Autumn 2016 – **Main Exam**

UTS
UNIVERSITY OF TECHNOLOGY SYDNEY

SEAT NUMBER:

STUDENT NUMBER:

SURNAME:
(FAMILY NAME)

OTHER NAMES:

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.

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 and bands
- 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.

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

- Leaving early
- Using the toilet
- Accessing your bag

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

68101 Foundations of Physics

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

Please refer to the permitted materials below:

Permitted materials for this exam:

- Calculators (non-programmable only)
- Drawing instruments
  i.e. Rulers, Set Squares and Compasses

Materials provided for this exam:

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

Students please note:

- QUESTION ONE IS COMPULSORY
- ANSWER ONLY **THREE** QUESTIONS FROM QUESTION TWO – QUESTION FIVE
- 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 your answer booklets. Failure to do this may result in your answers being lost or marks wrongly allocated.
- A list of useful formulae and graph paper are provided at the end of the paper.

Do not open your exam paper until instructed.

Rough work space
Do **not** write your answers on this page.

QUESTION 1 [20 marks]
To be answered in a separate booklet

a) A biomedical physicist has developed a new tonometer, which is an instrument for measuring interocular pressure (the pressure of the liquid in a human eyeball). The data in the table below were collected to calibrate the new instrument. The interocular pressure for each of ten glaucoma patients was measured by the new instrument and by a standard, reliable, but more time-consuming method.

Patient	Pressure by Reliable Method (mmHg)	Pressure by New Tonometer (mmHg)
1	21.8	22.1
2	19.1	18.9
3	22.9	22.2
4	23.5	24.0
5	17.0	18.1
6	20.2	20.0
7	16.7	17.1
8	17.7	17.2
9	26.3	25.1
10	22.2	22.0

A sheet of graph paper is provided at the end of this exam paper for you to use in this question. Write your name and student number on it and insert it into your Question 1 exam booklet.

(i) Only the data from the first five patients have been included in the graph provided. Determine which axis corresponds to which column of data then add the data from the final five patients. Properly label the graph.

[3 marks]

(ii) Draw a line of best fit on the graph and determine the gradient and intercept of the line with the y-axis.

[3 marks]

(iii) Taking into account the uncertainty associated with individual measurements, draw additional lines on the graph as you see fit and determine the uncertainty in your values of gradient and y-intercept.

[3 marks]

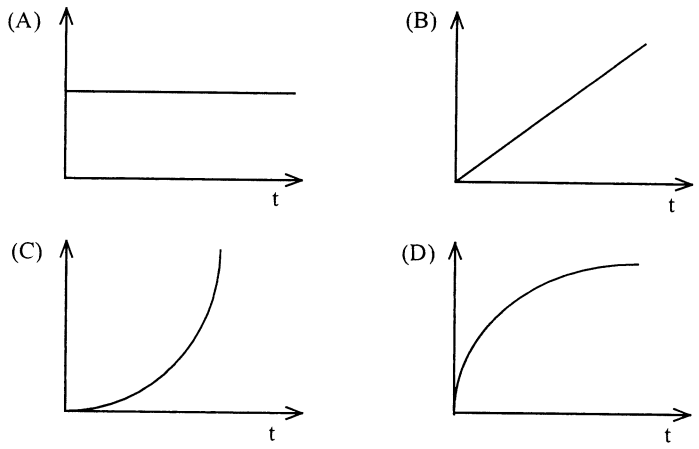
(iv) If the gradient is 0.87 ± 0.05 and the y-intercept is 2.6 ± 1.1 mmHg for a similar calibration graph, predict the pressure measured by the reliable method and its uncertainty when the new instrument gives a reading of 20.0 mmHg.

[3 marks]

b) Write the answers to the following questions in your exam booklet. Show working where appropriate.

(i) An object is falling under gravity. Which of the following graphs represents the variation of the object's distance with time?

[2 marks]



(ii) Which one of the following statements about heat is **not true**:

A. The SI unit of heat is the joule.
B. When heat is transferred to ice, the temperature of the ice always increases.
C. Heat flows from a body at high temperature to a body at low temperature.
D. Heat can travel through a vacuum.
E. When two bodies are in thermal equilibrium with each other, no net heat is transferred between them.

[2 marks]

(iii) Which one of the following statements is **true** in the field of thermodynamics?

A. Work done by a thermodynamic system is always accompanied by a change in volume.
B. An isothermal process is one in which gas pressure remains constant.
C. Heat and work are both state variables.
D. Energy can only be created but not destroyed by an isolated thermodynamic system.

[2 marks]

(iv) The period of a harmonic oscillator with mass m attached to a spring with a spring constant k, is T_1. What will the new period T_2 be if the value of the spring constant is doubled while the mass of the oscillator is halved?

A. $2T_1$
B. $T_1/4$
C. T_1
D. $T_1/2$

[2 marks]

[Question Total: 20 marks]

QUESTION 2 [20 marks]
To be answered in a separate booklet

a) A 3.1×10^5 kg plane starts at rest on a runway and takes off after 25 seconds having covered 900 metres.

(i) What is its acceleration (assuming it is constant)?

(ii) What is the plane's take-off velocity?

(iii) What is the force exerted by the engines as the plane travels along the runway?

[5 marks]

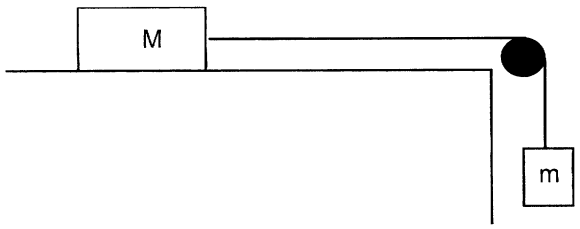
b) In the following diagram an object of mass m = 0.15 kg makes the object of mass M = 0.35 kg move with an acceleration is 0.60 ms^{-2}. The mass M experiences a frictional force from the table surface. The string does not stretch and the pulley is massless and frictionless.

(i) In your answer booklet draw the following diagram and put in ALL the forces acting on the two masses (including friction).

(ii) Complete these two equations in terms of the forces acting on each mass

$$0.15a =$$
$$0.35a =$$

(iii) Calculate the frictional force.



[6 marks]

c) A 0.90 m piece of string breaks if the tension exceeds 85 N. If a 0.6 kg object is attached to one end and swung in a circular path in a horizontal plane, calculate:

(i) the linear speed of the object when the string breaks

(ii) the angular speed of the object when the string breaks.

[3 marks]

d) A 5.1 g bullet travelling at 120 ms^{-1} is fired into a freely suspended 1.500 kg block of wood (as shown in the diagram). After the collision the bullet remains in the block of wood.

(i) Immediately after the collision what is the speed of the block of wood?

(ii) How far does the block rise when it swings (measured vertically)?

[4 marks]

e) What is the work done in moving an object with a force of 35 N applied at 30° to the displacement vector at a constant speed of 2 ms^{-1} for 6s?

[2 marks]

[Question Total: 20 marks]

QUESTION 3 [20 marks]
To be answered in a separate booklet

a)

(i) What is the net upward force on a plane wing of area 20.0 m^2 if the speed of the air across the top of the wing is 300 m/s and the speed of the air is 275 m/s across the bottom? Take the density of air to be 1.3 kg/m^3.

[2 marks]

(ii) Calculate the flow rate of blood in an aorta with a cross-sectional area of 2.0 cm^2 if the speed flow is 40 cm/s.

[2 marks]

(iii) What is the rate of heat flow from a human body due to radiation?

Use the data of the average human body: surface temperature is 33°C, surface area is 1.5 m^2, and emissivity is 0.95.

[2 marks]

(iv) 50 g of ice at −10°C is put into a glass of tea (volume 250 mL) at 80°C. Calculate the temperature of the tea after the transfer of heat from the tea to the ice has ceased. Ignore the effect of the glass and wider environment.

Useful data:
Specific heat capacity of water = 4186 J/(kg °C)
Specific heat capacity of ice = 2005 J/(kg°C)
Heat of fusion of water = 3.33×10^5 J/kg
Density of water = $1 g/cm^3$

[3 marks]

b) This is a Fermi type question for which there is no single 'correct answer'. We are much more interested in your methods than the numerical answer you arrive at.

If every home in Australia had solar cells on its roof, how much electrical energy would they generate over one day?

Useful data: on a sunny day with the sun overhead, the amount of solar energy striking the earth is about 1000 J/s.

To assist you to answer this question please consider

(i) What physical principles are you going to apply, and/or what information do you need? (Write these down.)

[2 marks]

(ii) What values or equations do you already know that will help you solve the problem? (Write these down.)

[2 marks]

(iii) What assumptions have you made? (Write these down.)

[2 marks]

(iv) What have you guessed or estimated? (Categorise your confidence in the guesses/estimates as poor, moderate or high.)

[2 marks]

(v) Show your calculations.

[2 marks]

(vi) What is your answer?

[1 mark]

[Question Total: 20 marks]

QUESTION 4 [20 marks]
To be answered in a separate booklet

a) What is the "number density" of gas molecules? What are the units of this quantity?

[2 marks]

b) Consider a container filled with an ideal gas. If the temperature of the gas is increased so as to double the gas molecule flux, what happens to the pressure of the gas?

[2 marks]

c) Consider a container filled with an ideal gas. Which one of the following statements is **true**?

(i) The gas molecules interact only through attractive forces.

(ii) All collisions are inelastic.

(iii) The gas molecules slow down as a result of molecule-molecule collisions.

(iv) Momentum and energy of the gas molecules are conserved, but the angular momentum is always zero.

[2 marks]

d) Consider a container filled with helium that is heated from an initial temperature T_1 to a final temperature T_2, whereby: $T_2 = 4T_1$. The initial and final mean velocities of gas molecules that make up the gas are given by v_1 and v_2, respectively. Given that $v_1 = 400$ m/s, and the mass of a helium atom is 6.65×10^{-27} kg, calculate:

(i) The final velocity v_2.

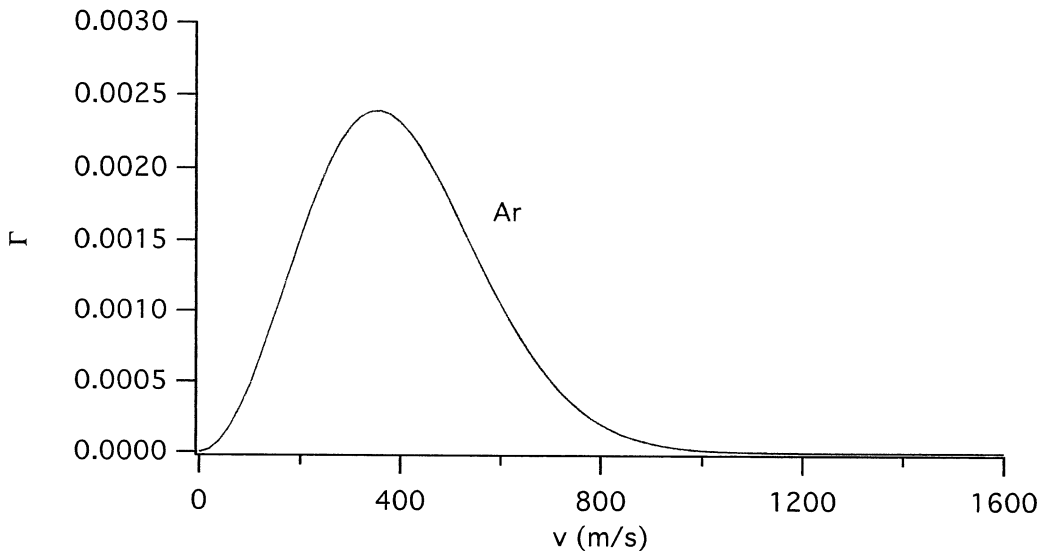
(ii) The initial temperature T_1.

[4 marks]

e) Consider water vapour leaking out of a spacecraft into space. Explain why the vapour cools as it expands into vacuum.

[2 marks]

f) Consider the probability density function for Argon shown below:



(i) Write down the Maxwell-Boltzmann distribution function, and use the equation to explain what causes $f(v)$ to initially increase and then decrease as v is increased from 0 to 1000 m/s.

(ii) Sketch the above probability density function in your answer booklet. On the same graph, sketch the function for the same gas after the gas pressure was increased by a factor of two.

(iii) Sketch the above probability density function again in your answer booklet a second time. On the same graph, sketch the function for a hypothetical gas that has a molecular mass that is half that of Argon.

[8 marks]

[Question Total: 20 marks]

QUESTION 5 [20 marks]
To be answered in a separate booklet

a) Answer the following-multiple choice questions by writing your answers in your Question 5 answer booklet.

(i) If the wavelength λ of a sound wave triples what will its frequency be, provided the initial frequency was f?

A. $3f$
B. $f/3$
C. $9f$
D. $f/9$

[1 mark]

(ii) The term 'diffraction' refers to

A. Superposition of two or more waves.
B. Reflection of a wave.
C. Standing wave.
D. Deviation of a wave from straight propagation.

[1 mark]

(iii) A point object rotates 5m from a centre with a constant angular velocity ω. What will its linear velocity be if the radius of rotation is doubled?

A. 2.5 ω
B. 5 ω
C. 10 ω
D. 20 ω

[1 mark]

(iv) The wave number, k, of a plane wave is doubled. What is its wavelength now?

A. The wavelength is doubled.
B. The wavelength is halved.
C. The wavelength is quadrupled.
D. None of the above.

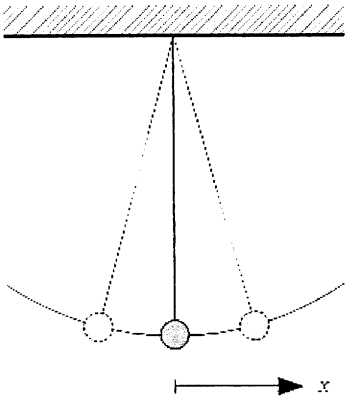
[1 mark]

(v) If the period, T, of a harmonic oscillation is halved what will the maximum magnitude of its acceleration be, if the initial magnitude of the acceleration was a? (It is assumed the amplitude of the oscillations remains the same.)

A. $2a$
B. $a/2$
C. $a/4$
D. $4a$

[1 mark]

b) A pendulum consists of a 2 kg mass attached to a string with length L (as shown below). The mass approximately undergoes simple harmonic motion described by the equation $x(t) = B\sin(\omega t + \varphi)$. The amplitude of the oscillations is 10 cm and its angular velocity is $\omega = \pi$ rad/s. The velocity of the mass is zero at $x = 0.1$ m when $t = 0$ s.



Use the above information to answer the following questions:

(i) What are the period and frequency of the motion?

[1 mark]

(ii) What is the displacement of the mass when $t = 5.0$ s?

[1 mark]

(iii) What is the length of the string?

[1 mark]

(iv) At what time does the maximum acceleration first occur for $t > 0$ s?

[1 mark]

(v) What is the total mechanical energy of the oscillator?

[1 mark]

(vi) What will the period be if the mass is doubled?

[1 mark]

(vii) What is the magnitude and direction of the velocity of the mass when $t = 7.0$ s?

[1 mark]

c) The counter propagation of two waves is given by the equation

$$f(x,t) = A\sin(kx - \omega t) + A\sin(kx + \omega t - \varphi).$$

(i) Find the value of the phase constant, φ, from the range $-\pi < \varphi < \pi$ if the nodes of the resulting standing wave are at $x = \frac{n\lambda}{2}$ where $n = 0, 1, 2, \ldots$

[4 marks]

(ii) If $\varphi = \frac{\pi}{4}$ find the positions of the nodes of the resulting standing wave.

[4 marks]

[Question Total: 20 marks]

USEFUL FORMULAE

$v = \frac{dx}{dt}$ $a = \frac{dv}{dt}$ $v = u + at$ $v^2 = u + 2as$ $s = ut + \frac{1}{2}at^2$

$p = mv$ $F = ma$ $F \leq \mu N$ $W = Fd\cos\theta$ $P = \frac{W}{t}$

$PE = mgh$ $KE = \frac{1}{2}mv^2$ $F\Delta t = \Delta p$ $F = \frac{mv^2}{R} = mR\omega^2$

$P = \frac{F}{A}$ $P = P_0 + \rho gh$ $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$ $Q = Av$

$Q = mc\Delta T$ $Q = mL$ $\frac{Q}{t} = kA\left(\frac{T_H - T_C}{l}\right)$ $\frac{Q}{t} = \varepsilon\sigma A(T^4 - T_S^4)$ $W = \int_{V_i}^{V_f} P\, dV$

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

$\sum m_i v_i = \sum m_f v_f$ $W = nRT\ln\left(\frac{V}{V_0}\right)$ $E = \frac{3}{2}kT$ $\kappa = \kappa_0 e^{-(E/kT)}$

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

$Q = m\int_{T_1}^{T_2} c\, dT$ $\Pi = P/(kT)$ $\rho = \Pi m$ $l = \frac{1}{\sqrt{2}\pi d^2 n_v}$

$\omega^2 = \frac{k}{m}$ $T = \frac{2\pi}{\omega}$ $v = f\lambda$ $U = \frac{1}{2}kx^2$ $F = -kx$

Physical Constants
Charge of an electron: 1.602×10^{-19} C
Boltzmann's constant: 1.38066×10^{-23} JK^{-1}
Stefan-Boltzmann constant: 5.670×10^{-8} $Wm^{-2}K^{-4}$

Student Number: _____
Surname: _____
Other Names: _____