STUDENT NUMBER:

SURNAME:
(FAMILY NAME)

OTHER NAMES:

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

This paper and all materials issued must be returned at the end of the examination.
They are not to be removed from the exam centre.

68101 Foundations of Physics

Tuesday 17 June 2014, 2.00pm – 4.10pm

Examination Conditions:

It is your responsibility to fill out and complete your details in the space provided on all the examination material provided to you. Use the time before your examination to do so as you will not be allowed any extra time once the exam has ended.

You are **not** permitted to have on your desk or on your person any **unauthorised material**. This includes but not limited to:

- Mobile phones
- Smart watches
- Electronic devices
- Draft paper (unless provided)
- Textbooks (unless specified)
- Notes (unless specified)

You are **not** permitted to obtain assistance by improper means or ask for help from or give help to any other person.

You are **not** permitted to leave your seat (including to use the toilet):

- Until 90 mins has elapsed
- During the final 15 mins

During the examination **you must first seek permission** (by raising your hand) from a supervisor before:

- Leaving early (after 90 mins)
- Using the toilet
- Accessing your bag

Disciplinary action will be taken against you if you infringe university rules.

Time Allowed: 2 hours and 10 mins

Includes 10 minutes of reading time.

Reading time is for reading only. You are not permitted to write, calculate or mark your paper in any way during reading time.

This is a Closed Book exam

Unauthorised materials as specified in the examination conditions are not allowed.

Permitted materials for this exam:

- Calculators (non-programmable only)
- Ruler/pens/pencils

Materials provided for this exam:

- This examination paper
- Four (4) answer booklets (5-pages)

Students please note:

- You must answer each question in a separate booklet. Ignoring this may mean that your answer is not marked.
- You must write the subject information, your full name and your student number on each of the answer booklets. Failure to do this may result in your paper being lost or marks wrongly allocated.
- A formula sheet, which includes required formulae and other information, is attached to the paper.

Do not turn over or open your exam paper until instructed.

Rough work space

Do **not** write your answers on this page.

QUESTION 1

A group of students have conducted an experiment to determine the speed of sound at different temperatures. The relationship is assumed to be in the form $V = 0.6\ T_c + 331.4$, where T_c is the temperature in °C.

a) The students make a set of measurements and generate a set of data points with uncertainties, which they tabulate and plot. Their results are shown in the graph that is printed at the back of this paper. Use this graph, together with your knowledge of experimental physics, to complete the following tasks.

(i) Draw the line of best fit on the graph and determine your best value for the gradient and intercept of this line.

[4 marks]

(ii) Draw additional lines on the graph as you see fit and determine the uncertainty in the values in part (i)

[4 marks]

(iii) Based on your results, does the experiment conducted validate the assumed equation? Explain your reasoning.

[4 marks]

b) One of the students suggests leaving out the value for 1°C because they are concerned about a discontinuity in the graph.

(i) What would be your reasoned response to such a suggestion and how would such action affect the answer?

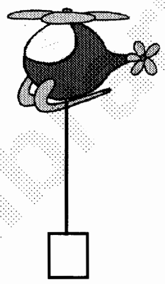
[2 marks]

(ii) Based on your experience in the laboratory over the semester, what are the three key characteristics of good, professional laboratory practice?

[6 marks]

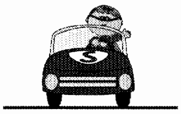
Tear out the graph page from the back of this exam paper, <u>write your name and student number</u> on it and insert it in the exam booklet for this question.

QUESTION 2



a) A National Parks helicopter is lifting a 320 kg package of gravel and sand to a remote site at the end of a cable. As it flies over a road, the helicopter's velocity is 12 m s^{-1}. At the instant it passes over the road, the cable breaks and the load starts to fall. The load takes 4.5 seconds to hit the ground.

(i) How high was the package above ground when it started to fall?
(ii) Neatly sketch the horizontal velocity and vertical velocity of the package as a function of time between the time of release and the time of impact. Label key points on your graph with numerical values.
(iii) What is the total kinetic energy of the package when it hits the ground?
(iv) What happens to this kinetic energy in the impact?
(v) How far is the package from the road when it impacts the ground?



[8 marks]

b) A 12 000 kg locomotive is observed, while pulling a set of carriages (total mass of carraiges 36 000 kg), to accelerate at 1.10 m s^{-1}. If the train was pulling half the number of carriages, and given that the locomotive generates the same overall driving force:
(i) What is the velocity of the train after 15 seconds if it starts from rest?
(ii) What is the force required to cause this acceleration?
(iii) What is the total momentum of the train after the 15 seconds have passed?

[5 marks]

c) Later, after settling at a constant velocity of 15 m s^{-1} the train then collides with a stationary locomotive on the track (mass 10 000 kg) and the combination continues along the track as a single unit.

(i) What is the velocity of the new combination?
(ii) What is meant by the terms elastic and inelastic when applied to collisions?
(iii) Is this collision elastic or inelastic?

[7 marks]

[Useful data: $g = 9.8\ m\ s^{-2}$]

QUESTION 3

a) The power output of a camping stove is measured by the manufacturer to be 840 watts. As an explorer heats her soup, 57% of this power is transferred to 400 g of soup which is initially
at 1 °C.

(i) How much energy is transferred to the soup each minute?

(ii) What will be the temperature of her soup after 7 minutes? State any assumptions you made in carrying out your calculations.

[8 marks]

b) On a particularly sunny Sydney day, the solar power per unit area incident on a solar cell is measured as 950 W m^{-2}. The solar cell has dimension 0.6 m × 1.2 m. A technician measures the power output of the solar cell in this situation to be 82 watts.

(i) What is the value of the efficiency of this solar cell (expressed as a percentage)?

[6 marks]

(ii) Suggest two reasons why organic solar cells might be preferred over silicon solar cells for converting the energy from the sun into electrical energy.

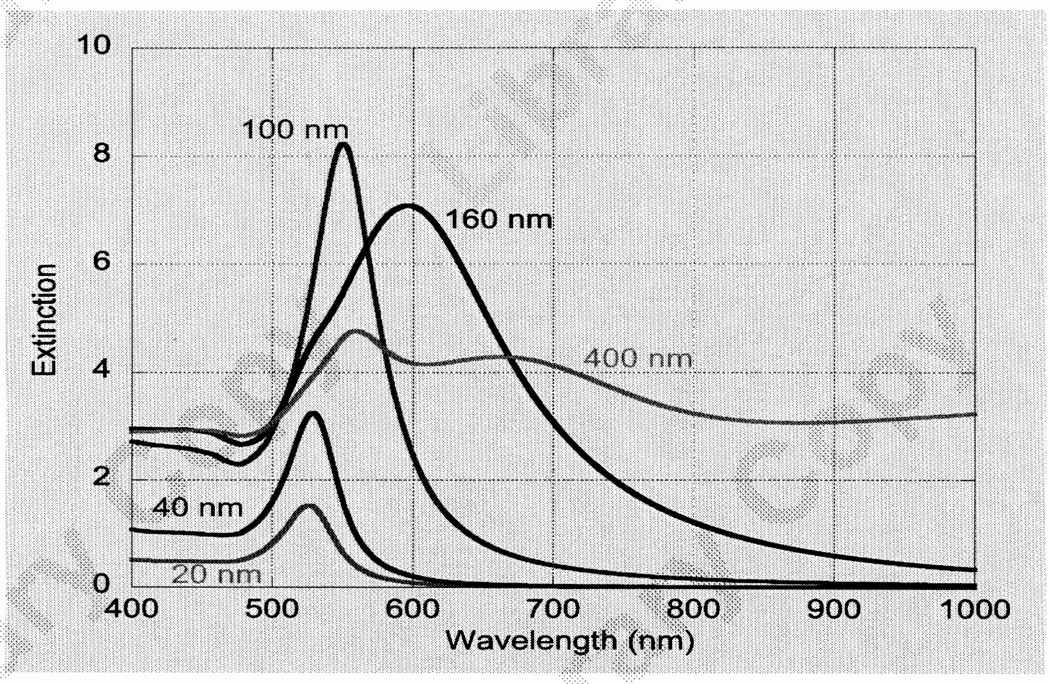
ii)

[6 marks]

[useful data: Specific heat capacity of water = 4190 J kg^{-1} $°C^{-1}$]

Question 4 [20 marks]

This figure shows the adsorption spectrum for gold nanoparticles, varying in size from 20 nm diameter to 400 nm, as a function of wavelength of the incident light. These adsorption spectra are examples of resonance curves.



Explain what you understand by the term 'resonance' and how resonance gives rise to these adsorption spectra.

[20 marks]

Guidelines and Instructions
For a pass level answer you could describe in qualitative terms your understanding of resonance and its manifestation in the adsorption curves. For a higher mark in this question you will need to demonstrate you understand the underlying mathematical description of resonance.

Your final answer needs to be less than one page.
Anything over one page will be ignored in the marking process.

Question 5 [20 marks]

a) Some gases can be treated as 'ideal'. What are the key features of the microscopic behaviour of a gas that result in it behaving in an 'ideal' way?

[4 marks]

b) An orbiting spacecraft initially has a habitable interior (Pressure=1 Atm; Temperature = 293 K) and is filled with air. A malfunctioning temperature regulation system results in the internal air temperature rising to 310 K. Assume that the air inside the spacecraft can be treated as an ideal gas:

i. What will happen to the pressure within the craft at this higher temperature?
ii. Calculate the new pressure within the spacecraft at this higher temperature.

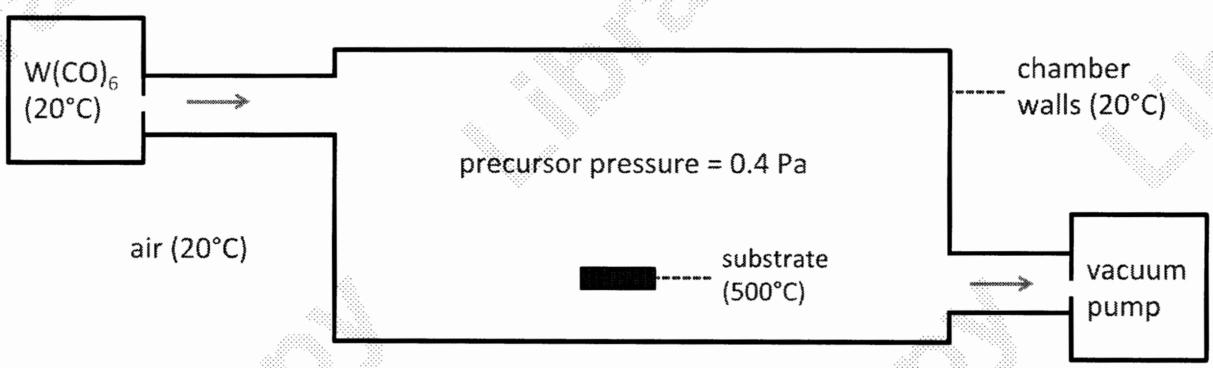
[4 marks]

c) The spacecraft then develops a pinhole leak resulting from a micro-meteor collision. If the air inside the spacecraft behaves as a real (non-ideal) gas:

i. Does the temperature of the air inside the craft increase, decrease, or stay the same as the air leaks from the craft?
ii. What happens to the temperature of the air from the spacecraft that escapes into space?
iii. Why does this change in the escaping air temperature occur?

[6 marks]

d) A chemical vapour deposition (CVD) system has an internal surface area of 1 m^2 and $W(CO)_6$ precursor gas is being used to deposit metallic tungsten (W) onto a heated tungsten substrate at 500°C. The chamber walls and the (ideal) precursor gas are at the laboratory temperature of 20°C. The system is operated so as to yield a constant pressure of 0.4 Pa inside the CVD chamber, as shown in the following diagram:



Assume that $W(CO)_6$ behaves like an ideal gas, and that the surface area of the substrate is much smaller than the internal surface area of the CVD chamber:

i. Calculate the force exerted onto the CVD chamber walls by the gas molecules.
ii. Calculate the average translational kinetic energy of a single precursor molecule.
iii. Sketch the speed distribution of the precursor molecules on a properly labelled diagram, and indicate the root-mean-squared, most probable and average speed of the precursor molecules.
iv. Calculate the root-mean-squared speed of the precursor molecules.
v. What are the applications that CVD systems like this can be used for?

[6 marks]

USEFUL FORMULAE

$$F = ma \qquad s = ut + \tfrac{1}{2}at^2 \qquad Q = mc\Delta T \qquad W = \int_{v_i}^{v_f} P\,dV$$

$$k.e. = \tfrac{1}{2}mv^2 \qquad v^2 = u^2 + 2as \qquad Q = -kA\frac{dT}{dx}$$

$$p.e. = mgh \qquad Q = mL_f$$

$$\tfrac{1}{2}m\overline{v^2} = \tfrac{3}{2}kT \qquad v_{rms} = \sqrt{\frac{3kT}{m}} \qquad c_p - c_v = R \qquad PV = nRT = NkT$$

$$\sum_{before} m_i v_i = \sum_{after} m_i v_i \qquad p = mv \qquad v = u + at \qquad W = nRT\ln(V/V_o)$$

$P=F/A$; $E = (3/2)kT$; $\kappa = \kappa_0 e^{-(E/kT)}$

$N_v = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/(2kT)}$; $f = P/(2\pi mkT)^{0.5}$

$Q = m\int_{T1}^{T2} c\,dT$; $\Pi = P/(kT)$; $\rho = \Pi m$

$$l = \frac{1}{\sqrt{2}\pi d^2 n_v}$$

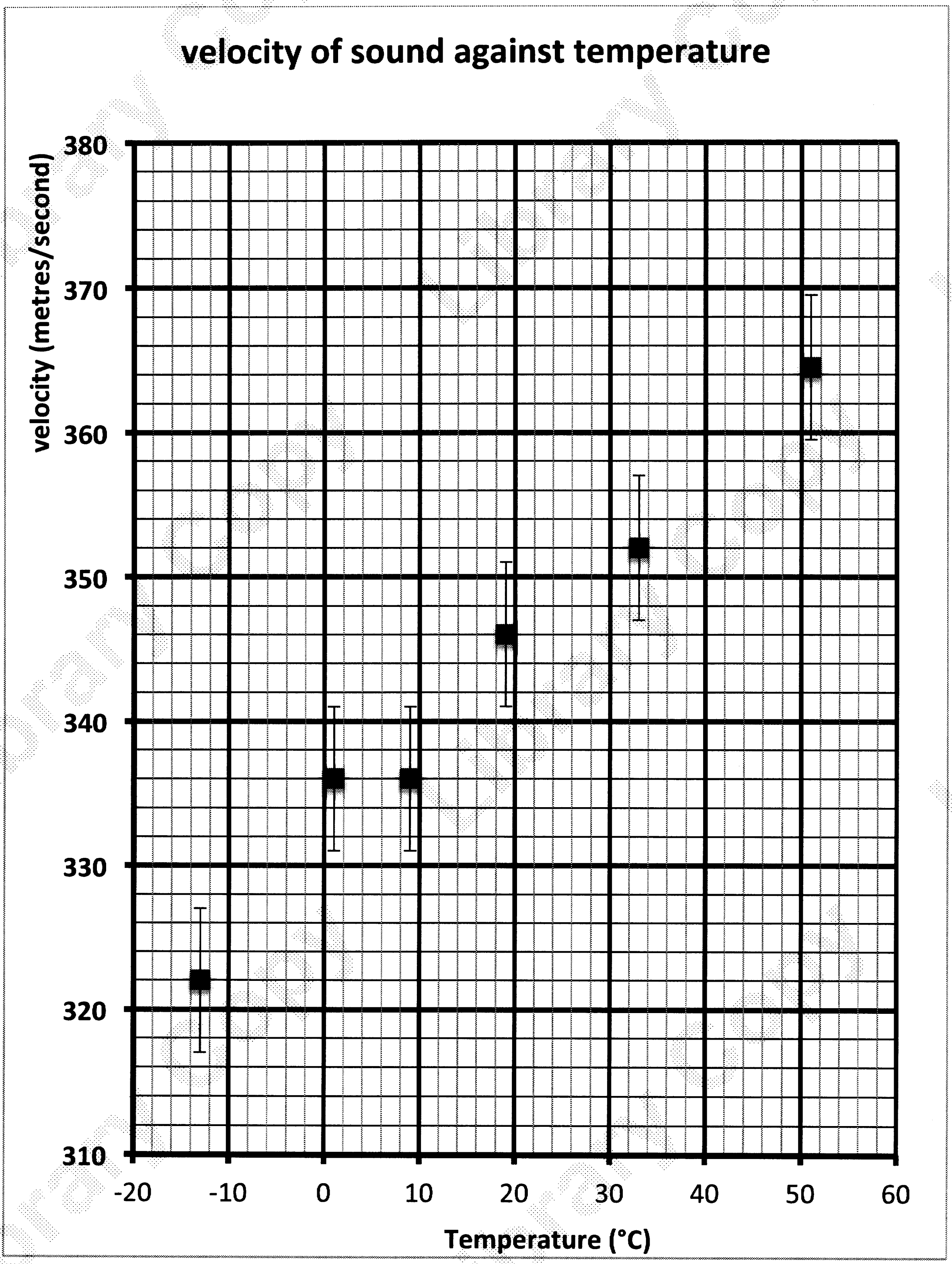
Constants

Charge of an electron: 1.602×10^{-19} C

Boltzmann's constant: 1.38066×10^{-23} JK^{-1}

Material properties:

- Mass of an aluminium atom: 4.48×10^{-26} kg
- Mass of a $W(CO)_6$ molecule: 5.84×10^{-25} kg
- Specific heat of aluminium: 900 J/kg/°C
- Specific heat of tungsten: 134 J/kg/°C
- Sublimation of a W atom from the substrate is characterized by an attempt frequency of 10^{13} Hz and a binding energy of 8 eV
- Approximate composition of air: 21% O_2, 78% N_2, 1% Ar



NAME:______________________________ STUDENT NUMBER:________________

TEAR OUT THIS PAGE AND PLACE IT IN THE BOOKLET FOR QUESTION 1