Physics A

Unit: G484: The Newtonian World

1(a) State Newton's second law of motion. **[2]**	
Candidate style answer	*Examiners commentary*
The force acting on an object equals the rate of change of momentum of the object.	In part (a) *equals* should have been *proportional to* but is still adequate to score one mark. However there is no further qualification, e.g. *the momentum change is in the direction of the force* and so does not gain the second mark

(b) Explain how the principle of conservation of momentum is a natural consequence of Newton's laws of motion. **[3]**	
Candidate style answer	*Examiners commentary*
In a collision between two objects, the force acting on one object is equal but opposite to the force acting on the other object so the change in momentum of one object is equal and opposite to the change of momentum for the other object.	In part (b) there is no mention of which of Newton's laws is being quoted nor of the principle of conservation of momentum. The time of the collision to translate equal forces into equal momentum changes is also omitted Therefore there is a good mark but not enough for two marks to be awarded for this answer.

(c) Most cars are now fitted with safety airbags. During a sudden impact, a triggering mechanism fires an ammunition cartridge that rapidly releases nitrogen gas into the airbag. **In a particular simulated accident, a car of mass 800 kg is travelling towards a wall. Just before impact, the speed of the car is 32 m s^{-1}. It rebounds at two-thirds of its initial speed. The car takes 0.50 s to come to rest. During the crash, the car's airbag fills up to a maximum volume of 3.4×10^{-2} m^3 at a pressure of 1.0×10^5 Pa. The temperature inside the airbag is 20 ^{0}C. Calculate:** **(i) the change in the momentum of the car** **[2]**	
Candidate style answer	*Examiners commentary*
initial speed = 32 after impact speed = 2/3 × 32 = 21.3 the momentum change = 800(32 - 21.3) = 8.6×10^3 momentum change = 8.6×10^3.Ns.	There is much to do for two marks in part (c)(i). A harsh examiner would award zero; a kinder one would award one mark for calculating a change of momentum and giving the correct unit. Another approach is to state that there are two marks and one error so award one mark. The harsh examiner states that the error is fundamental physics so the answer scores zero. One mark has been given.

(ii) the magnitude and direction of the average force acting on the car during impact. **[3]**	
Candidate style answer	*Examiners commentary*
$F = 8.6 \times 10^3 / 0.50 = 1.72 \times 10^4$ force = . 1.72×10^4.N direction:. away from the wall	With *error carried forward* applied the candidate scores all three marks in part (c)(ii).

(iii) the mass of nitrogen inside the cartridge. **molar mass of nitrogen = 0.014 kg mol^{-1}** **[3]** **[Total: 13]**	
Candidate style answer	*Examiners commentary*
using $pV = NkT$ $N = pV/kT = (1.0×105 × 3.4×10–2)/(1.38×10–23 × 20) = 1.23 × 1024$ mass = $(1.23 × 1024/ 6.02×1023) × 0.014 = 0.287$ kg mass = ..0.29.kg	In part (c)(iii) the candidate makes the common error made by both strong and weak candidates alike and surprising often, namely giving the temperature in celsius and not kelvin. This loses the candidate two marks so one mark is awarded for the correct conversion of particle number into mass.

Comments: The questions on the paper usually follow specification order unless the mechanics question is considered to be sufficiently more demanding than other questions. This question requires some careful thought and possibly question 3 might have been an easier starter question to ease the candidates into the paper. However this is a judgment taken by a committee at the time that the paper is set.

The candidate scores 7/13 through omissions and by making two fundamental errors.

2(a) Define *gravitational field strength* at a point in a gravitational field. **[1]**	
Candidate style answer	*Examiners commentary*
The gravitational field strength at a point equals the force on a unit mass placed at that point.	Part (a) is not awarded the mark because the word *on* is not an alternative to *per*. It could mean *force x mass* rather than *force/mass*.

(b) A satellite of mass 1500 kg is launched from the surface of the Earth into a circular orbit around the Earth at a height of 6800 km above the Earth's surface. At this height the satellite has an orbital period of 8.5×10^3 s. The radius of the Earth is 6400 km. **(i) A student uses the equation.** **gain in potential energy = mgh** **to determine the increase in the potential energy of the satellite. Suggest why this equation cannot be used and state whether the student's answer would be less than, equal to, or greater than the actual value.** **[2]**	
Candidate style answer	*Examiners commentary*

The equation assumes a constant value of g. It gets smaller as you move away from the Earth so the value that the student calculates will be too big.	Parts (b)(i) adequate to gain full marks

(ii) Calculate the kinetic energy of the satellite.

[3]

Candidate style answer	*Examiners commentary*
the speed of the satellite = 2πr /T *v = 2×π × 6800 ×103 / 8.5×103 = 5.03 × 103* *so KE = ½mv2 = 1/2×1500× 25 ×106 = 1.88 × 1010* *Kinetic energy = .1.9 × 1010.J*	Parts (b) (i) and (iii) are adequate to gain full marks but there is an error in (b) (ii). The candidate has forgotten to add the Earth's radius to the height of the satellite above the Earth. This is taken as an arithmetic error rather than a fundamental error in physics so only loses one mark as the rest of the calculation is carried out correctly.

(iii) State a benefit of having a satellite in a geostationary orbit round the Earth.
Explain whether or not a satellite orbiting at a height of 6800 km above the Earth's surface is in a geostationary orbit.

✐ ***In your answer, you should use appropriate technical terms, spelled correctly.***

[3]

Candidate style answer	*Examiners commentary*
A geostationary satellite is at a fixed point above the Equator and is used for communications *The period of the satellite is less than a day so it will not stay over the same place.*	

(c) q Fig. 2.1 shows how the gravitational field strength g varies with distance r from the centre of a planet of radius 2.0 × 107 m

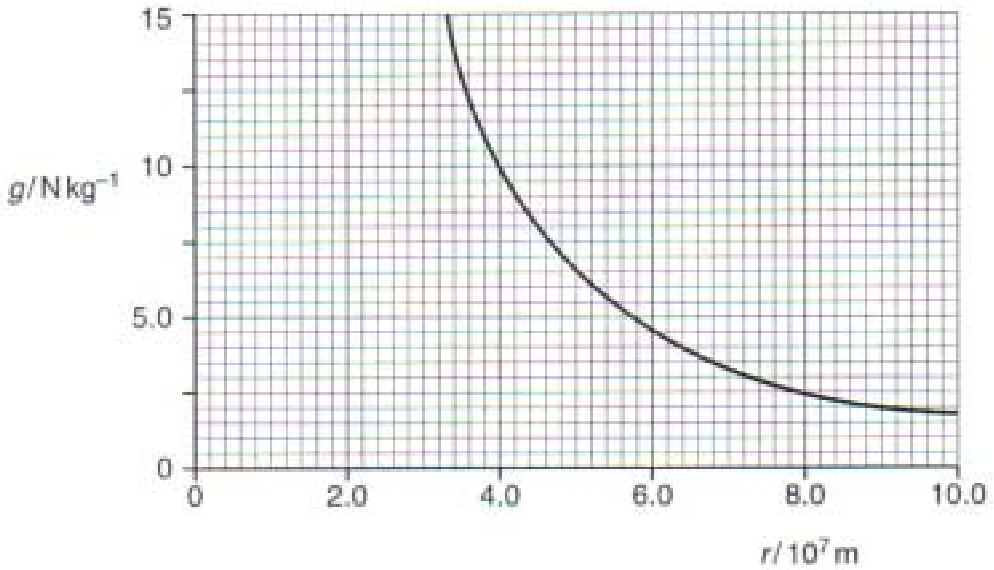

Fig. 2.1

The gravitational field strength on the surface of the planet is 40 N kg^{-1}.

(i) Use Fig. 2.1 to write down the value for *g* at a height of 4.0 × 10^7 m above the surface of the planet. **[2]**	
Candidate style answer	*Examiners commentary*
g = .10...N kg-1	In (c) (i) the candidate makes the same mistake despite the word surface being in bold. The value on the graph at r = 4.0 x 10^7 is 10 so the candidate is awarded one mark for the skill of being able to read the graph correctly.

(ii) Calculate the mass *M* of the planet. Assume that the planet can be treated as a point mass of magnitude *M* situated at its centre. **[2]**	
Candidate style answer	*Examiners commentary*
$g = GM/r^2$ $M = gr^2/G = 40 \times 4.0 \times 10^{14} / 6.67 \times 10^{-11}$ $M = . . 2.4 \times 10^{26}$. kg	The candidate correctly answers part (c)(ii)

(iii) Astronomers investigating the planet believe that the planet's interior has a uniform density. Show that within the interior of the planet, its gravitational field strength *g* is proportional to the distance *r* from the centre. **[2]** **[Total: 15]**	
Candidate style answer	*Examiners commentary*
	but does not attempt part (c)(iii).

Comments: The candidate scores a total of 10/15 for this question on gravitation.

3(a) Define *simple harmonic motion*. ✎ **In your answer, you should use appropriate technical terms, spelled correctly.** **[2]**	
Candidate style answer	*Examiners commentary*
A motion where the acceleration is proportional to the displacement in the opposite direction. .	In part (a) the first mark is secure as the word displacement is spelled correctly and the statement is correct. However the last four words are not adequate to secure the second mark.

(b) Fig. 3.1 shows a trolley attached to the end of a helical spring. The trolley executes simple harmonic motion on the smooth table.	

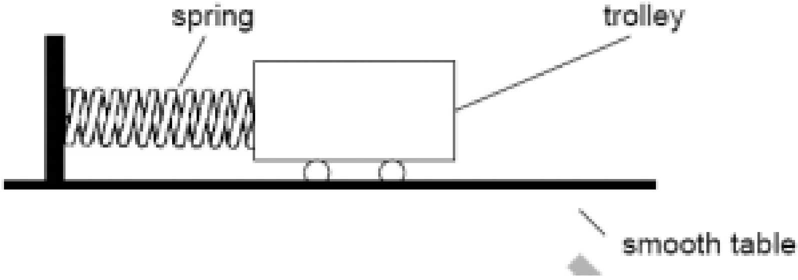

Fig. 3.1

(i) Describe how, for this oscillating trolley, you can determine the following quantities using a stopwatch and a ruler.

1 the frequency oscillation

[2]

Candidate style answer	*Examiners commentary*
You measure the time for 10 full oscillations so that the total time is at least about 10 s and then you divide by 10 to find the period. The frequency equals 1/period.	In part (b) (i) the frequency measurement description scores both marks but the maximum speed measurement only gains the first mark.

2 the maximum speed of the trolley

[2]

Candidate style answer	*Examiners commentary*
You measure the amplitude of the oscillations with the ruler. Then you divide four times the amplitude by the period which gives the average speed and you double this value for the maximum speed…	

(ii) The amplitude of the trolley is doubled. The trolley still moves in simple harmonic motion. State with a reason the change, if any, in the maximum speed of the trolley.

[2]

Candidate style answer	*Examiners commentary*
The maximum speed is doubled because the trolley has to travel twice as far in the same time	In part (b) (ii) the candidate has definitely gained the first mark and the 'commonsense approach' is given the second mark with a *benefit of the doubt.*

(iii) Using your knowledge of Hooke's law and Newton's second law, determine the period T of the trolley in terms of the force constant k of the spring and the mass m of the trolley.

[2]

[Total: 10]

Candidate style answer	*Examiners commentary*
Hooke's law states that T = kx where T is the tension and x is the extension	In part (b) (iii) the candidate has only stated Hooke's law; not enough to gain the first mark. The *Formulae and relationships sheet* has all

	of the formulae needed to complete the question. The candidate's understanding of this subject is obviously not strong as the formula required for the maximum speed is also on the sheet but he/she still scores 7/10.

Comments: The candidate scores 6/10 for this question on simple harmonic motion.

4(a) (i) Explain the term *internal energy*.

[2]

Candidate style answer	*Examiners commentary*
The internal energy of a body is the sum of the random kinetic and potential energies of the body	Part (a) (i) contains a common error which is to omit any reference to the atoms, i.e. that this is a definition at atomic scale. Some exam setters consider this to be a fatal error and give zero marks; others as one omission and give one mark. We will be generous here and give one mark.

(ii) Define *specific heat capacity of a substance*.

[1]

Candidate style answer	*Examiners commentary*
Specific heat capacity is the energy required to increase the temperature of unit mass of a substance by one degree.	Part (a) (ii) is correct and gains all three marks.

(b) Consider a 2.0 kg block of aluminium. Assume that the heat capacity of aluminium is independent of temperature and that the internal energy is zero at absolute zero. Also assume that the volume of the block does not change over the range of temperature from 0 K to 293 K. The specific heat capacity of aluminium is 920 J kg^{-1} K^{-1}.

(i) Show that the internal energy of this block at 20 ^{o}C is 540 kJ.

[2]

Candidate style answer	*Examiners commentary*
$E = 2.0 \times 920 \times 293 = 540$ kJ	(b)(i) are correct and gain all three marks.

(ii) Hence show that the mean internal kinetic energy per atom in the 2.0 kg aluminium block at 20 ^{o}C is about 1.2×10^{-20} J.

molar mass of aluminium is 0.027 kg mol^{-1}.

[3]

Candidate style answer	*Examiners commentary*
the number of atoms in 2.0 kg is $(2.0/0.027) \times 6.02 \times 10^{23} = 4.46 \times 10^{25}$ and the mean energy per atom $= 540/4.46 \times 10^{25} = 1.21 \times 10^{-23}$ J	In part (b) (ii) there is one error in the calculation. The candidate has forgotten the factor of 1000 in 540 k and has used 540 in the calculation. This is the only error so the candidate scores two marks losing one for an arithmetic error.

(iii) In 1819, Dulong and Petit measured the specific heat capacities of bodies made from different substances and found that for one mole of each substance, the molar heat capacity was about 25 J mol^{-1} K^{-1}. Use the data from either (i) or (ii) to show that this is true for aluminium. **[2]**	
Candidate style answer	*Examiners commentary*
The mean energy per atom is 1.21×10^{-23} J *There are 6.02×10^{23} atoms in one mole so the molar heat capacity is $1.21 \times 6.02 = 7.3$* *This is not the right answer?*	In part (b) (iii) the calculation is left incomplete. For some reason the candidate has not realised that all that has to be done is to divide the number that has been reached by the temperature, namely 293 to achieve the required answer. The mark scheme requires this division for the first mark so the candidate scores zero.

(c) A student performs an experiment to measure the specific heat capacity of a 1 kg aluminium block using the apparatus shown in Fig 4.1.

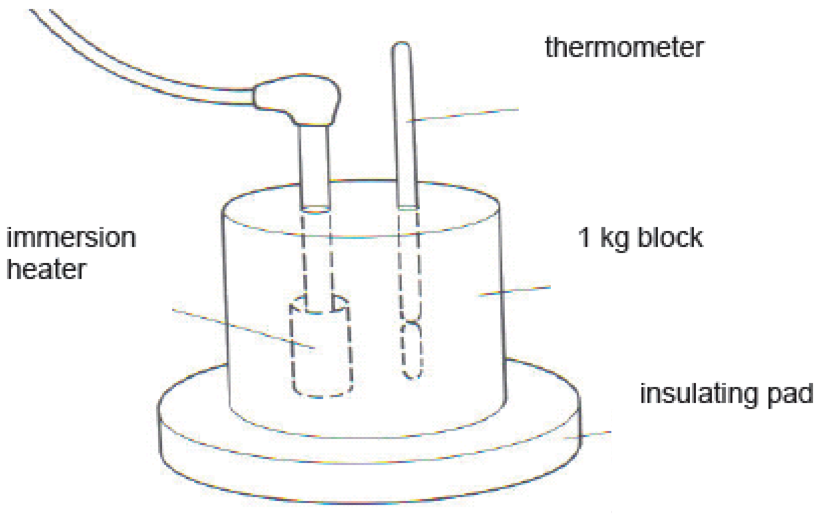

Fig 4.1

He heats the block using a 50 W electrical heater. Using the value for aluminium from a data book, he predicts the time to heat the block from 20 °C to 30 °C, to be 3.1 minutes. He heats the block for this time but finds that the temperature of the block continues to rise after he switches the heater off. He also finds that the highest temperature reached is only 9.1 °C.

Explain his observations and why he does not obtain the data book value of 920 J kg^{-1} K^{-1}.

[4]

[Total: 14]

Candidate style answer	*Examiners commentary*
Heat is conducted through the aluminium from the heater to the thermometer. It takes time for the heat to reach the thermometer so there is a delay between switching off and the thermometer reaching its final temperature. Not all of the energy goes towards the thermometer so the	In part (c) the answer to the first part of the observations is correct and scores two marks. However the idea of energy dissipation to the surroundings is not given so no further marks are awarded.

temperature there can never reach 30°C.	

Comments: The candidate scores 8/14 for this question.

5(a) State any two assumptions of the kinetic theory of gases.

[2]

Candidate style answer	*Examiners commentary*
There are a very large number of atoms moving randomly so that statistical analysis can be applied.	Part (a) gains both marks.

(b) The atoms on the surface of a hot star may be treated as an ideal gas. Ideal gases obey the kinetic theory of gases. The interior of a particular star has a core temperature of 10^9 K and its surface temperature is 4000 K. For the hydrogen atoms of this star, calculate the ratio:

$$\text{ratio} = \frac{\text{average speed of atoms in the core}}{\text{average speed of atoms on the surface}}$$

[2]

Candidate style answer	*Examiners commentary*
the kinetic energy of the atoms is proportional to the temperature and the kinetic energy is related to the speed so the ratio = $10^9/4000 = 2.5 \times 10^5$ *ratio = ... 2.5×10^5.*	Part (b) is awarded one mark for stating that k.e. is proportional to absolute temperature.

(c) Suggest why the hydrogen atoms on the surface of the star do not all have the same speed.

[1]

Candidate style answer	*Examiners commentary*
because they are not all at the same temperature. There are hot spots on the surface of a star	Part (c) is a good idea but fails because the stem of the question states that the surface is to be considered as an ideal gas so the answer does not gain the mark.

(d) The emission spectrum of hydrogen gas atoms shows a strong red light of wavelength 656.3 nm. The motion of the atoms on the surface of the star in (b) causes *spectral broadening* of this line due to an effect known as the Doppler effect. The wavelength of light become longer when the hydrogen atoms on the surface of the star are moving away from our line of sight and shorter when they are moving towards us. This wavelength λ of the spectral line is broadened by an amount Δλ. Astronomers use the equation below to determine the surface temperature *T* in kelvins (K) of a star:

$$\frac{\Delta\lambda}{\lambda} = \sqrt{\frac{2kT}{mc^2}}$$

where *k* is the Boltzmann factor, *m* is the mass of the hydrogen atom and *c* is the speed of light in a vacuum.

(i) Calculate the spectral broadening Δλ for the 656.3 nm line emitted from the star in <u>(b).</u>

[2]

Candidate style answer	*Examiners commentary*

$\Delta\lambda = 656 \times \sqrt{(2\times1.38\times10^{-23} \times 4000 / 1.67 \times10^{-27} \times9.0\times10^{16})}$ $\Delta\lambda = 1.8 \times 10^{-2}$ $\Delta\lambda =$ 1.8×10^{-2}....................nm	The substitution of figures into the formula in part (d) (i) is completed successfully so is awarded both marks.

(ii) Suggest why the spectral lines from heavier atoms, such as carbon, show very little broadening. **[8]** **Paper Total [60]**	
Candidate style answer	*Examiners commentary*
A carbon atom has a bigger mass than a hydrogen atom.	The answer for (ii) is not sufficient to gain the mark – reference must be made to the equation.
Comments: The candidate is awarded 5/8 marks for this question. The total score for the paper is 36/60 which is 60%; which is a good middle grade. The candidate has shown a reasonable knowledge of the topics covered on this paper. Marks have been lost both through lack of examination technique and some errors in understanding of the topics. The script shows some promise and with practice and application the candidate has potential to improve the grade on further papers.	