FULLY WORKED SOLUTIONS

Chapter 4: Isaac Newton on the road

Chapter questions

1. $R = w = mg = 4 \times 9.8 = 39.2$ N

2. (a) $R = w + F_A = (1.2 \times 9.8) + 20 = 31.8$ N

   (b) $R = w - F_A = (1.2 \times 9.8) - 4 = 7.8$ N

3. $w = mg = 8 \times 9.8 = 78.4$ N

   $F_y = 70 \sin 40° = 45$ N

   $R = w - F_y = 78.4 - 45 = 33.4$ N

4. $R = w = mg = 3 \times 9.8 = 29.4$ N

   $F_f = \mu R = 0.4 \times 29.4 = 11.8$ N

5. $R = w = mg = 2 \times 9.8 = 19.6$ N

   $\mu = F_f/R = 3.5/19.6 = 0.18$

6. $F_y = 130 \sin 25° = 54.9$ N

   $w = mg = 12 \times 9.8 = 117.6$ N

   $R = w - F_y = 117.6 - 54.9 = 62.7$ N

   $\mu = F_f/R = 8/62.7 = 0.13$

7. $a = F_{net}/m = 50/7 = 7.14$ m s^{-2}

8. $R = w = mg = 1200 \times 9.8 = 11\,760$ N

   $F_f = \mu R = 0.78 \times 11\,760 = 9.17 \times 10^3$ N

   As speed is constant, $F_{net} = 0$.

   $F_A = F_f = 9.17 \times 10^3$ N

9. $R = w = mg = 3 \times 9.8 = 29.4$ N

   $F_f = \mu R = 0.24 \times 29.4 = 7.1$ N

   $F_A = F_{net} + F_f$

   $= ma + F_f = (3.0 \times 2) + 7.1$

   $= 13.1$ N

10. $m = w/g = 100/9.8 = 10.2$ kg

    $F_{net} = w_{\parallel} = 100 \sin 15° = 25.9$ N

    $a = F_{net}/m = 25.9/10.2 = 2.54$ m s^{-2}

11. $R = w_{\perp} = mg \cos \theta = 1400 \times 9.8 \times \cos 20° = 12\,893$ N

    To make $F_{net} = 0$,

    $F_A = F_f + w_{\parallel} = \mu \mathrm{R} + mg \sin \theta$

$= (0.12 \times 12\,893) + (1400 \times 9.8 \sin 20°)$

$= 6240$ N up the slope

12. $F_{net} = F_A - F_f - w_{\parallel}$

$= 200 - 35 - (18 \times 9.8 \sin 30°)$

$= 76.8$ N

$a = F_{net}/m = 76.8/18.0 = 4.27$ m s^{-2} up the slope

Review questions

6. (a) $\boldsymbol{R} = \boldsymbol{w} = m\boldsymbol{g} = 2 \times 9.8 = 19.6$ N

(b) $\boldsymbol{R} = w + \boldsymbol{F}_A = (4 \times 9.8) + 38 = 77$ N

(c) $\boldsymbol{R} = w + \boldsymbol{F}_A = (40 \times 9.8) - 100 \sin 50° = 315$ N

(d) $\boldsymbol{R} = w_{\perp} = (30 \times 9.8) \cos 20° = 276$ N

7. (a) $\boldsymbol{w} = m\boldsymbol{g} = 1200 \times 9.8 = 11760$ N

As v is constant, $\mathbf{F}_{net} = 0$, so $\boldsymbol{F}_f = \boldsymbol{F}_A = 7\,000$ N

$\boldsymbol{R} = \boldsymbol{w} = 11\,760$ N

$$\mu = \frac{F_f}{R} = \frac{7000}{11760} = 0.6$$

(b) Friction will decrease, therefore the applied force needed to move the car will also be less.

8. $\boldsymbol{w} = 100$ N; $\mu = 0.14$; $\theta = 40°$

$\boldsymbol{R} = \boldsymbol{w} = 100$ N

$\boldsymbol{F}_f = \mu\boldsymbol{R} = 0.14 \times 100 = 14$ N

As there is no acceleration, the horizontal component of the applied force ($\boldsymbol{F}_x$) must be equal in size to $\boldsymbol{F}_f$. Therefore:

$\boldsymbol{F}_f = \boldsymbol{F}_x = \boldsymbol{F}_A \cos 40°$

$14 = \boldsymbol{F}_A \cos 40°$

$\boldsymbol{F}_A = 18$ N

9. $m = 3$ kg, $\theta = 40°$, $\boldsymbol{F}_A = 4.0$ N

$\boldsymbol{w} = m\boldsymbol{g} = 3 \times 9.8 = 29.4$ N

$\boldsymbol{R} = \boldsymbol{w}$, so $\boldsymbol{R} = 29.4$ N

As there is no acceleration, $\boldsymbol{F}_{net} = 0$, so the horizontal component of the applied force ($\boldsymbol{F}_x$) must be equal in magnitude to $\boldsymbol{F}_f$.

$\boldsymbol{F}_f = \boldsymbol{F}_x = \boldsymbol{F}_A \cos \theta = 4 \cos 40° = 3.1$ N

$\mu = \frac{F_f}{R} = \frac{3.1}{29.4} = 0.11$ N

10. $m = 1200$ kg, $u = 22$ m s^{-1}, $v = 0$, $\mu = 0.3$, $\boldsymbol{F}_A = 0$

$\boldsymbol{w} = m\boldsymbol{g} = 1200 \times 9.8 = 11\ 760$ N

As $\boldsymbol{R} = \boldsymbol{w}$, $\boldsymbol{R} = 11\ 760$ N

$\boldsymbol{F}_f = \mu\boldsymbol{R} = 0.3 \times 11\ 760 = 3\ 528$ N

$\mathbf{F}_{net} = \boldsymbol{F}_A - \boldsymbol{F}_f = 0 - 3\ 528 = -3\ 528$ N

$a = \frac{F_{net}}{m} = \frac{-3528}{1200} = -2.9$ m s^{-2}

$v = u + at$

$0 = 22 + (-2.9)t$

$2.9t = 22$

$t = 7.6$ s

11. $m = 2\ 000$ kg, $u = 0$, $v = 15$ m s^{-1}, $s = 200$m, $\boldsymbol{F}_A = 10\ 000$ N

$v^2 = u^2 + 2as$

$15^2 = 0^2 + 2a \times 200$

$225 = 400a$

$a = 0.56$ m s^{-2}

$\boldsymbol{F}_{net} = $ ma $= 2\ 000 \times 0.56 = 1120$ N

As $\boldsymbol{F}_{net} = \boldsymbol{F}_A - \boldsymbol{F}_{f,}$

$\boldsymbol{F}_f = \boldsymbol{F}_A - \boldsymbol{F}_{net} = 10\ 000 - 1120 = 8\ 880$ N

12. $m = 120$ g $= 0.12$ kg, $u = 0$, $v = 28$ m s^{-1}, $t = 0.2$ s

$v = u + at$

$28 = 0 + a \times 0.2$

$a = 140$ m s^{-2}

$\mathbf{F}_{net} = $ ma $= 0.12 \times 140 = 16.8$ N

13. $a = \frac{F}{m} = \frac{100}{12} = 8.3$ m s^{-2}

(a) If $\boldsymbol{F}$ is doubled, then a will be doubled, i.e. $a = 16.6$ m s^{-2}

(b) When the mass is decreased from 12 kg to 4 kg, the mass has been decreased by a factor of 3, therefore a will be increased by a factor of 3, i.e. $a = 25$ m s^{-2}

14. $m = 50$ g $= 0.050$ kg, $u = 30$ m s^{-1}, $v = -35$ m s^{-1}, $t = 0.5$ s

$v = u + at$

$-35 = 30 + a \times 0.5$

$-65 = 0.5a$

$a = -130 \text{ m s}^{-2}$

Note the negative sign on the acceleration; this indicates that the ball has been slowed in its original direction, then accelerated in the opposite direction.

$\boldsymbol{F} = m\boldsymbol{a} = 0.05 \times -130 = -6.5 \text{ N}$

15. (a) $t = 3$ s

(b) Graphical solution: change in speed will be equal to the area under the graph up to the 3 s mark = 30 m s^{-1}

Calculated solution: $u = 0$, $a = 10$ m s^{-2}, $t = 3$

$v = u + at = 0 + 10 \text{ x } 3 = 30 \text{ m s}^{-1}$

(c) $\boldsymbol{w} = m\boldsymbol{g} = 10 \times 9.8 = 98 \text{ N}$

$\boldsymbol{R} = \boldsymbol{w}$, therefore $\boldsymbol{R} = 98$ N

$\boldsymbol{F}_{\text{net}} = m\boldsymbol{a} = 10 \times 10 = 100 \text{ N}$

As $\boldsymbol{F}_{\text{net}} = \boldsymbol{F}_{\text{A}} - \boldsymbol{F}_{\text{f}}$,

$\boldsymbol{F}_{\text{f}} = \boldsymbol{F}_{\text{A}} - \boldsymbol{F}_{\text{net}} = 150 - 100 = 50 \text{ N}$

$$\mu = \frac{F_{\text{f}}}{R} = \frac{50}{98} = 0.51$$

(d) $\boldsymbol{w} = \mathbf{m}\boldsymbol{g} = 14 \times 9.8 = 137 \text{ N}$

$\boldsymbol{R} = \boldsymbol{w}$, so $\boldsymbol{R} = 137$ N

$\boldsymbol{F}_{\text{f}} = \mu\boldsymbol{R} = 0.51 \times 137 = 70 \text{ N}$

16. $\boldsymbol{w} = m\boldsymbol{g} = 110 \times 9.8 = 1078 \text{ N}$

(a) $\boldsymbol{w}_{\parallel} = \boldsymbol{w} \sin\theta = 1078 \sin 15° = 280 \text{ N}$

(b) $\boldsymbol{w}_{\perp} = \boldsymbol{w} \cos\theta = 1078 \cos 15° = 1040 \text{ N}$

(c) $\boldsymbol{F}_{\text{net}} = m\boldsymbol{a} = 110 \times 1.2 = 132 \text{ N}$

(d) As $\boldsymbol{F}_{\text{net}} = \boldsymbol{w}_{\parallel} - \boldsymbol{F}_{\text{f}}$,

$\boldsymbol{F}_{\text{f}} = \boldsymbol{w}_{\parallel} - \boldsymbol{F}_{\text{net}} = 279 - 132 = 147 \text{ N}$

(e) $\boldsymbol{R} = \boldsymbol{w}_{\perp} = 1041 \text{ N}$

$$\mu = \frac{F_f}{R} = \frac{147}{1041} = 0.14$$

17. $u = 35 \text{ km h}^{-1} = 9.7 \text{ m s}^{-1}$, $v = 0$, $m = 8 \text{ t} = 8\,000 \text{ kg}$; $s = 10$ m

$v^2 = u^2 + 2as$

$0 = 9.7^2 + 2a \times 10$

$-94 = 20a$

$\boldsymbol{a} = –4.7 \text{ m s}^{-2}$

$\boldsymbol{F}_{net} = m\boldsymbol{a} = 8\,000 \times –4.7 = - 3\,7\,600 \text{ N}$

The negative sign indicates that the net force is a decelerating force up the hill. As the net force in this case is the result of the frictional force acting on the truck and the parallel component of its weight, then we can see that:

$\boldsymbol{F}_{net} = –\mathbf{F}_f – \boldsymbol{w}_{\|}$

$–37\,600 = –\boldsymbol{F}_f – (8\,000 \times 9.8 \times \sin 15°)$

$\boldsymbol{F}_f = –17\,300 \text{ N}$

18. $m = 50 \text{ kg}, \theta = 40°$

$\boldsymbol{w} = m\boldsymbol{g} = 50 \times 9.8 = 490 \text{ N}$

$\boldsymbol{w}_{\|} = \boldsymbol{w} \sin \theta = 490 \sin 40° = 315 \text{ N}$

$\boldsymbol{w}_{\perp} = \boldsymbol{w} \cos \theta = 490 \cos 40° = 375 \text{ N}$

(a) As $\boldsymbol{T} = \boldsymbol{w}_{\|}$, $\boldsymbol{T} = 315 \text{ N}$

(b) As $\boldsymbol{F}_{Net} = \boldsymbol{w}_{\|}$, $\boldsymbol{F}_{net} = 315 \text{ N}$

$$\boldsymbol{a} = \frac{F_{net}}{m} = \frac{315}{50} = 6.3 \text{ m s}^{-2}$$

19. $m = 600 \text{ kg}, \theta = 20°, \mu = 0.56$

$\boldsymbol{w} = m\boldsymbol{g} = 600 \times 9.8 = 5\,880 \text{ N}$

$\boldsymbol{w}_{\|} = \boldsymbol{w} \sin \theta = 5\,880 \sin 20° = 2011 \text{ N}$

$\boldsymbol{w}_{\perp} = \boldsymbol{w} \cos \theta = 5\,880 \cos 20° = 5\,525 \text{ N}$

(a) As speed is constant, $\boldsymbol{F}_{net} = 0$, so

$\boldsymbol{F}_A = \boldsymbol{F}_f + \boldsymbol{w}_{\|}$

$\boldsymbol{R} = w_{\perp} = 5\,525 \text{ N}$

$\boldsymbol{F}_f = \mu\boldsymbol{R} = 0.56 \times 5\,525 = 3\,094 \text{ N}$

$\boldsymbol{F}_A = 3\,094 + 2\,011 = 5\,105 \text{ N}$

(b) $\boldsymbol{F}_{net} = \text{ma} = 600 \times 1 = 600 \text{ N}$

As $\boldsymbol{F}_{net} = \text{F}_A – \boldsymbol{F}_f – \boldsymbol{w}_{\|}$,

$\boldsymbol{F}_A = \boldsymbol{F}_{net} + \boldsymbol{F}_f + \boldsymbol{w}_{\|} = 600 + 3094 + 2011 = 5\,705 \text{ N}$

20. (a) 20 N

(b) Approximately 2 kg

(c) 15 N