SYDNEY GRAMMAR SCHOOL

2018
FORM VI
HALF-YEARLY EXAMINATION
Wednesday 21st February

Physics

General Instructions

- Working time – **2 hours**
- Board-approved calculators may be used
- Write using black pen
- Draw diagrams using pencil
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your student number at the top of the Multiple Choice Answer Sheet and each page of Part B
- Hand in your Multiple Choice Answer Sheet and all of Part B in one bundle. (Do not staple together)

Total marks (80)

This paper has two parts, Part A and Part B

Part A
Total marks **(15)**
- Attempt ALL Questions
- Allow about 20 minutes for this part

Part B
Total marks **(65)**
- Attempt ALL Questions
- Allow about 1 hour and 40 minutes for this part

CHECKLIST	
Each boy should have the following:	
1 Question Paper	
1 Multiple Choice Answer Sheet	

Physics Classes

1. PCK	2. MRW	3. ILM
4. SRW	5. PCK	6. AAH

EXAMINERS: AAH / MRW / SRW / PCK

1. When an object of mass 80 kg on the Earth's surface is taken to the Moon's surface, it would:

(A) have the same weight.

(B) have the same gravitational force acting on it.

(C) have the same mass.

(D) reach the ground in the same time if dropped from the same height.

The following information applies to the next two questions.

A satellite is in orbit at a radius of r metres from the Earth with a period of T seconds and a GPE of E_p. It is desired to increase its orbital radius to $4r$.

2. The gravitational potential energy of the satellite is now:

(A) $0.25E_p$

(B) $0.75E_p$

(C) E_p

(D) $3E_p$

3. The period of the satellite in its new orbit will be:

(A) T

(B) $2T$

(C) $4T$

(D) $8T$

4. If the cable tethering an astronaut to the shuttle in Earth orbit breaks during a spacewalk, then:

(A) she will fly off into space, as the gravitational forces acting on shuttle and astronaut are different.

(B) she will remain next to the shuttle as the acceleration of the shuttle and the astronaut are the same.

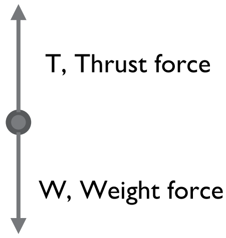
(C) she will remain next to the shuttle as the force of the Sun on the astronaut and shuttle keeps them in orbit.

(D) she will fly off into space as the force of the Sun on the astronaut will cause her to fall into the Sun.

5. Which of the following is **not** correct when comparing these two types of satellites?

	Property	*Low Earth Orbit Satellite*	*Geostationary Satellite*
(A)	**speed**	slower	faster
(B)	**acceleration**	higher	lower
(C)	**latitude**	any	equatorial
(D)	**orbital period**	shorter	longer

7. When a descending Space-X reusable rocket stage (two pictured) of mass, *m, is* slowing down to land it has the following forces on it:



Which of the following is the correct acceleration of the rocket?

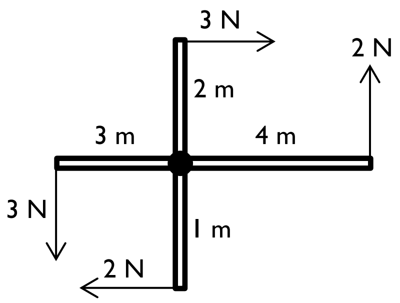
(A) $\frac{T-W}{m}$ downwards

(B) $\frac{T}{m}$ upwards

(C) $\frac{W}{m}$ downwards

(D) $\frac{T-W}{m}$ upwards

13. A four-arm cross is set up to rotate around an axis as shown below.



What is the magnitude of the net torque acting on the cross?

(A) 0 Nm

(B) 9 Nm

(C) 11 Nm

(D) 25 Nm

Part B
Total marks (65)
Attempt ALL Questions
Allow about 1 hour and 40 minutes for this Part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 16 (3 marks) **Marks**

The acceleration due to gravity on Mars is about 1/3 of *g* on Earth, whereas the radius of Mars is roughly half that of Earth.

Estimate the ratio of the mass of Mars to the mass of Earth.

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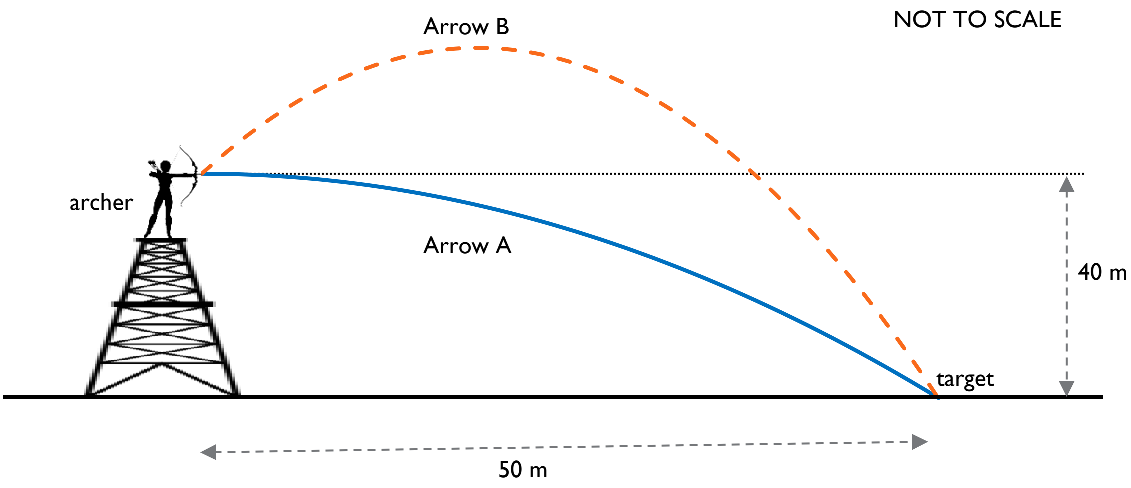
Question 17 (6 marks) **Marks**

On a tall platform an arrow (arrow A) is fired horizontally from a height of 40 m and hits a target 50 m horizontally away. Another arrow (arrow B) is fired upwards, hitting the same target again. Arrow B was in the air for twice as long as arrow A.



(a) What is the time of flight of arrow A?

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(b) What is the initial horizontal velocity of arrow A?

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Question 17 continued on next page.

Question 17 continued **Marks**

(c) Determine the initial velocity of arrow B. **4**

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Question 18 (4 marks) **Marks**

A spanner of mass 2 kg is dropped from rest from a distance of 2.737×10^6 m from the centre of the moon, which has a mass of 7.35×10^{22} kg and a radius of 1.737×10^6 m.

Determine the speed of the spanner on collision with the moon.

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Candidate Number

Question 19 (3 marks) **Marks**

A satellite of mass m is in a circular orbit around a planet of mass M at a distance of r metres from the centre of the planet.

Use Newton's Law of Universal Gravitation to derive a formula for the kinetic energy of the satellite in terms of G, M, m and r.

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Question 20 (7 marks) **Marks**

A satellite is orbiting a planet α that rotates once every 7.0 earth-days. In a low orbit the satellite goes around the planet 11.2 times for every rotation of the planet at an orbital radius of 3.46×10^{7} m.

(a) What is the period of the satellite around planet α?

.... **1**

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(b) The satellite then has its orbital radius increased so the satellite is in a synchronous orbit, remaining at the same fixed point above the planet's surface.

i) Determine the orbital radius that would be required for this to occur.

.... **2**

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ii) What other condition needs to be met for the satellite to remain at the same fixed point above the planet's surface?

.... **1**

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iii) Determine the mass of the planet α.

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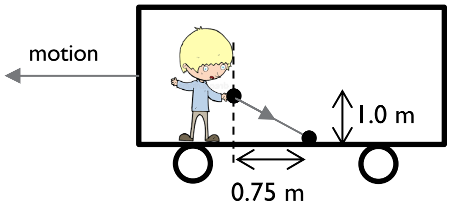
Question 22 (5 marks) **Marks**

A boy performs an experiment on a moving train, as shown in the diagram below.



When he drops the ball, he finds that its falls diagonally backwards, and lands 0.75 m behind where he was standing. He concludes that the train is a non-inertial frame of reference.

(a) Outline the meaning of the term 'non-inertial frame of reference'.

.... **1**

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(b) Explain the behaviour of the ball, from the perspective of an observer standing on the Earth.

.... **2**

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(c) Estimate the magnitude of the train's acceleration.

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SYDNEY GRAMMAR SCHOOL

Class

Student Number

PHYSICS
Form VI
Half-Yearly Examination
2018
Wed 21 Feb PM

Multiple Choice
ANSWER SHEET

General Instructions

- Write your class and Candidate Number in the space provided.
- Attempt all questions
- Use a blue or black pen
- Select the alternative A, B, C, or D that best answers the question.
- Fill in the response oval completely.

ANSWER DISTRIBUTION

	Answer	A	B	C	D
1	**C**	0%	0%	100%	0%
2	**A**	97%	0%	2%	1%
3	**D**	0%	1%	7%	92%
4	**B**	11%	87%	2%	0%
5	**A**	93%	6%	1%	0%
6	**C**	32%	3%	38%	27%
7	**D**	13%	0%	2%	84%
8	**B**	16%	81%	3%	0%
9	**C**	0%	4%	93%	1%
10	**D**	3%	6%	8%	83%
11	**C**	3%	2%	94%	0%
12	**D**	0%	0%	9%	91%
13	**B**	3%	89%	4%	3%
14	**A**	97%	3%	0%	0%
15	**B**	17%	78%	1%	3%

1. When an object of mass 80 kg on the Earth's surface is taken to the Moon's surface, it would:

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(B) have the same gravitational force acting on it.

(C) have the same mass.

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The following information applies to the next two questions.

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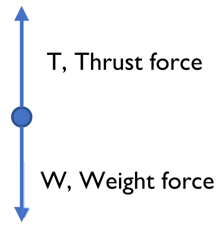

Which of the following is the correct acceleration of the rocket?

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(B) $\frac{T}{m}$ upwards

(C) $\frac{W}{m}$ downwards

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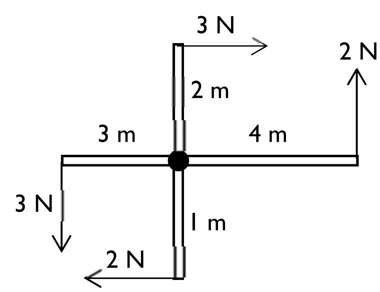


What is the magnitude of the net torque acting on the cross?

(A) 0 Nm

(B) 9 Nm

(C) 11 Nm

(D) 25 Nm

Candidate Number

Part B
Total marks (65)
Attempt ALL Questions
Allow about 1 hour and 40 minutes for this Part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 16 (3 marks) **Marks**

The acceleration due to gravity on Mars is about 1/3 of g on Earth, whereas the radius of Mars is roughly half that of Earth.

Estimate the ratio of the mass of Mars to the mass of Earth. 3

$g_{Mars} = \frac{GM_{Mars}}{r_{Mars}^2}$ $g_{Earth} = \frac{GM_{Earth}}{r_{Earth}^2}$

$\therefore \frac{g_{Mars}}{g_{Earth}} = \frac{1}{3} = \frac{M_{Mars} r_{Earth}^2}{M_{Earth} r_{Mars}^2} = \frac{M_{Mars}}{M_{Earth}} \times 4$

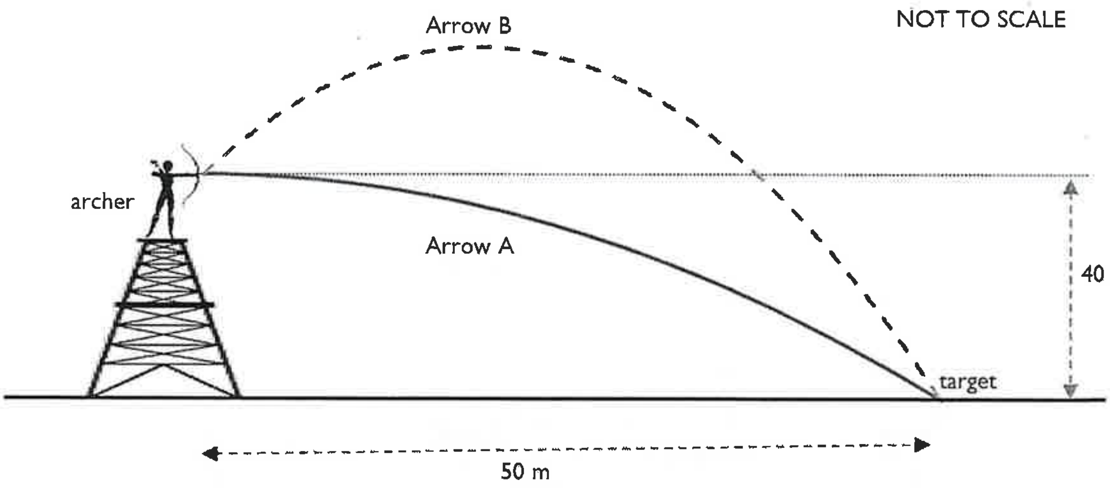
2 marks

$\therefore \boxed{\frac{M_{Mars}}{M_{Earth}} = \frac{1}{12}}$ 1 Mark

Many boys wrote 12:1 without indicating this was Earth to Mars. I penalised this 1 mark.

Question 17 (6 marks) **Marks**

On a tall platform an arrow (arrow A) is fired horizontally from a height of 40 m and hits a target 50 m horizontally away. Another arrow (arrow B) is fired upwards, hitting the same target again. Arrow B was in the air for twice as long as arrow A.



(a) What is the time of flight of arrow A? 1

$40 = 4.9t^2$

$\boxed{t = 2.857 \text{ sec}}$ $\doteqdot 2.9$ sec (2 sig fig)

$\left(t = \frac{20}{7}\right)$ 2.86 sec (3 sig fig)

(b) What is the initial horizontal velocity of arrow A? 1

$\frac{50}{(a)} = \boxed{17.5 \text{ m/s}}$ exactly

2.9 sec $\Rightarrow$ 17.24 m/s 2.857 $\Rightarrow$ 17.5 m/s

2.86 $\Rightarrow$ 17.48 m/s

Question 17 continued on next page.

Candidate Number

Question 17 continued **Marks**

(c) Determine the initial velocity of arrow B. **4**

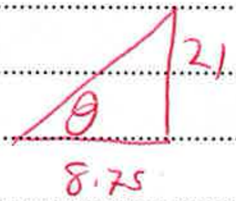
$-40 = u \times 2 \times \frac{20}{7} - 4.9 \times \left(\frac{20 \times 2}{7}\right)^2$

$\therefore u_v = (160 - 40) \times \frac{7}{40}$

$= 21 \text{ m/s}$ exactly (1) (Vertical)

$u_H = \frac{50}{2 + \frac{20}{7}} = 8.75 \text{ m/s}$ exactly (1) (Horizontal)

$\therefore u =$



22.75 m/s exactly (1)

$\theta = \tan^{-1} \frac{21}{8.75} = 67.38°$ (1)

If $t = 2.9$ $u_v = 21.52$

$u_H = 8.62$

$\therefore u = 23.2 \text{ m/s}$ $\theta = 68.2°$

Question 18 (4 marks) **Marks**

A spanner of mass 2 kg is dropped from rest from a distance of 2.737×10^6 m from the centre of the moon, which has a mass of 7.35×10^{22} kg and a radius of 1.737×10^6 m.

Determine the speed of the spanner on collision with the moon. **4**

$E_i = \frac{-GMm}{r} = \frac{-6.67\times10^{-11} \times 2 \times 7.35\times10^{22}}{2.737\times10^6}$

$= -3.582\times10^6$ J ① ✓

$E_f = \frac{-GMm}{r} + \frac{1}{2}mv^2 = \frac{-6.67\times10^{-11}\times2\times7.35\times10^{22}}{1.737\times10^6} + v^2$

$= -5.645\times10^6 + v^2$ ① ✓

$E_i = E_f$ (conservation of Energy) ①

$\therefore v^2 = 5.645\times10^6 - 3.582\times10^6 = 2.063\times10^6$

$v = 1436$ m/s ①

Candidate Number

Question 19 (3 marks) **Marks**

A satellite of mass m is in a circular orbit around a planet of mass M at a distance of r metres from the centre of the planet.

Use Newton's Law of Universal Gravitation to derive a formula for the kinetic energy of the satellite in terms of G, M, m and r. 3

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \quad (1)$$

$$\therefore v^2 = \frac{GM}{r} \quad (1)$$

$$\therefore \frac{1}{2}mv^2 = \frac{GMm}{2r} \quad (1)$$

Candidate Number

PCK CRIB

Question 20 (7 marks) **Marks**

A satellite is orbiting a planet α that rotates once every 7.0 earth-days. In a low orbit the satellite goes around the planet 11.2 times for every rotation of the planet at an orbital radius of 3.46×10^7 m.

(a) What is the period of the satellite around planet α? **1**

Period $T = \frac{7}{11.2} = 0.625$ earth days $= 15$ hours $= 900$ min

$= \boxed{54{,}000\,s \text{ or } 5.4\times10^4\,s}$

Form av 0.8
Full marks 67%

(b) The satellite then has its orbital radius increased so the satellite is in a synchronous orbit, remaining at the same fixed point above the planet's surface.

i) Determine the orbital radius that would be required for this to occur. **2**

$T_{low} = 0.625$ earth days $T_{geo} = 7$ earth days

$r_{low} = 3.46\times10^7$ m $r_{geo} = ?$

(1) Identify period of geo orbit

By Kepler $\frac{r_{low}^3}{T_{low}^2} = \frac{r_{geo}^3}{T_{geo}^2}$ $r_{geo} = r_{low}\sqrt[3]{\left(\frac{T_{geo}}{T_{low}}\right)^2}$

$= 3.46\times10^7\sqrt[3]{(11.2)^2} = \boxed{1.73\times10^8\,m}$

(1) Using ratio correctly

Form av 1.7
Full marks 68%

ii) What other condition needs to be met for the satellite to remain at the same fixed point above the planet's surface? **1**

It needs to orbit around the equator of the planet in the same direction as the planets rotation.

Form av 0.6
Full marks 57%

iii) Determine the mass of the planet α. **3**

$\frac{r_{low}^3}{T_{low}^2} = \frac{r_{geo}^3}{T_{geo}^2} = \frac{GM}{4\pi^2}$, $M = \frac{4\pi^2}{G}\left(\frac{r_{low}^3}{T_{low}^2}\right)$

$T_{low} = 5.4\times10^4$ s $= \frac{4\pi^2}{6.67\times10^{-11}}\left(\frac{(3.46\times10^7)^3}{(5.4\times10^4)^2}\right)$

(1) must use period in SI seconds (1) correct pair of r, T

$= 8.41\times10^{24}$ kg

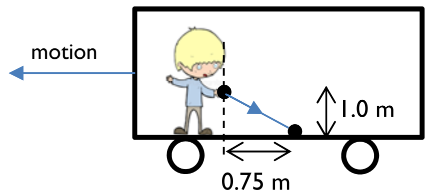
(1) correct answer

Form av 2.2
Form full marks 53%

CRIB (AAH)

Question 22 (5 marks) **Marks**

A boy performs an experiment on a moving train, as shown in the diagram below.



When he drops the ball, he finds that its falls diagonally backwards, and lands 0.75 m behind where he was standing. He concludes that the train is a non-inertial frame of reference.

(a) Outline the meaning of the term 'non-inertial frame of reference'. **1**

1 Mark for any sensible outline, e.g.:

- A frame of reference that is accelerating.
- A frame of reference in which the law of inertia does not hold.
- A frame of reference which is experiencing a non-zero net force.

(b) Explain the behaviour of the ball, from the perspective of an observer standing on the Earth. **2**

Marks	Criteria
2	• ***Explains*** that the ball falls in a parabolic arc (constant horizontal velocity, constant vertical acceleration). • ***Explains*** why the ball lands behind the boy (the boy continues to accelerate to the left but the ball does not).
1	• Either of the points above.

The question asks pupils to explain the *"behaviour"* of the ball. The most significant (because it is in some sense 'anomalous') feature of this behaviour is that the ball *falls behind the boy*. An explanation of this is therefore essential to gaining full marks in this question.

NB_1: The question required pupils to ***explain*** the behaviour, not simply to ***describe*** it. Pupils who scored only one mark usually did so because they did not ***explain why*** the ball lands behind the boy.

NB_2: Many pupils answered the question from the train's frame of reference, not that of an external observer. These answers scored **no marks**.

NB_3: Answers that ***incorrectly describe the ball's motion*** to the stationary observer (e.g. 'the ball falls straight down' or 'the ball falls in a straight line') usually scored no marks. However, a number of pupils assumed that the ball is dropped when the train is initially at rest, but accelerating to the left (the question makes it clear that this is not the case); these answers scored a *maximum* of 1 Mark.

NB_4: As the question is only worth two marks, it was not necessary to explain why the ball appears to fall in a ***straight*** line. (Though this might have been required if the question had been worth more marks.)

Sample Answer to Part (b)

- After the boy lets the ball go, it continues with a constant horizontal velocity (to the left) as it accelerates towards the ground, so it falls in a parabolic arc.

- After he has let go of the ball, the boy continues to accelerate to the left with the train. He therefore travels a greater horizontal distance than the ball, which ends up somewhere behind him when it hits the floor.

(c) Estimate the magnitude of the train's acceleration. **2**

Multiple approaches are possible here, but the simplest was to recognise that, since $r_H = \frac{1}{2}at^2$ and $r_V = \frac{1}{2}gt^2$, *a*/*g* are in the same ratio as r_H/r_V.

Thus, *a*/*g* = 0.75/1.0 **a = 7.4 ms^{-2}**. **[2 Marks]**

[**1 Mark**] for using $r_V = \frac{1}{2}gt^2$ to calculate t = 0.45 s.