Physics Session 2 - Question Pack

Projectile Motion

Q1. A bowling ball of mass 7.5 kg travelling at 10 m s^{-1} rolls off a horizontal table 1.0 m high. (Assume the acceleration due to gravity is 9.80 m s^{-2}, and the effects of air resistance may be ignored unless otherwise stated.)

a Calculate the ball's horizontal velocity just as it strikes the floor.

b What is the vertical velocity of the ball as it strikes the floor?

c Calculate the velocity of the ball as it reaches the floor.

d What time interval has elapsed between the ball leaving the table and striking the floor?
e Calculate the horizontal distance travelled by the ball as it falls.

Q2. During training, an aerial skier takes off from a ramp that is inclined at 40.0° to the horizontal and lands in a pool that is 10.0 m below the end of the ramp. If she takes 1.50 s to reach the highest point of her trajectory, calculate:

a the speed at which she leaves the ramp

b the maximum height above the end of the ramp that she reaches

c the time for which she is in mid-air.

Q3. A projectile is launched with an initial velocity of 1.5 km s^{-1} at an angle θ. The target is located at a distance of 3000 m and on the same level. The projectile strikes the target after 4.0 s.

a Determine the horizontal velocity of the projectile.

b Calculate the value of θ.

Moments, Torques and Couples

Q1.

A uniform metre ruler of weight 2.0 N is freely pivoted at the 70 cm mark. A student holds the ruler in a horizontal position and suspends a 5.0 N weight from the 100 cm end.

What is the magnitude of the resultant moment when the student releases the ruler?

A 0.15 N m

B 0.19 N m

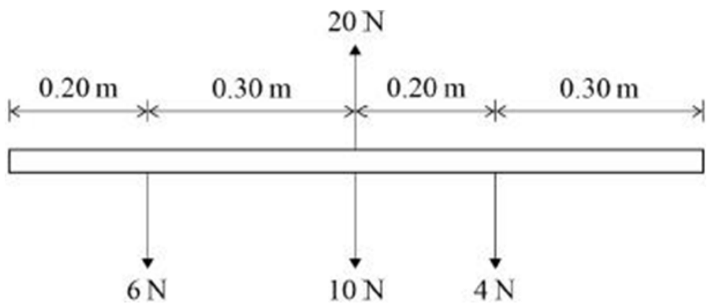
C 1.1 N m

D 1.9 N m

(Total 1 mark)

Q2.

The diagram shows the forces acting on a uniform rod. Which statement is correct?



A The rod is in equilibrium.

B For equilibrium, an anticlockwise moment of 1.0 N m is needed.

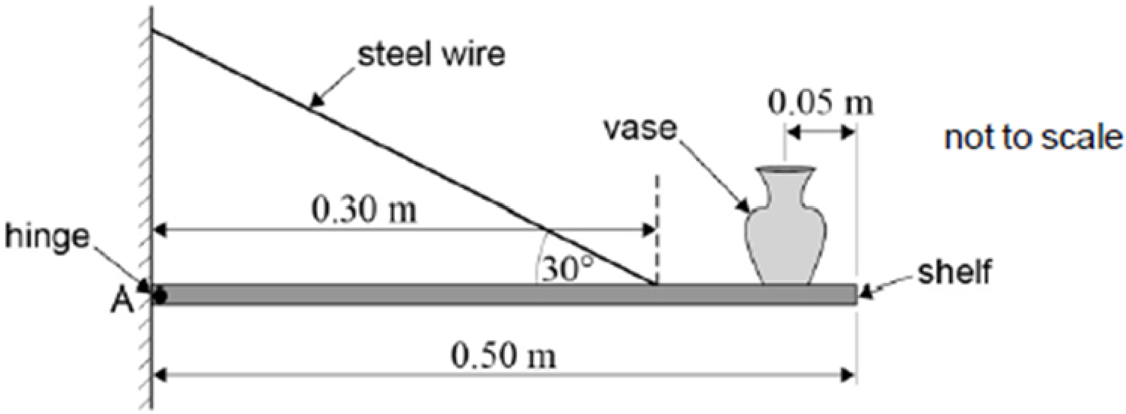
C For equilibrium, a clockwise moment of 1.0 N m is needed.

D For equilibrium, the 10 N force should be increased to 20 N.

(Total 1 mark)

Q3.

The diagram below shows a vase placed on a uniform shelf that is supported by a steel wire.



The mass of the vase is 0.65 kg and the mass of the shelf is 2.0 kg. The shelf is hinged at A. The steel wire is attached to the shelf 0.30 m from A and is at an angle of 30° to the shelf. The other end of the steel wire is attached to the wall.

(a) State the principle of moments.

___

___

___

___

___

(2)

(b) Show, by taking moments about A, that the tension in the steel wire is about 50 N.

(4)

(Total 6 marks)

Newton's Laws of Motion:

Q1.

A railway truck of mass 2000 kg travelling horizontally at 1.5 m s^{-1} collides with a stationary truck of mass 3000 kg. After the collision they move together.

Which row is correct?

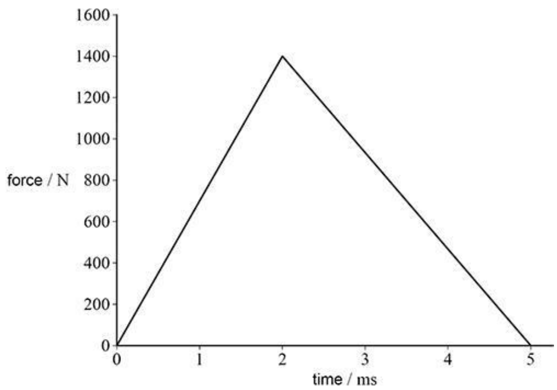
	Speed of the trucks immediately after collision / m s^{-1}	Effect of collision on total kinetic energy	
A	0.6	no change	⬭
B	0.6	decrease	⬭
C	1.0	no change	⬭
D	1.0	decrease	⬭

(Total 1 mark)

Q2.

A stationary ball is free to move. The ball is hit with a bat.

The graph shows how the force of the bat on the ball changes with time.



The ball has a mass of 0.044 kg.

What is the speed of the ball immediately after being hit?

A 13 m s^{-1} ⬭

B 60 m s^{-1} ⬭

C 80 m s^{-1} ⬭

D 160 m s^{-1} ⬭

(Total 1 mark)

Q3.

What is true for an inelastic collision between two isolated objects?

A	Both total momentum and total kinetic energy are conserved.	⬭
B	Neither total momentum nor total kinetic energy is conserved.	⬭
C	Only total kinetic energy is conserved.	⬭
D	Only total momentum is conserved.	⬭

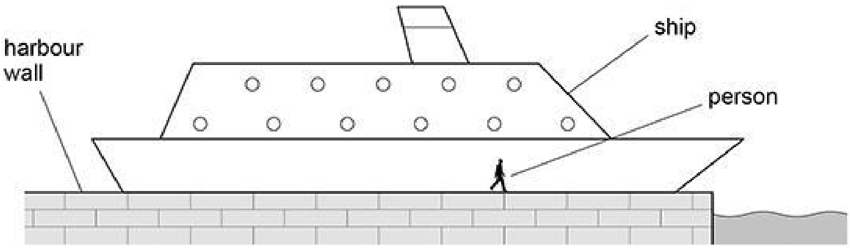
(Total 1 mark)

Q4.

(a) **Figure 1** shows a ship leaving a harbour at a constant velocity.

The ship moves at the same velocity as a person walking on the harbour wall alongside the ship.

Figure 1



The momentum of the ship is approximately 1×10^7 N s.

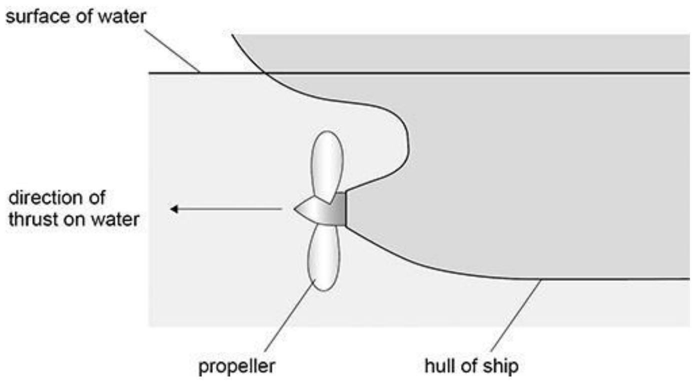
Estimate the mass of the ship.

mass of ship = _______________ kg

(2)

(b) **Figure 2** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 2

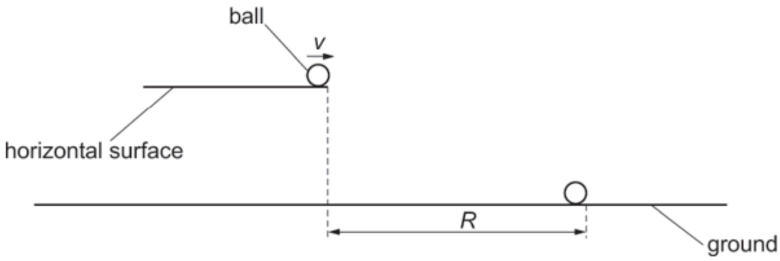


Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

(4)

Practical Skills

Q1: A metal ball leaves a horizontal surface with velocity *v*.
A student investigates the horizontal distance *R* that the ball travels before it hits the ground.



It is suggested that the relationship between *R* and *v* is given by $R = v\sqrt{\frac{Q}{g}}$ where *g* is the acceleration of free fall and *Q* is a constant.

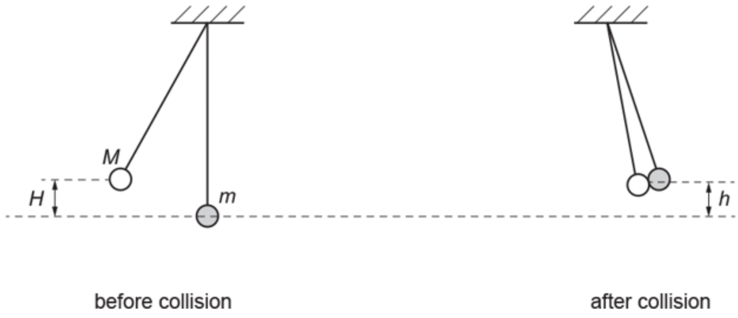
Describe with the aid of a suitable diagram how an experiment can be safely conducted, and how the data can be analysed, to determine *Q*.

Q2

A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is *M*.

A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is *m*.

The arrangement of the pendulums is shown below.



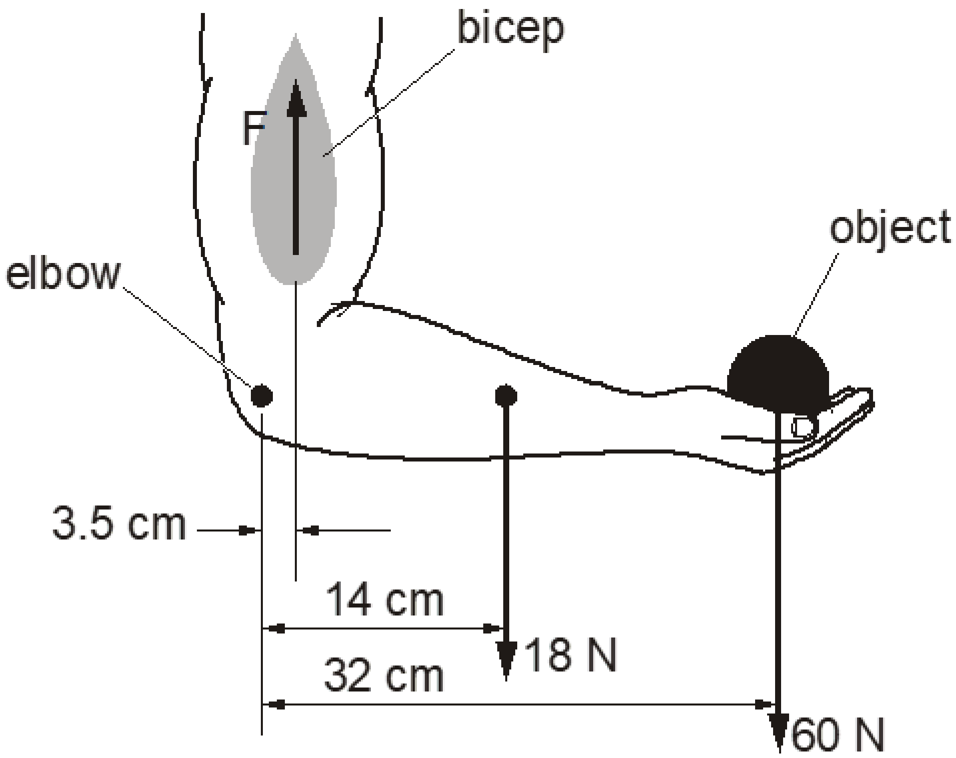
The bob of mass *M* is pulled back to a vertical height of *H* from its rest position. It is released and collides with the bob of mass *m*. The two bobs then stick together and reach a maximum vertical height *h* from the rest position.

The height *h* is given by the equation $h = \left(\frac{M}{M+m}\right)^2 H$.

Describe how to perform an experiment to test the validity of this equation and how the data can be analysed.

Stretch & Challenge

The figure below shows a section of the human forearm in equilibrium.



The weight of the object in the hand is 60 N. The centre of gravity of this object is

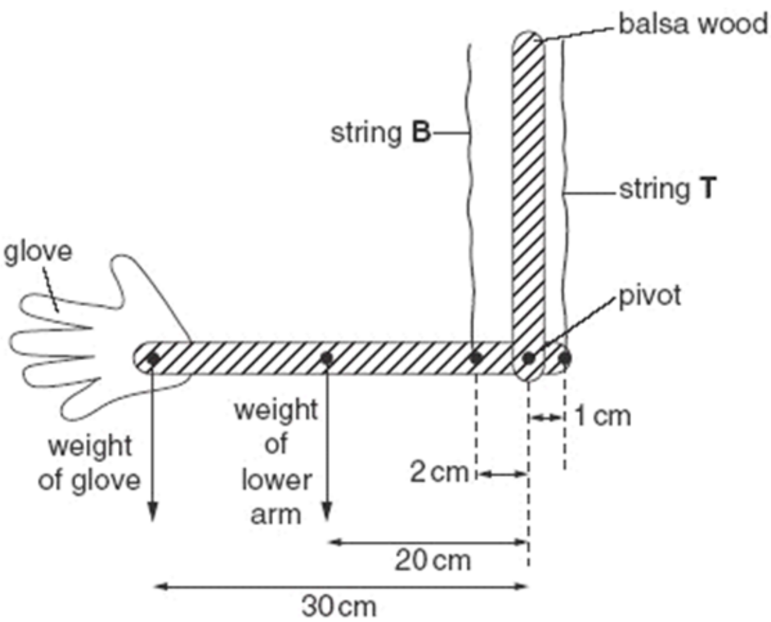
32 cm from the elbow. The bicep provides an upward force of magnitude *F*. The distance between the line of action of this force and the elbow is 3.5 cm. The weight of the forearm is 18 N. The distance between the centre of gravity of the forearm and the elbow is 14 cm.

By taking moments about the elbow, determine the magnitude of the force *F* provided by the bicep.

F = ... N

[Total 3 marks]

2. A student constructs a model arm to demonstrate how two particular muscles in the upper arm control movement of the lower arm. The figure below is a simplified diagram of this model arm.



Use the following data for the model to calculate the tension required in string **B** to maintain the arm in the position shown in the figure above.

mass of lower arm = 75 g

mass of glove = 135 g

distance of centre of mass of lower arm from pivot = 20 cm

distance of centre of mass of glove from pivot = 30 cm

string **B** is attached to lower arm at a distance of 2.0 cm from the pivot

string **T** is attached to the lower arm at a distance from the pivot of 1.0 cm

the tension in string **T** is zero.

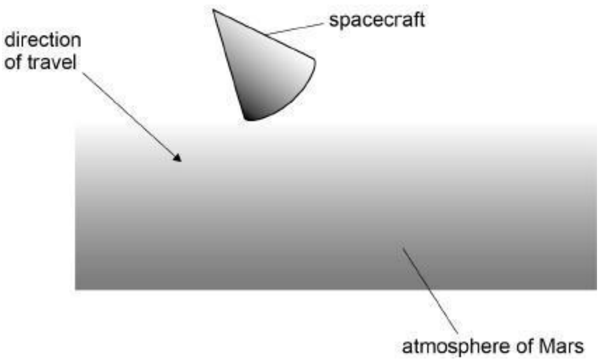
tension = ... N

[Total 3 marks]

Q3.

A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

Figure 1



(a) **Figure 1** shows the spacecraft of total mass 610 kg entering the atmosphere at a speed of 5.5 km s^{-1}.

Calculate the kinetic energy of the spacecraft as it enters the atmosphere. Give your answer to an appropriate number of significant figures.

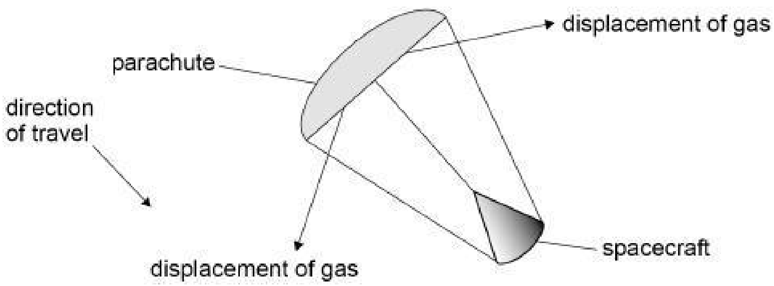
kinetic energy = _______________ J

(3)

(b) A parachute opens during the spacecraft's descent through the atmosphere.

Figure 2 shows the parachute–spacecraft system, with the open parachute displacing the atmospheric gas. This causes the system to decelerate.

Figure 2



Explain, with reference to Newton's laws of motion, why displacing the atmospheric gas causes a force on the system **and** why this force causes the system to decelerate.

(4)

(c) As the parachute–spacecraft system decelerates, it falls through a vertical distance of 49 m and loses 2.2×10^5 J of kinetic energy.
During this time, 3.3×10^5 J of energy is transferred from the system to the atmosphere.
The total mass of the system is 610 kg.

Calculate the acceleration due to gravity as it falls through this distance.

acceleration due to gravity = _______________ m s^{-2}

(3)

(d) Dust from the surface of Mars can enter the atmosphere. This increases the density of the atmosphere significantly.

Deduce how an increase in dust content will affect the deceleration of the system.

(3)
(Total 13 marks)

Answers:

Projectile Motion:

Q1

a The horizontal velocity of the ball remains constant and $v_x = 10 \text{ m s}^{-1}$.

b $v^2 = u^2 + 2ax$ and $v_y^2 = 0^2 + 2(9.8 \text{ m s}^{-2})(1.0 \text{ m})$ and $v_y = 4.4 \text{ m s}^{-1}$ down

c $v = [(10 \text{ m s}^{-1})^2 + (4.43 \text{ m s}^{-1})^2]^{½} = 10.9 \text{ m s}^{-1}$ at 24° to the horizontal, where the angle is determined from $\tan \theta = 4.43 \text{ m s}^{-1}/10 \text{ m s}^{-1} = 0.443$ and $\theta = 24$

d $x = ut + 0.5at^2$ and $1.0 \text{ m} = 0 + 0.5(9.8 \text{ m s}^{-2})t^2$ so $t = 0.45$ s

e Horizontal distance = (horizontal speed)(time) = $(10 \text{ m s}^{-1})(0.45 \text{ s}) = 4.5$ m

Q2.

a Taking down as positive and the top of the ramp as the zero position. Using the vertical component and finding initial velocity by analysing motion to maximum height:

$a = 9.80 \text{ m s}^{-2}$, $t = 1.5$ s, $v = 0$, $u = ?$ $v = u + at$

$0 = u + 9.80 \times 1.50$

$u_v = -14.7 \text{ m s}^{-1}$; i.e. 1.47 m s^{-1} up Trigonometry can be used to determine initial speed: $v = u_v/\sin 40° = 14.7/0.643 = 22.9 \text{ m s}^{-1}$

b Using vertical component: $a = 9.80 \text{ m s}^{-2}$, $t = 1.50$ s, $u = -14.7 \text{ m s}^{-1}$, $v = 0$, $x = ?$

$x = ½(u + v)t = 0.5 \times -14.7 \times 1.50 = 11.0$ m

c Using vertical component: $u = -14.7 \text{ m s}^{-1}$, $a = 9.8 \text{ m s}^{-2}$, $x = 10$ m, $t = ?$

First find final vertical velocity (to avoid quadratic equation): $v = ?$

$v^2 = u^2 + 2ax = (-14.7)^2 + 2 \times 9.80 \times 10 = 412$

$v = 20.3 \text{ m s}^{-1}$

Now find total flight time: $t = ?$ $v = u + at$

$20.3 = -14.7 + 9.80 \times t$

$t = 3.57$ s

Q3

a $v_x = x/t = (3000 \text{ m})/4.0 \text{ s} = 750 \text{ m s}^{-1}$

b $(1500 \text{ m s}^{-1})(\cos \theta) = 750 \text{ m s}^{-1} \Rightarrow \theta = 60°$

Moments:

Q1.

C

[1]

Q2.

C

[1]

Q3.

(a) Sum of / total clockwise moments = sum of / total anticlockwise moments✔

For a body in equilibrium✔

2

(b) Clockwise moments = 2.0 × 9.81 × 0.25 + 0.65 × 9.81 × 0.45

= 7.77 (N m)✔

Anticlockwise moments = Tsin30 × 0.3✔

Tsin30 × 0.3 = 7.77 or T = 7.77/(sin30 × 0.3) ✔

T = 52.0 (N) ✔

First mark for clockwise moments, workings or correct answer.

Second mark for anticlockwise moments.

Third mark for equating clockwise and anticlockwise moments.

Fourth mark for correct answer.

4

[6]

Newton's Laws of Motion:

Q1.

B

[1]

Q2.

C

80 m s^{-1}

[1]

Q3.

D

Only total momentum is conserved.

[1]

Q4.

(a) Use of $p = mv$ **or** estimates walking speed = 1 or 2 m/s✔

Allow use of where m has been made the subject and p has been substituted.

Accept any answer in range 2×10^6 to 10×10^6 (kg) ✔

Range on answer:

(Using speeds in range 0.5 ms^{-1} to 2.5 ms^{-1})

Accept 1 significant figure answer

2

(b) **Max 4**

There is a force on the water (from the propeller) and this produces an equal force on the propeller (from the water in the opposite direction) ✔
Correctly links to Newton's 3rd law ✔

This force on the ship equals the drag force on the ship✔
Correctly links to Newton's 1st law✔

Force is needed to change the water's momentum✔ Correctly links to Newton's 2nd law✔

Must link correct law to at least one correct statement for all 4 marks

4

Practical Skills:

Q1

Diagram and procedure

- labelled diagram
- horizontal surface supported
- description of procedure
- method to release ball
- method to identify position ball hits the ground
- repeats experiment for each *v*
- method to prevent ball rolling on floor in laboratory

Measurements

- measuring instruments to determine *v*
- measurements to determine *v* e.g. *mgh* conversion or one light gate with diameter of ball measured or two light gates with distance between light gates measured
- use of ruler to measure *R*.

Analysis

- equation to determine *v*
- appropriate graph, e.g. plot *R* against *v* or plot R^2 against v^2
- Expect straight line passing through origin
- $Q = g \times \text{gradient}^2$ or $Q = g \times \text{gradient}$

Q2

Description

- Release method
- Ensure bob is not pushed
- Repeat experiment for same *H*
- Repeat for different H
- Centre of mass of single bob and joined bob considered
- Keep bob string taught

Measurements

- Measure heights *h* and *H* with ruler
- Use centre of mass of bob or another suitable method
- Use video camera to record motion
- Use of datalogger and appropriate sensor to measure *H* and *h*
- Measure mass with (top pan) balance

Analysis

- Construct a table of *h* and *H*
- Plot graph of *h* against *H*
- LoBF should pass through origin.
- Determine gradient or calculate *h*/*H repeatedly*
- gradient (gradient must be consistent with the plot)

Masses substituted into above expression and checked against experimental gradient

Stretch & Challenge:

Q1. (sum of) clockwise moment(s) = (sum of) anticlockwise moment(s)

Not: 'CWM = ACWM'

(18 × 0.14) + (60 + 0.32) = 0.035F

Allow: working in consistently in cm

C1

F ≈ 620 (N)

Note: Bald answer scores 3 marks

Allow: 1 mark for 21.72 (N m) or 2172 (N cm)

Q2. clockwise moments = anticlockwise moments (for equilibrium) (1)

B × 0.020m = 0.075 × 9.8 × 0.20 + 0.135 × 9.8 × 0.30 (1)

do not penalise distance in cm

2 / 3 if g = 10 m s^{-2} leading to 27.7 N

B = 27.2 N (1) allow 27 N

Q3.

(a) Use of $E_k = ½ mv^2$ ✔

(Kinetic energy =) 9.2 × 10^9 (J) ✔

Condone POT error on 1st MP
Allow use where v where has been converted from 5.5 km h^{-1}

An answer to 2 significant figures (with some working) ✔

Significant figure mark requires evidence of some relevant working.

3

(b) **Why force on the gas:**
The gas's momentum is changing ✔
This require a force according to **Newton's 2nd law** ✔

Or

The gas is being accelerated ✔
This require a force according to **Newton's 2nd law** ✔

Max 3 *for* ***why there is a force on the gas*** *and* ***why there is a resistive force on the system***

Must have ***why the system decelerates*** *to obtain all* ***4 marks****.*

The reason why the resultant force causes the deceleration rather than the acceleration.

Why (resistive) force on system:

The gas exerts a force on the parachute (with an equal magnitude and opposite direction force) / there is air resistance (on the system) / there is drag (on the system) / there is a resistive force (on the system) ✔

(because) the Parachute exerts a force on the gas according to **Newton's 3rd law** ✔

Allow statement that is equivalent to N1 / N2 / N3.

Allow: air resistance (or drag) increases.

Allow: there is an upward force

must have a clear action-reaction pair for this ***N3*** *mark.*

Why system decelerates:
The resistive force is <u>greater than the weight</u> so there is a resultant force
Or
The **resultant** force is acting in the opposite direction (to its motion). ✔

acceleration in same direction as resultant force according to **Newton's 2nd law** ✔

allow the ***resultant*** *force is vertically upwards*

Or

Links *to violation for conditions of Newton's 1st law and therefore cannot continue at constant velocity.*

4

(c) Attempt at determining difference = 3.3 (× 10^5) − 2.2 (× 10^5) or difference = 1.1 (× 10^5) ✔

1st mark: Credit an application of conservation of energy (allow written statement, or equation without substitution)

Ignore signs on difference and answer.

MP2 allow their energy in a substitution that is, otherwise correct.

Condone an answer = 18.4 (m s^{-2}) is worth 2 marks.

Use of $E_p = mgh$ ✔

(g =) 3.7 (m s^{-2}) ✔

Condone mgh = ½ mv^2 where rearranged to make g *subject.*

*Condone 610 x g x 49 = **their energy***

Alternative:

- *Attempt to use appropriate equations of motion to determine acceleration*
  $v^2=u^2+2as$ rearranged to make a the subject (condone use of their values for v and u and / or g = a)
- *Attempt to use W=Fs to determine the air resistance F_D (or F_D= 6734(.7) (N) seen)*
- *Attempt to determine g from the deceleration of the system*

$$g = \frac{F_D - ma}{m}$$

3

(d) More mass to **displace** / more particles to **collide with** / more gas / dust to displace ✔

Must have some interaction with parachute-spacecraft.

N/E to say there are more particles / gas / dust /mass

(at any given speed)
Greater (rate of) change of momentum / More work done (per unit distance) / Greater (resistive) force / more kinetic energy transferred (per unit distance) ✔

Greater **resultant** force **on** the system (therefore greater deceleration) / greater loss of velocity per second (therefore greater deceleration) ✔

3rd MP for greater resultant force: allow the idea that the difference between the drag and weight has increased

3rd MP
Allow clear statement that links:

- *rate of change of momentum of gas / dust to rate of change of momentum of system*
- *rate of work done on gas / dust to rate of work done by system*

3

[13]