QQQ – Mechanics Year 1 – Chapter 8 – Introduction & Modelling (Version 1)

Total Marks: 23

(23 = Platinum, 21 = Gold, 18 = Silver, 16 = Bronze)

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1. A horizontal force of 30 N causes a crate to travel with an acceleration of 2 m s^{-2}, in a straight line, on a smooth horizontal surface.

Find the **weight** of the crate.

Circle your answer. **[1 mark]**

- 15 kg
- 15g N
- 15 N
- 15g kg

(Total 1 marks)

2. Jackie says:

"A person's weight on Earth is directly proportional to their mass."

Tom says:

"A person's weight on Earth is different to their weight on the moon."

Only one of the statements below is correct.

Identify the correct statement.

Tick (✓) **one** box. **[1 mark]**

- Jackie and Tom are both wrong.
- Jackie is right but Tom is wrong.
- Jackie is wrong but Tom is right.
- Jackie and Tom are both right.

(Total 1 marks)

3. One of the following is an expression for the distance between the points represented by position vectors $5\mathbf{i} - 3\mathbf{j}$ and $18\mathbf{i} + 7\mathbf{j}$

Identify the correct expression.

Tick (✓) **one** box. **[1 mark]**

- $\sqrt{13^2 + 4^2}$
- $\sqrt{13^2 + 10^2}$
- $\sqrt{23^2 + 4^2}$
- $\sqrt{23^2 + 10^2}$

(Total 1 marks)

4. A force $\mathbf{F}$ is $\begin{bmatrix} p \\ -0.5 \end{bmatrix}$ newtons, where p is a constant.

Given that the magnitude of $\mathbf{F}$ is 1.3 newtons, find the possible values of p **[3 marks]**

(Total 3 marks)

5. In this question the unit vectors $\mathbf{i}$ and $\mathbf{j}$ are directed east and north respectively.

A canal narrowboat of mass 9 tonnes is pulled by two ropes. The tensions in the ropes are $(450\mathbf{i} + 20\mathbf{j})$ N and $(420\mathbf{i} - 20\mathbf{j})$ N. The boat experiences a resistance to motion $\mathbf{R}$ of magnitude 300 N.

(a) Explain what it means to model the boat as a particle. **[1]**

The boat is travelling in a straight line due east.

(b) Find the equation of motion of the boat. **[2]**

(c) Find the acceleration of the boat giving your answer as a vector. **[1]**

(Total 4 marks)

6. An astronaut on the surface of the moon drops a ball from a point 2 m above the surface.

(a) Without any calculations, explain why a standard model using $g = 9.8 \text{ m s}^{-2}$ will not be appropriate to model the fall of the ball. **[1]**

The ball takes 1.6 s to hit the surface.

(b) Find the acceleration of the ball which best models its motion. Give your answer correct to 2 significant figures. **[2]**

(c) Use this value to predict the maximum height of the ball above the point of projection when thrown vertically upwards with an initial velocity of 15 m s^{-1}. **[2]**

(Total 5 marks)

7. A particle P is moving with constant velocity. The position vector of P at time t seconds $(t \geqslant 0)$ is $\mathbf{r}$ metres, relative to a fixed origin O, and is given by

$$\mathbf{r} = (2t - 3)\mathbf{i} + (4 - 5t)\mathbf{j}$$

(a) Find the initial position vector of P. **(1)**

The particle P passes through the point with position vector $(3.4\mathbf{i} - 12\mathbf{j})$ m at time T seconds.

(b) Find the value of T. **(3)**

(c) Find the speed of P. **(4)**

(Total 8 marks)

Solutions

1. AQA June 2022 Paper 1 Q12

Scheme	Marks	AO
Circles correct answer.	B1	1.1b
	(1 mark)	

Typical solution

$15g$ N

2. AQA June 2021 Paper 1 Q11

Scheme	Marks	AO
Ticks correct box	B1	2.2a
	(1 mark)	

Typical solution

Jackie and Tom are both right

3. AQA June 2020 Paper 1 Q12

Scheme	Marks	AO
Ticks correct box	B1	1.1b
	(1 mark)	

Typical solution

$$\sqrt{13^2 + 10^2}$$

4. AQA June 2025 Paper 1 Q19

Scheme	Marks	AO
Obtains $p^2 + (-0.5)^2$ or $p^2 + 0.5^2$ ACF Condone any variable for p	B1	1.1b

Equates their expression for the magnitude of the given vector to 1.3 or the square of the magnitude of the given vector to 1.3^2 to obtain at least one value for p	M1	3.1a
Deduces $p = \pm 1.2$	R1	2.2a
	(3 marks)	

Typical solution

Magnitude of given vector

$$= \sqrt{p^2 + (-0.5)^2}$$

$$\sqrt{p^2 + 0.25} = 1.3$$

$$p^2 = 1.44$$

$$p = \pm 1.2$$

5. OCR MEI June 2022 Paper 1 Q7

Mark scheme (a)

Scheme	Marks	AO
When the boat is modelled as a particle, the size and shape of the boat are not taken into account in the model Any rotation of the boat is neglected	B1	3.3
	[1]	

Notes

B1: A sensible comment

Mark scheme (b)

Scheme	Marks	AO
Resistance is $-300\mathbf{i}$ N Newton's second law $((450\mathbf{i} + 20\mathbf{j}) + (420\mathbf{i} - 20\mathbf{j})) - 300\mathbf{i} = 9000\mathbf{a}$	M1 A1	1.1a 1.1b
$[570\mathbf{i} = 9000\mathbf{a}]$		
	[2]	

Notes

M1: Sum of at least two forces seen in a N2L equation. Also allow for scalar equation in the **i** direction only. Allow missing or incorrect resistance

A1: Accept equivalent scalar equation and statement that there is no [resultant] force or no acceleration in the **j** direction)

Mark scheme (c)

Scheme	Marks	AO
$\mathbf{a} = \frac{570}{9000}\mathbf{i} = 0.0633\mathbf{i}\ \text{m s}^{-2}$	B1	2.5
	[1]	

Notes

B1: Must be vector. FT their equation(s) of motion

6. OCR MEI October 2020 Paper 1 Q10

Mark scheme (a)

Scheme	Marks	AO
Acceleration due to gravity is not a constant but depends on location in the universe.	B1	3.5b
	[1]	

Notes

B1: Allow any sensible comment that g might be different on the moon

Mark scheme (b)

Scheme	Marks	AO
Using $s = 2,\ u = 0,\ t = 1.6$ and $s = ut + \frac{1}{2}at^2$ Downwards as the positive direction $2 = \frac{1}{2} \times 1.6^2 a$ giving $[a = 1.5625]$	M1	3.3
which 1.6 m s^{-2} to 2 sf	A1	1.1
	[2]	

Notes

M1: Allow any sign convention

A1: Allow –1.6 m s^{-2} if upwards is clearly indicated as positive. Must be 2 significant figures.

Mark scheme (c)

Scheme	Marks	AO
Using $u = 15,\ v = 0,\ a = -1.6$ and $v^2 = u^2 + 2as$ Upwards as the positive direction $0 = 15^2 - 2 \times 1.6s$	M1	3.4
$s = 70.3$ m	A1	1.1
	[2]	

Notes

M1: Use of *suvat* equation(s) leading to a value for s. Allow sign errors

A1: Must follow from correct working and if negative, explained.

Allow answers in the range 70 to 72.2

7. Edexcel M1 June 2015 Q6

Mark scheme (a)

Scheme	Marks
$\mathbf{r} = (-3\mathbf{i} + 4\mathbf{j})$ m	B1
	(1)

Notes

Allow column vectors throughout. B1 for $(-3\mathbf{i} + 4\mathbf{j})$ (m)

Mark scheme (b)

Scheme	Marks
$3.4 = 2T - 3$ or $-12 = 4 - 5T$	M1 A1
$T = 3.2$	A1
	(3)

Notes

M1 for a clear attempt at either $3.4\,(\mathbf{i}) = (2T - 3)\,(\mathbf{i})$ or $-12\,(\mathbf{j}) = (4 - 5T)\,(\mathbf{j})$

First A1 for a correct equation (either) without $\mathbf{i}$'s and $\mathbf{j}$'s

A1 for 3.2 oe

N.B. $T = \dfrac{6.4\mathbf{i} - 16\mathbf{j}}{2\mathbf{i} - 5\mathbf{j}} = 3.2$ scores M1A1A1 BUT if RHS is not a single number, then M0. Also, if they get 3.2 and another value and don't clearly choose 3.2 then A0

Mark scheme (c)

Scheme	Marks
$\mathbf{r} = (-3\mathbf{i} + 4\mathbf{j}) + t(2\mathbf{i} - 5\mathbf{j})$	M1
$\mathbf{v} = (2\mathbf{i} - 5\mathbf{j})$	A1
speed $= \sqrt{(2^2 + (-5)^2)} = \sqrt{29} = 5.4\text{ m s}^{-1}$ or better	M1 A1
	(4)
	(8 marks)

Notes

First M1 for a complete method for finding $\mathbf{v}$

e.g. $\mathbf{r} = (-3\mathbf{i} + 4\mathbf{j}) + t(2\mathbf{i} - 5\mathbf{j})$ so $\mathbf{v} = 2\mathbf{i} - 5\mathbf{j}$

OR: $\mathbf{v} = \dfrac{(3.4\mathbf{i} - 12\mathbf{j}) - (-3\mathbf{i} + 4\mathbf{j})}{\text{their } T}$

OR: $\mathbf{v} = \dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t} = 2\mathbf{i} - 5\mathbf{j}$

First A1 for $2\mathbf{i} - 5\mathbf{j}$; M1A1 can be awarded for $2\mathbf{i} - 5\mathbf{j}$ only.

Second M1 for attempt to find magnitude of their $\mathbf{v}$, i.e. $\sqrt{2^2 + (-5)^2}$

Second A1 for $\sqrt{29}$ or 5.4 or better

OR

First M1 for attempt to find distance travelled: $d = \sqrt{(-3 - 3.4)^2 + (4 - -12)^2}$

First A1 if correct

Second M1 for their d / their T

Second A1 for $\sqrt{29}$ or 5.4 or better

Alt (c)

$\lvert\mathbf{s}\rvert = \sqrt{6.4^2 + (-16)^2} = 17.23\ldots$	M1 A1
$\therefore \text{speed} = \dfrac{17.23}{3.2} = 5.4$ or better	M1 A1