Topic 1 Mechanics
1A Motion

1A.1 Velocity and acceleration

1 (a) 8.33 m s^{-1}
  (b) 2.08 m s^{-1}
  (c) zero

2 (a) 11.2 m s^{-1}
  (b) 1.5 s
  (c) 4.5 m s^{-2}

3 (a) 1.5×10^8 m s^{-1}
  (b) 8.82×10^{22} m s^{-2}

1A.2 Motion graphs

1 A: The bike is at constant speed for the first 10 s (2 m s^{-1}).
B: The bike is stationary from 10 s to 30 s (20 m distance).
C: The bike is at constant speed from 30 s to 40 s (3 m s^{-1}).
The bike finishes stationary.

2 A: The car has constant acceleration for the first 10 s (0.5 m s^{-2}).
B: The car is at constant speed from 10 s to 30 s (5 m s^{-1}).
C: The car has constant acceleration from 30 s to 40 s (1 m s^{-2}).
D: The car has constant deceleration from 40 s to 50 s (−1.5 m s^{-1}).

3 d = 240 m

1A.3 Adding forces

1 12.1 N forwards

2 6621 N at an angle of 65.0° up from the horizontal

3 Students should draw the weight force arrow vertically down from centre of body, exactly the same size as the reaction force from the chair acting vertically upwards on bottom.

4 (a) 800 N, θ = 18° (accuracy depends on quality of scale drawing)
  (b) As part (a)

5 4100 N, 4° left of the forwards direction

1A.4 Moments

1 438 Nm

2 1.51 m

3 If the book swings past the position of the second picture, a moment will then act against the motion, slowing it and pushing it back towards that position with the diagonal vertical. Thus it will oscillate back and forth until it comes to rest as in the second picture. In reality, the swinging is likely to be minimal as the finger friction will be significant.

4 55 cm

1A.5 Newton's laws of motion

1 In terms of Newton's laws of motion:
  (a) Weight balanced by reaction force,
  so resultant force = zero, so acceleration = zero, as per Newton's first law of motion.
  (b) It will accelerate upwards, as per Newton's first law.

(c) Newton's third law: the book will offer an equal and opposite force to that of the hands on the book.

Touch sensors in the skin detect this reaction force.

2 (a) 0.5 kg

(b) accelerating force of 0.5 N

3 (a) $a = 65.4$ m s^{-2}

(b) $a = 7.16$ m s^{-2}

(c) $a = 9.80$ m s^{-2}

(d) $a = 179$ m s^{-2}

1A.6 Kinematics equations

1 4 m s^{-1}

2 40 m

3 (a) $a = 5.4$ m s^{-2}

(b) $a = 0.384$ m s^{-2}

(c) $a = 0.89$ m s^{-2}

4 4.24 s

5 −122 m s^{-2}

1A.7 Resolving vectors

1 (a) 7.1 cm = 7.1 m s^{-1} for each arrow

(b) same answers as (a)

2 horizontal = 13.1 m s^{-1}; vertical = 9.18 m s^{-1}

3 horizontal = 207 N; vertical = 388 N

4 138 m s^{-1} southwards vector

197 m s^{-1} eastwards vector

1A.8 Projectiles

1 (a) 0.98 s

(b) 1.17 m

2 (a) 1.92 s

(b) 5.94 m

3 (a) It will rise 1.08 m, so yes.

(b) No. The horizontal velocity is 3.86 m s^{-1}. Therefore, horizontal time of flight is 0.78 s. Time to maximum height is 0.47 s. Therefore, time from max height to horizontal hoop distance is 0.31. In 0.31 s, the ball falls 0.47 m, so the ball will be below the hoop when it reaches it horizontally. (Even accounting for the diameter of the ball, it would not hit the hoop.)

1A Exam practice

1 B

2 B

3 C

4 C

5 A

6 (a) Magnitude and direction

(b) Direction changing / not a straight line, so velocity is changing / not constant

7 (a) QWC (quality of written communication) – work must be clear and organised in a logical manner using technical wording where appropriate; including:

State sufficient quantities to be measured (e.g. *s* and *t* or *v, u* and *t* or *u, v* and *s*)

Relevant apparatus (includes rule and timer/datalogger/light gates)
Describe how a distance is measured
Describe how a speed or time is measured
Further detail of measurement of speed or time
Vary for described quantities and plot appropriate graph
State how result calculated

(b) Repeat and calculate the mean
A suitable precaution relating to experimental procedure

8 (a) Draw a tangent at $t = 4.0$ s:

$v = \frac{(32\text{ m} - 0\text{ m})}{(6.0 - 2.0\text{ s})}$

$v = 8.0\text{ m s}^{-1}$

(b) $a = \frac{(v - u)}{t}$

$a = \frac{(8.0\text{ m s}^{-1} - 0)}{4\text{ s}}$

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

9 (a) (i) Area under graph between 0.5 and 1.0 s / X and Y, or use average velocity between these points × time
(ii) Gradient of line at Y

(b) QWC (quality of written communication) – work must be clear and organised in a logical manner using technical wording where appropriate. Include up to four of the following:
Lines not parallel
Acceleration should be the same / both should have same gradient
Max +ve and −ve speeds (from 0.5 s) all the same
There will be some energy losses (bounce, air resistance) so max should have smaller magnitude each time
Velocity at X/Z greater than that at the start
Ball cannot gain energy
Starts with positive velocity
but initial movement is down
Starts with non-zero velocity / graph starts in wrong place
From photo, it is dropped from rest
There is a vertical line
Bounce must take some time / acceleration cannot be infinite
The graph shows a change in direction of velocity between 0 and 0.5 s / release and striking the ground
It is travelling in one direction / down this whole time
Graph shows an initial deceleration
It is actually accelerating downwards

10 (a) $s = ut + \frac{1}{2}at^2$

$a = \frac{2 \times 2\,500\,000\text{ m}}{((30 \times 60)\text{s})^2}$

$a = 1.54\text{ m s}^{-2}$

(b) $v = u + at$

$v = 0 + 1.5\text{ m s}^{-2} \times (30 \times 60)\text{s}$

$v = 1.5\text{ m s}^{-2} \times (30 \times 60)\text{s}$

$v = 2700\text{ m s}^{-1}$

(c) $F = ma$

$F = 4.5 \times 10^5\text{ kg} \times 1.5\text{ m s}^{-2}$

F = 675 000 N

11 QWC (quality of written communication) – work must be clear and organised in a logical manner using technical wording where appropriate, including the following points:

No acceleration / constant velocity ('constant speed' not sufficient) / (at rest or) uniform motion in straight line unless unbalanced / net / resultant force

Acceleration proportional to force / $F = ma$

Qualify by stating resultant / net force / $\Sigma F = ma$

If (resultant) force zero, then Newton's second law states that acceleration = 0

OR acceleration only non-zero if (resultant) force non-zero.

12 (a) (i) $v = \frac{1.88 \text{ m}}{0.88 \text{ s}}$

$v = 2.14 \text{ m s}^{-1}$

(ii) $v = u + at$

$0 = u + (-9.81 \text{ m s}^{-2}) \times 0.44 \text{ s}$

$u = 9.81 \text{ m s}^{-2} \times 0.44 \text{ s}$

$u = 4.3 \text{ m s}^{-1}$

OR

$s = ut + ½at^2$

$0 = (u \times 0.88 \text{ s}) + (½ \times (-9.81 \text{ m s}^{-2}) \times (0.88 \text{ s})^2)$

$u = 4.3 \text{ m s}^{-1}$

(iii) $\text{velocity}^2 = (2.1 \text{ m s}^{-1})^2 + (4.3 \text{ m s}^{-1})^2$

velocity = 4.8 m s^{-1}

tan of angle = $\frac{4.3 \text{ m s}^{-1}}{2.1 \text{ m s}^{-1}}$

angle = 63.9°

(b) (i) Air resistance has not been taken into account

OR air resistance acts on the rocket

OR friction of the rocket on the stand has not been taken into account

OR energy dissipated/transferred due to air resistance

(ii) Any two from:

Can watch again

Can slow down / watch frame by frame / stop at maximum height

Too fast for humans to see

Does not involve reaction time

Can zoom in (to see height reached).