000 - 10\,000)^2 + (22\,000 - 20\,000)^2\}^{1/2}$

= 5400 N at an angle of 22° above the horizontal (to the left). (tan θ = 2/5)

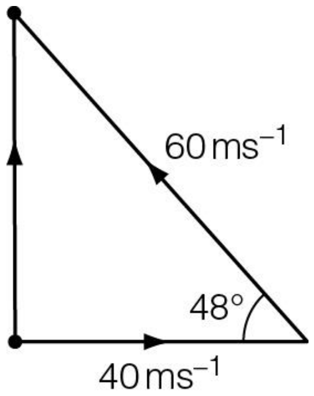
6 **a)** 100 m s^{-1}



b) 72 m s^{-1} on a bearing of 34° or 34° east of north



c) 45 m s^{-1} the plane heads on a bearing of 318° or 42° west of north.



Pages 121–122 Activity

a) Pin paper on board behind where W_3 is suspended; mark position of each string with at least two dots taking care not to displace string or angle (or dark paper and snap chalk-covered string); remove paper and use ruler to draw position of string by joining the dots; use a protractor to measure angles.

b) Apart from errors in measuring angles, friction in pulleys or between weights and board might lead to tensions in string not being equal to those calculated. Errors in weights (typically 0.5g/100g so 0.5%) are likely to be relatively small in comparison.

W_1/N	W_2/N	W_3/N	θ_1	θ_2
6	6	**6***	60°	60°
8	8	**12◊**	40°	40°
7	**10‡**	14	42°	28°
6	8	10	53°	**37°†**

* $6\cos(60°) + 6\cos(60°) = W_3$
$W_3 = 6$ N

◊ $8\cos(40°) + 8\cos(40°) = W_3$

$W_3 = 12$ N (12.2 N)

‡ $7\cos(42°) + W_2\cos(28°) = 14$ N

$W_2 = 10$ N

† $6\cos(53°) + 8\cos(\theta_2) = 10$ N;

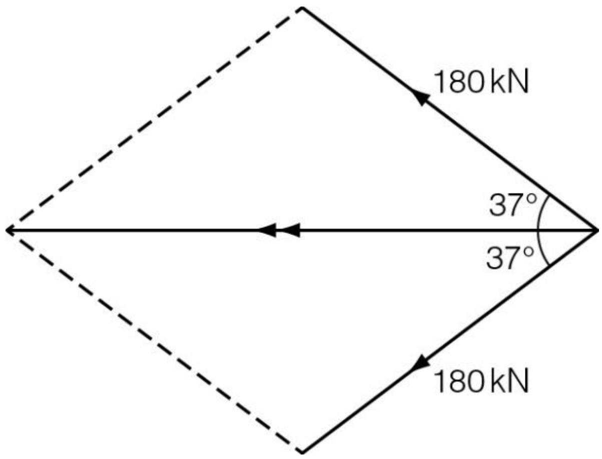
$\theta_2 = 37°$

Page 122 Test yourself

7 The two components of the forces along the forwards direction of the tanker add up to:

F = 2 x 180 000 x cos 37

= 290 kN



8 Resolving north: $F_N = 200 \cos 60° - 100 = 0$

Resolving east: $F_E = 200 \sin 60° - 173 = 0$

So the total force is zero.

9 a) $L_v = L \cos 10 = 177\,000$ N

$L_h = L \sin 10 = 31\,000$ N

b) $W = L_v = 177\ 000$ N

$W = mg$

$M = W/g$

$= 177\ 000\text{N}/9.8\ \text{N kg}^{-1}$

$= 18\ 000$ kg

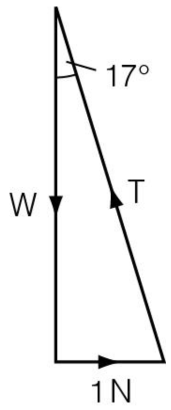
10 a) $\sin\theta = 1/5 = 0.2$

Resolving down the slope: Force = $W \sin\theta + 40$ N = $(0.2 \times 950$ N$) + 40$ N = 230 N

b) To climb at constant speed, force up the slope must equal that down the slope, so the cyclist must exert a force of 230 N.

11 a) $\sin\theta = 0.3 \Rightarrow \theta = 17°$

b)



c) Resolving horizontally: $T \sin\theta = 1$ N

$\Rightarrow T = 3.3$ N

Resolving vertically: $W = T \cos\theta$

$\Rightarrow W = 3.2$ N

Page 124 Test yourself

12 N m (Newton metre)

13 a) Calculating moments about the pivot:

The anticlockwise turning moments = 250 N × 1.8 m + 350 N × 1.0 m = 800 N m

The clockwise turning moment = 500 N × 1.6 m = 800 N m

The moments balance, so the seesaw is in equilibrium.

b) The pivot exerts a force of 1100 N, which balances the weights of the three children.

14 a) The long handles exert a larger turning moment.

b) At A. When the distance to the pivot is small a larger force must act to balance the turning moment from the handles.

c) $210 \text{ N} \times 5 \text{ cm} = F \times 30 \text{ cm}$

$\Rightarrow F = 35 \text{ N}$

Page 126–127 Test yourself

15 a) $F \times 0.5 = (80 \times 1) + (20 \times 3) = 140 \text{ Nm}$

$\Rightarrow F = 280 \text{ N}$

b) $R = 280 \text{ N} + 80 \text{ N} + 20 \text{ N} = 380 \text{ N}$

c) $(F \times 0.5) + (20 \times 1) = 80 \times 1 = 80 \text{ Nm}$

$\Rightarrow F = 120 \text{ N}$

$\Rightarrow R = 220 \text{ N}$

d) She needs to move the combined centre of mass of the ladder and the bucket over her shoulder.

16 $R_1 \times 5 \text{ m} = 1\,200 \text{ N} \times 2.5 \text{ m} + 800 \text{ N} \times 3 \text{ m} = 5400 \text{ Nm}$

$R_1 = 1\,080 \text{ N}$

$R_2 = 2000 \text{ N} - 1\,080 \text{ N} = 920 \text{ N}$

17 In 7.26a: Couple = 10 N × 20 cm + 10 N × 20 cm = 400 N cm

In 7.26b: Couple = 20 N × 20 cm = 400 N cm

Both couples are 400 N cm. But, because only one hand is used, twice the force has to be applied in the second case to get the same couple.

18 Work is done when a force is applied to an object and is calculated using the distance it moves in the direction of that applied force

. However, the distance used to calculate a moment is perpendicular to the applied force. Often, when we calculate a turning moment, the object does not move, so no work is done.

19 Taking moments about the point where the sail is attached to the board:

$500 \text{ N} \cos 30 \times 1.5 \text{ m} = 650 \text{ N} \times d$

$D = 1.0 \text{ m}$

20 a) Taking moments about B: $250 \text{ N} \times 2 \text{ m} = R_c \times 5 \text{ m}$

$\Rightarrow R_c = 100 \text{ N}$

Resolving vertically: $R_B + R_c = W = 250 \text{ N}$

$\Rightarrow R_B = 150 \text{ N}$

b) $R_B + R_c = 250 \text{ N} + 850 \text{ N} = 1100 \text{ N}$

Since $R_B = R_C$, both must be 550 N

c) Taking moments about B:

$250 \times 2 + 850 \times BD = 550 \times 5$

BD = 2.65 m

AD = 3.65 m

21 Taking moments about the pillar closer to the jeep:

$32\,000 \times 9 + 12\,000 \times 6 = R_1 \times 18$

$R_1 = 20\,000$ N

$R_1 + R_2 = 32\,000$ N + 12 000 N

$\Rightarrow R_2 = 24\,000$ N

Page 128–131 Practice questions

1 C

2 B

3 D

4 B

5 A

6 A

7 B

8 B

9 C

10 B

11 Award 1 mark for correct each pair

Quantity	Fundamental SI units	Type of quantity
Kinetic Energy	kgm^2s^{-2}	scalar
Acceleration	ms^{-2}	vector
Displacement	m	vector
Power	kgm^2s^{-3}	scalar

12 a) 320 N × 0.54 m – 780 N × 0.18 m = R_3 × (0.81 – 0.54) m [moments calculated = 1 mark, directions correct = 1 mark]

$\Rightarrow R_3$ = 32.4 Nm / 0.27 m = 120 N [1]

b) R_2 = 780 N – 120 N – 320 N = 340 N [1]

13 a) Moment = 16 000 N × 1.5 m + 8 000 N × 0.75 m [1]

= 30 000 N m [1]

b) i) The principle of moments states that when a body is in equilibrium the moments acting on it balance. [1]

ii) Taking moments about B: 30 000 N m = $R_1 \times 3$m [1]
$\Rightarrow R_1$ = 10 000 N [1]
Balancing vertical forces: R_2 = 16 000 N + 8 000 N – R_1 = 14 000 N [1]

c) When the truck carries no load, R_1 and R_2 are the same at 8 000 N because the only downward force acting acts midway between them. [1]

14 a) A stable equilibrium is produced as the moment of the weight of the club is balanced by the moment of the 5.4N weight suspended from the shaft. [1]

b) W = mg = 0.35 kg × 9.8 N kg^{-1} = 3.4 N [1]

c) Taking moments about the pivot: 3.4 N × x = 5.4 N × 28 cm $\Rightarrow x$ = 44.5 cm [1]
Distance from head end of club = 60 cm – 44.5 cm = 15.5 cm [1]

d) i) V_v = (45 sin 40) m s^{-1} [1]
= 29 m s^{-1} [1]

ii) V_h = (45 cos 40) m s^{-1} [1]
= 34 m s^{-1} [1]

e) s = $V_h \times$ t [1]
= 34 m s^{-1} × 5.9 s = 200 m (2 sf) [1]

15 a) T sin 20 = 7.4 N [1]

$T = \frac{7.4\ \text{N}}{\sin 20}$ [1]

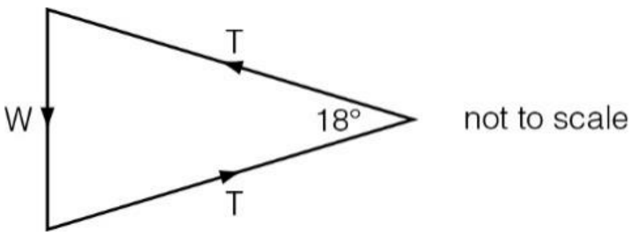
= 22 N (2 sf) [1]

b) L = W + T cos θ [1]

= 1.7 N + 22 N cos 20 [1]

= 22 N (2 sf) [1]

16 a) Diagram as below:



Arrows follow round [1]; correctly labelled [1]; angle correct [1]

b) W = T sin 9^0 + T sin 9^0

$T = \frac{W}{2 \sin 9^0}$

$T = \frac{13500}{0.3129}$

= 43 kN

17 a) 8 N each (assuming the centre of gravity is at C, midway between)

b) Taking moments about B: 40 N × 15 cm + 16 N × (75 – 25) cm = R_2 × 2(75 – 25) cm

$R_2 = \frac{600\ \text{N cm} + 800\ \text{N cm}}{100\ \text{cm}}$

= 14 N

R_1 = 40 N + 16 N – 14 N = 42 N

c) If the box is d cm from B then, taking moments about B: 40 N × d = 16 N × 50 cm

$d = \frac{800\ \text{N cm}}{40\ \text{N}}$ = 20 cm

d) With box at A, limiting case is R_2 = 0 (and R_1 = 0 for box at E)

Taking moments about B: 40 N × 25 cm = F × 50 cm (this is the same if box at E and moments taken about A) $\Rightarrow F = \frac{1\,000\ \text{N cm}}{50\ \text{cm}}$

= 20 N

So the extra weight to be added = 20 N – 16 N = 4N

18 a) Taking moments around pivot 1: 20 N × 9 cm = F_R × 18 cm

F_R = 10 N (F_R is the vertical component of the force on the rod)

b) i) Taking moments around pivot 2: W × 15 cm = 10 N × 3 cm

W = 2 N

ii) Taking up as positive: 0 = R +10 N – 2 N

R = 8 N downwards

c) When you move the pedal, point A moves twice as far because it is twice as far from the pivot. When R lifts the lid, the far end moves 10 times as far as A. (In total the distance is multiplied by 20.)

Page 132 Stretch and challenge

19 a) i) Let the radius of the of wheel be r:
The anticlockwise turning moment from B = 800 r
The clockwise turning moment from A = 1600 r sin(30^0) = 800 r
So the wheel is balanced (unstable equilibrium) and no force is needed at C to prevent it rotating.

ii) The anticlockwise turning moment from B = 800 r sin(30^0) = 400r
The clockwise turning moment from A = 1600r
To prevent rotation a vertical downwards force must be applied at C to create a moment of 1200r.
So, 1200r = Fr cos(30^0)
F = 1390 N

b) The wheel is in stable equilibrium when it has been rotated by 180^0. The force required to prevent rotation at C is again zero, but now the centre of gravity of the wheel is below the point of rotation.

c) In the position shown in figure 7.43, the only car to which people can be added without causing rotation is the one below point O. Let us assign them weight W.

Consider what happens if the wheel is now rotated clockwise through 90^0 so the weight at B provides no turning moment. For the wheel to remain in balance:

$Wr = 1600r\cos(30^0)$

$W = 1390$ N

20 Assume the beam has a length L.

Taking moments about the hinge: $MgL = T(L/2)\cos(60^o)$

$T = 4\,Mg$

The vertical component of $T = 4Mg\cos(60^0) = 2Mg$

The horizontal component of $T = 4Mg\sin(60^0) = 2\sqrt{3}\,Mg$

So the vertical component of the force the hinge exerts the beam = 2Mg – Mg = Mg downwards and the horizontal component is = $2\sqrt{3}$ Mg away from the wall.

The magnitude of resultant force on the beam from the hinge is $Mg\sqrt{1^2 + \left(2\sqrt{3}\right)^2} = \sqrt{13}Mg$

and it acts at an angle θ to the beam, where $\tan\theta = 1/(2\sqrt{3})$.

The force on the hinge is equal and opposite to this so it is $\sqrt{13}$ Mg acting up and into the wall at an angle of 16^o.