Cover Type A

University of Technology, Sydney

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AUTUMN SEMESTER EXAMINATION, 2006
FACULTY OF SCIENCE

SUBJECT NAME: Foundations of Physics

SUBJECT NO.: 68101

DAY/DATE: Friday 16th June, 2006

TIME ALLOWED: 3 hours + 10 minutes reading time

START/END TIME: 9:30 am – 12:40 pm

Instructions to Candidates:

This paper was designed to be completed in 3 hours. An extra 10 minutes have been added to the time allowed and it is recommended that you use these 10 minutes to read the paper before commencing to answer the questions.

THERE ARE 7 QUESTIONS IN THIS PAPER

ATTEMPT QUESTION 1 AND ANY OTHER FIVE (5) QUESTIONS

ANSWER EACH QUESTION IN A SEPARATE BOOKLET

CLEARLY MARK THE QUESTION NUMBER ON THE FRONT OF EACH BOOKLET

Calculators may be used. Any text or formulae stored in your calculator must have been removed before entering the examination room.

A *Physics Data Sheet* is provided on the next page.

Formula sheets and graph paper are provided at the end of the examination paper.

Physics Data Sheet

$$g = 9.81\ \mathrm{m{\cdot}s^{-2}}$$

$$\sigma = 5.670\times 10^{-8}\ \mathrm{W{\cdot}m^{-2}K^{-4}}$$

$$R = 8.314\ \mathrm{J{\cdot}mole^{-1}\,K^{-1}}$$

$$N_A = 6.022\times 10^{23}\ \mathrm{molecules{\cdot}mole^{-1}}$$

$$k_B = 1.381\times 10^{-23}\ \mathrm{J{\cdot}K^{-1}\ molecule^{-1}}$$

$$c = 3.00\times 10^{8}\ \mathrm{m{\cdot}s^{-1}}$$

$$h = 6.626\times 10^{-34}\ \mathrm{J{\cdot}s}$$

$$I_0 = 1.0\times 10^{-12}\ \mathrm{W{\cdot}m^{-2}}$$

$$\varepsilon_0 = 8.854\times 10^{-12}\ \mathrm{F{\cdot}m^{-1}}$$

$$\frac{1}{4\pi\varepsilon_0} = 9\times 10^{9}\ \mathrm{N{\cdot}m^2/C^2}$$

$$\mu_0 = 4\pi\times 10^{-7}\ \mathrm{H{\cdot}m^{-1}}$$

$$e = 1.602\times 10^{-19}\ \mathrm{C}$$

$$m_e = 9.110\times 10^{-31}\ \mathrm{kg} = 0.00055\ \mathrm{u}$$

$$m_p = 1.673\times 10^{-27}\ \mathrm{kg} = 1.00728\ \mathrm{u}$$

$$m_n = 1.675\times 10^{-27}\ \mathrm{kg} = 1.00866\ \mathrm{u}$$

$$1\mathrm{u} = 1.661\times 10^{-27}\ \mathrm{kg}$$

$$G = 6.673\times 10^{-11}\ \mathrm{m^2\,N{\cdot}kg^{-2}}$$

Rydberg's constant = $1.097\times 10^{7}\ \mathrm{m^{-1}}$

Temperature of Ice Point = 273.15 K

1 atmosphere = 1.013×10^{5} Pa

Mass of Earth = 5.974×10^{24} kg

Radius of Earth = 6.37×10^{6} m

1 curie = 3.70×10^{10} becquerel

SECTION A

THIS QUESTION IS COMPULSORY

(Answer this question in a separate booklet)

Question 1 (20 marks)

Write the answers to the following multiple choice questions in your examination booklet. Show all working where appropriate

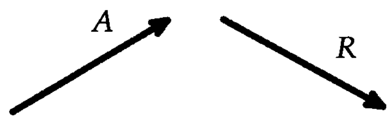
(a) i. Multiplying the experimentally-determined values 43.0 and 2 437 on a calculator gives 104 791. Expressed to the correct number of significant figures, this result should best be written as:

A. 1.04791×10^5
B. 1.0479×10^5
C. 1.048×10^5
D. 1.05×10^5 [1]

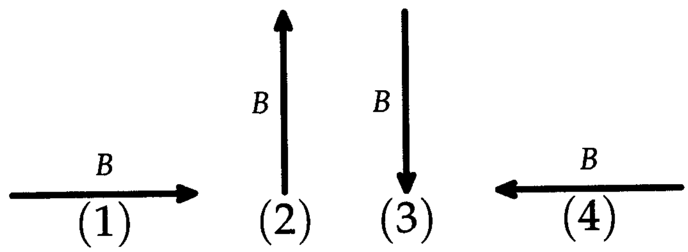
ii. A 0.150 kg blue ball is thrown horizontally at a speed of 4 m/s from a height of 3 m. A 0.300 kg yellow ball is thrown horizontally from the same height at a speed of 8 m/s. It takes the blue ball T seconds to reach the ground. How many seconds does it take the yellow ball to reach the ground? [1]

A. $\frac{1}{2}T$
B. T
C. $2T$
D. $4T$

iii. Forces $\vec{A}$ and $\vec{B}$ produce a resultant force $\vec{R}$. $\vec{A}$ and $\vec{R}$ are shown below.



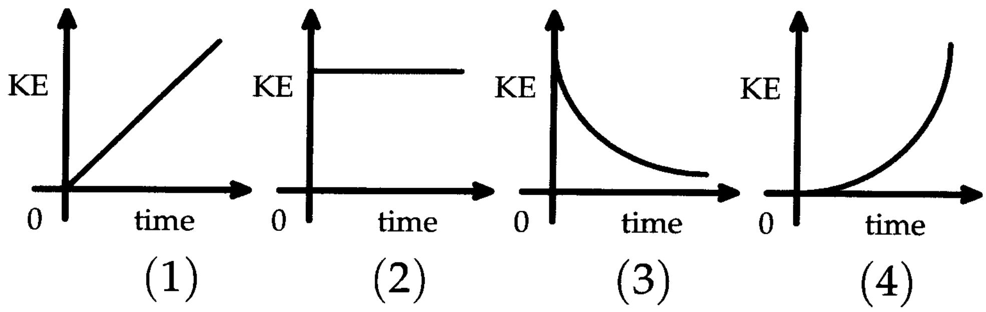
Which of the following vectors best represents force $\vec{B}$? [1]



A. 1
B. 2
C. 3
D. 4

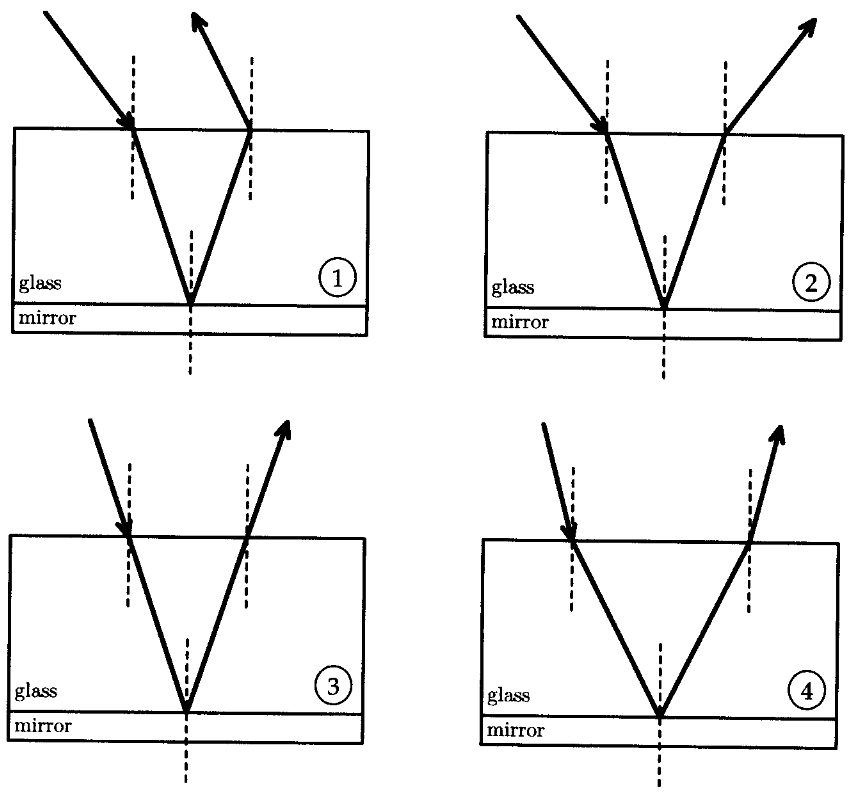
Q1 continues on next page ...

iv. An object is accelerating in one dimension. Which of the following sketches best represents its kinetic energy as a function of time? [1]



A. 1
B. 2
C. 3
D. 4

v. A beam of monochromatic light travelling in air ($n = 1$) enters a block of glass ($n > 1$) and strikes the reflecting surface of a plane mirror at the bottom. The light then travels back through the glass and emerges from the glass-air interface. Four possible diagrams for the path of the light through the glass are shown below.

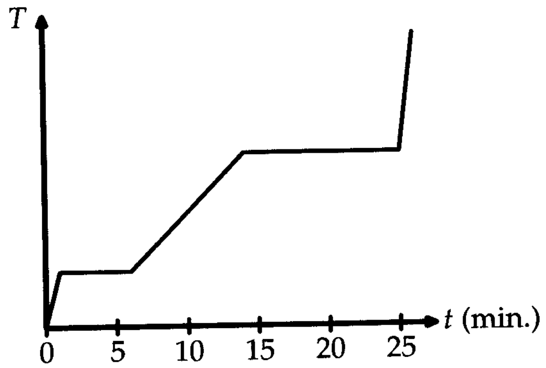


The diagram which best describes the path of the light is: [1]

A. 1
B. 2
C. 3
D. 4

Q1 continues on next page ...

vi. A 400 g sample of a pure compound (which can exist in one solid phase, the liquid phase and the vapour phase) is placed in a closed, well-insulated container. The container is then heated at a constant rate. The sample temperature is monitored, producing the results plotted below.



Which one of the following conclusions is justified from this plot? [1]

A. After 20 minutes the sample was a mixture of liquid and gas.
B. The sample was initially liquid.
C. The heat capacity of the solid phase was greater than that of the liquid phase.
D. The heat of fusion is greater than the heat of vapourisation.

vii. When a certain guitar string is plucked, the vibrations produce a sound wave with a frequency of 650 Hz. This sound wave is: [1]

A. a longitudinal wave of constant frequency
B. a transverse wave of constant amplitude
C. a mechanical wave of varying frequency
D. an electromagnetic wave of varying wavelengths.

viii. The magnitude of the buoyancy force on a submarine in the ocean is equal to: [1]

A. the weight of the sea water displaced by the submarine
B. the weight of the submarine
C. the product of the volume of the submarine and the density of the water surrounding the submarine
D. the density of the water displaced by the submarine.

Q1 continues on next page ...

(b) Some students are conducting an experiment on heat transfer through a material whose thermal properties are unknown. They are aware of the thermal conduction equation,

$$H = \frac{dQ}{dt} = kA\frac{dT}{dx}.$$

A heater supplying energy at a constant rate of 170 ± 0.5 mW is available. They cut off 8 different lengths of the material, each with the same cross-sectional area $A = 25.0 \pm 0.1\,\mathrm{mm}^2$, and measure the temperature difference across their ends. Their results are tabulated below.

Sample	Length ±20 mm	Temperature difference ±1°C
1	100	15
2	150	25
3	200	30
4	300	60
5	400	65
6	500	75
7	600	89
8	700	105

i. Rearrange the equation above to describe the expected temperature difference as a function of the length of sample. [½]

ii. Use one of the readings to obtain an estimate of the likely value of k for the material (and its units); do not calculate the uncertainty in this estimate. [½]

iii. Remembering their practical classes, the students decide to use a graphical method to find k, rather than a simple calculation as in part (ii). Why is this a preferred experimental technique? [1]

iv. Tear off the sheet of graph paper provided on page 17 of this examination paper, and on it plot an appropriate graph to determine k.
Don't forget to write your name on the graph paper and to include it inside your Q1 answer booklet. [3]

v. Using the graph, estimate the value of k and its uncertainty. [2]

vi. To identify the unknown material, the students consult a table of k values for different materials, as shown below.

Material	Fe	Steel	Al	Cu	Ag	Au	Pt	Brass
k (J/(kg K))	73	46	210	386	406	293	70	85

What conclusion about the material are they justified in making? Explain. [1]

(c) Discuss briefly (in no more than one page of writing) the 'Special Topic' that was presented by a guest lecturer this semester. Explain in your answer what synchrotrons are and how they work, and also give two specific examples of how they might be used to benefit humankind. [4]

Total Q1= 20

SECTION B

ANSWER ANY FIVE (5) OF THE SIX (6) QUESTIONS IN THIS SECTION
(Answer each question in a separate booklet)

Question 2 (20 marks)

(a) In the following equation:

$$F = -2\pi r L \frac{v}{D} \eta$$

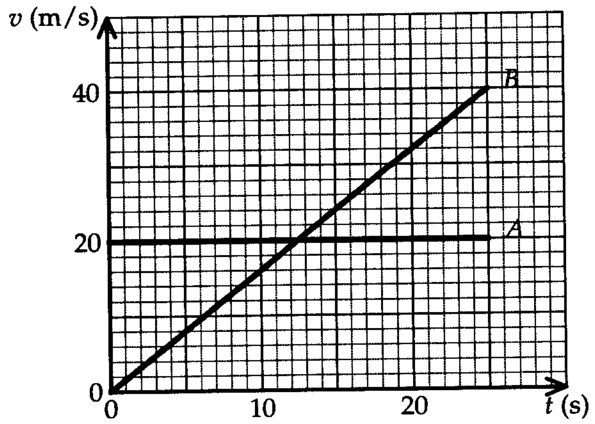
F = force, r = radius, L = length, v = speed and D = distance.

i. Find the dimensions of η that would make this equation dimensionally consistent. [2]

ii. What are the SI units of η in this equation? [1]

(b) You have been asked to act as a consultant on a project to build a new runway for an airport. After some research, you conclude that the lowest rate of acceleration of the aeroplanes using the runway is likely to be $3\,\text{m/s}^2$ and that the takeoff speed for such planes should be at least 234 kph. What is the minimum length for the runway? [3]

(c) The graph below shows two cars, A and B, travelling north on the Pacific Highway in adjacent lanes. One car has just finished a "stop, revive, survive" (rest) break.



i. The cars are side-by-side at time $t = 0$. Which car will initially take the lead? Justify your answer. [1]

ii. What is the acceleration of car B? [1]

iii. At what time will the two cars once again be side-by-side? [1]

iv. What will be the speed of each car at the instant when they pass each other? [1]

v. How far have the cars travelled when they are side-by-side for the second time? [1]

vi. In your answer booklet, sketch a position–time graph for each car in the time interval $0 \leq t \leq 20\,\text{s}$. [1]
[1]

Q2 continues on next page ...

(d) You are a passenger in a car which is driving at 80 kph through very heavy rain. You notice that the rain is sweeping past the side window, making an angle of 25° to the horizontal. Before getting into the car you observed that there was no wind and the rain was falling vertically.

i. Write a vector equation relating the three quantities $\vec{V}_{RE}$, $\vec{V}_{RC}$ and $\vec{V}_{CE}$. [***Hint***: the following abbreviations have been used: E = Earth, C = Car, and R = Rain; thus, $\vec{V}_{RC}$ (for example) is read as "the velocity of the rain relative to the car".] [1]

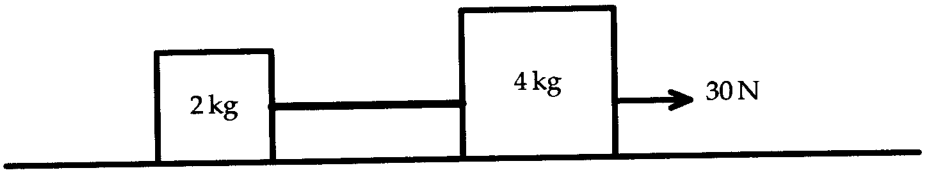
ii. Find the speed of the raindrops. [3]

Total Q2= 20

Question 3 (20 marks)

(a) State Newton's third law of motion and give two examples of its occurrence from your own everyday experience. [3]

(b) Two blocks, joined together by a rope of negligible mass, are initially at rest on a frictionless surface. One of the blocks is then pulled with a force of 30 N, as shown below.



i. Calculate the speed of the blocks after the force has been applied for 2.0 s. [2]

ii. Calculate the tension in the rope joining the blocks while they are being pulled across the smooth surface. [1]

After being pulled for some time, the blocks move onto a rough surface which exerts a frictional force. It is observed that on this surface the blocks move with an acceleration of $1.5\,m/s^2$ while the 30 N force is applied.

iii. Calculate the coefficient of kinetic friction between the blocks and the rough surface. [3]

After some time being pulled across the rough surface, the connecting rope between the blocks suddenly breaks.

iv. Calculate the new acceleration of the smaller block. [1]

(c) i. A 4 N force acts for 10 s on a 2 kg object initially moving at 8 m/s.

α) What impulse does the object experience? [1]

β) What is the object's final speed? [1]

γ) Briefly explain, using the concept of *impulse*, how air bags work to reduce injuries in car accidents. [1]

ii. A 1 300 kg car traveling north at 27 m/s collides with a 2 100 kg car moving east at 17 m/s. As a result of the collision, the two cars stick together. What is their *velocity* after the collision? [3]

(d) A golf ball is tied to a 75 cm length of string. It is then whirled in a horizontal circular path with an angular speed of 1.5 rev/s. The angle the string makes with the vertical is θ degrees.

i. Draw a free-body diagram for the golf ball. [1]

ii. Determine the value of θ. [3]

Total Q3= 20

Question 4 (20 marks)

(a) A 2 m rod is made up of a 1.2 m length of aluminium joined to a 0.8 m length of copper, measured at 20°C. What is the length of this rod when it is heated to a temperature of 600°C? [5]

Data: Coefficient of linear expansion for aluminium $= 2.4 \times 10^{-5}\,\text{K}^{-1}$

Coefficient of linear expansion for copper $= 2.0 \times 10^{-5}\,\text{K}^{-1}$

(b) An unknown solid of mass 400 g is dropped into a 200 g copper beaker containing 1.4 litres of water at a temperature of 90°C. All of the unknown solid melts and the final temperature of the mixture is observed to be 50°C. What is the heat of fusion of this solid? [5]

Data: Specific heat of copper $= 390\,\text{J}/(\text{kg K})$

Specific heat of water $= 4\,190\,\text{J}/(\text{kg K})$

(c) Typically, a traditional double brick house has walls made up of two separate brick layers with an air cavity between them. A modern brick veneer house, on the other hand, has a single brick wall with an interior cladding such as wood, and an air-filled cavity between these two layers. The two types of construction are shown in cross-section below.

Assume the brick walls are 8 cm thick, the air cavity is 12 cm thick and the wood cladding is 1.5 cm thick. Using the data provided below, determine which type of construction allows for the least loss of heat by conduction. [5]

Data: Thermal conductivity of brick $= 0.600\,\text{W}/(\text{m K})$

Thermal conductivity of air $= 0.024\,\text{W}/(\text{m K})$

Thermal conductivity of wood $= 0.08\,\text{W}/(\text{m K})$

(d) The human body can be likened to a cylinder with a total surface area of $1.8\,\text{m}^2$ and an emissivity of 0.98. The surface temperature of a healthy adult is 30°C. Determine the amount of energy the human body would have to generate to maintain this temperature in an environment at 0°C. [5]

Total Q4= 20

Question 5 (20 marks)

(a) A 4 litre tank holds helium gas at $T = 60°C$ and $P = 1\,\text{atm}$. The molar mass of helium is 4.0 g.

i. Determine the number of moles of helium in the tank. [1]

ii. How many molecules of helium are in the tank? [1]

iii. If the temperature is increased to 120°C and the volume is increased to 5 litres, what will be the pressure of the gas in the tank? [3]

iv. At 120°C, what is the internal energy of the helium? [2]

v. At 120°C, what is the rms velocity of a helium molecule? [2]

(b) A mass of 2.5 kg is suspended at the end of a vertical spring which has $k = 40\,\text{N/m}$. The mass is then extended a distance 0.6 m beyond its equilibrium position and released, allowing it to oscillate. If the maximum velocity of the mass is 0.8 m/s, determine the equation of the wave that describes this oscillation. [4]

(c) The equation of a transverse wave on a wire is given by

$$y(x,t) = 2.4\cos(6.0x + 4.0t) \qquad \text{(all lengths are in mm)}$$

i. Find the amplitude, period, frequency, wavelength and speed of propagation of the wave. [2½]

ii. The mass per unit length of the wire is 0.060 kg/m. What is the tension in the string? [1]

iii. What is the average power of this wave? [1]

iv. What is the intensity of this wave if it is transmitted through air as sound? [1½]

Data: Density of air at room temperature = $1.20\,\text{kg/m}^3$)

v. What is the decibel level of this sound? [1]

Total Q5= 20

Question 6 (20 marks)

(a) Light of wavelength 540 nm (as measured in air) is travelling down a glass tube which has a refractive index of 1.42. The glass tube has a thin clear plastic coating which has a refractive index of 1.24. Determine:

i. The frequency of the light in the glass tube [1]

ii. The velocity of light in the glass tube [1]

iii. The wavelength of the light in the glass tube [1]

iv. The critical angle at the glass-plastic interface for the light in the glass tube [2]

(b) An object is located 25 cm from a converging lens of focal length 20 cm.

i. Sketch a ray diagram showing the formation of the image by this lens. [2]

ii. Determine the location, magnification and type of image formed. [3]

(c) Light travels through two lenses which are separated by a distance of 10 cm. The first is a converging lens with a focal length of 20 cm and the second is a diverging lens with a focal length of -15 cm. Determine the location, magnification and type of image formed by this lens system. [5]

(d) An object is 12 m from a camera. The camera lens has a focal length of 40 mm and a maximum aperture of 20 mm. If the resolution of this camera is limited by diffraction only, what is the minimum distance between two points that can just be resolved on the image formed by the camera? (Assume the wavelength of light is 500 nm.) [5]

Total Q6= 20

Question 7 (20 marks)

(a) A brass wire and a copper wire are both 0.5000 m long and 1.00 mm in diameter. They are somehow connected to form a 1.0000 m single wire. The free end of the brass wire is secured to the ceiling, while the free end of the copper wire has an unknown weight suspended from it. This results in a total length change of 0.500 mm. Young's modulus for brass is 1.30×10^{11} Pa and for copper it is 1.00×10^{11} Pa.

Calculate how much each wire stretches. [4]

(b) i. State Archimedes' Principle. [1]

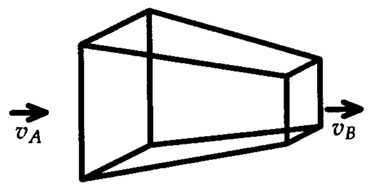
ii. A pressure sensor (gauge) is used to measure the hydrostatic pressure on the sea bed of a tidal estuary (where a river meets the sea). The water in the estuary is stratified (layered) at the point where the measurement is taken, with fresh water ($\rho_{FW} = 1\,000\,\mathrm{kg/m^3}$) overlying salt water ($\rho_{SW} = 1\,025\,\mathrm{kg/m^3}$). Water sampling shows that the fresh water extends from the surface to a depth of 2.6 m. If the sensor indicates a gauge pressure of 7.850×10^4 Pa, how deep is the layer of salt water? [3]

iii. A natural gas pipeline is to be laid on the sea floor. The weight of the pipe is 2 400 N per metre length, and its outside diameter is 1.0 m. The weight of the gas can be ignored. The density of sea water is $1\,025\,\mathrm{kg/m^3}$.

α) Draw a free-body diagram for a length of the pipe. [1]

β) Determine whether the pipe will remain on the sea bed or float. If it floats, what force would be required to hold the pipe on the sea bed? If it does not float, what new diameter would cause it to float, assuming the weight per metre does not change? [3]

(c) Water at room temperature and pressure flows steadily through the square cross-section nozzle shown below. At the wider (inlet) end, A, the water velocity is $v_A = 3.0\,\mathrm{m/s}$ and at the narrower (outlet) end, B, it is $v_B\,\mathrm{m/s}$. At the inlet the side length is 2.0 cm, while at the outlet it is 1.0 cm.



i. What is the volumetric flow rate at the outlet, Q, stated in SI units? [1]

ii. Determine V_B. [2]

(d) i. State Bernouilli's equation. [1]

ii. The water pipe on the first floor of a house has a gauge pressure of 2.10×10^5 Pa. The density of water is $1\,000\,\mathrm{kg/m^3}$, and the pipes throughout the house have a constant diameter.

α) A tap on the second floor, 6.80 m above the first floor, it turned off. What is the gauge pressure at this tap? [2]

β) At what height would a tap have zero flow, even if it were open? [2]

Total Q7= 20

Mechanics Equation Sheet

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

$F = ma$

$F = \mu N$

$F = -ks$

$W = Fs$

$W = \int \mathbf{F} \cdot d\mathbf{s}$

$P = Fv$

$KE = \frac{1}{2}mv^2$

$p = mv$

$J = Ft$

$J = \int F dt$

$\mathbf{v}_{ac} = \mathbf{v}_{ab} + \mathbf{v}_{bc}$

$s = ut + \frac{1}{2}at^2$

$v = u + at$

$v^2 = u^2 + 2as$

$c^2 = a^2 + b^2 - 2ab\cos C$

$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\dfrac{\sin A}{a} = \dfrac{\sin B}{b} = \dfrac{\sin C}{c}$

$W = -\frac{1}{2}ks^2$

$I = Mk^2$

$I_d = I_c + md^2$

$\bar{x} = \dfrac{\sum m_i x_i}{\sum m_i}$

$J_\theta = \int T dt$

$\vec{T} = \vec{r} \times \vec{F}$

Solid cylinder/Disk $I_C = \dfrac{1}{2}MR^2$

Hollow cylinder $I_C = \frac{1}{2}M(R^2 + r^2)$

Sphere $I_C = \dfrac{2}{5}MR^2$

Rod $I_C = \dfrac{1}{12}Ml^2$

$L = I\omega$

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\omega^2 = \omega_0^2 + 2\alpha\theta$

$s = R\theta$

$v = R\omega$

$a_t = R\alpha$

$a_n = \dfrac{v^2}{R} = \omega^2 R$

$\vec{v} = \vec{\omega} \times \vec{r}$

$L = mvr$

$T = I\alpha$

$W = T\theta$

$KE = \frac{1}{2}I\omega^2$

$P = T\omega$

Thermal Equation Sheet

$$\Delta l = l_0 \alpha \Delta T \qquad \Delta V = V_0 \beta \Delta T$$

$$Q = mc\Delta T \qquad Q = nC\Delta T \qquad Q = mL$$

$$H = \frac{dQ}{dt} = -kA\frac{dT}{dx} \qquad H = \frac{dQ}{dt} = e\sigma A\left(T^4 - T_0^4\right) \qquad \frac{dQ}{dt} = A\frac{\Delta T}{R}$$

$$R = \frac{L}{k} \qquad N = nN_A$$

$$PV = nRT \qquad PV = NkT \qquad PV^{\gamma} = \text{const.} \qquad n = \frac{m}{M}$$

$$PV = \frac{Nm\overline{v^2}}{3} \qquad \tfrac{1}{2}m\overline{v^2} = \tfrac{3}{2}kT \qquad H = -qA(T - T_S)$$

$$C_p - C_v = R \qquad C_v = \begin{cases} \frac{3}{2}R & \text{(mono-)} \\ \frac{5}{2}R & \text{(di-)} \\ \frac{6}{2}R & \text{(poly-)} \end{cases} \qquad \gamma = \frac{C_p}{C_v}$$

$$Q = W + \Delta U \qquad \Delta U = nC_v\Delta T \qquad W = P\left(V_f - V_i\right)$$

$$W = \frac{P_iV_i - P_fV_f}{\gamma - 1} \qquad W = nRT\ln\left(\frac{V_f}{V_i}\right) \qquad W = nC_v\left(T_f - T_i\right)$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \qquad e = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} \qquad \text{C.O.P.} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2}$$

$$dS = \frac{dQ}{T} \qquad T_iV_i^{\gamma-1} = T_fV_f^{\gamma-1}$$

Waves / Optics Equation Sheet

$F = -kx$ $\qquad T = 2\pi\sqrt{\frac{l}{g}}$ $\qquad \omega^2 = \frac{k}{m}$

$U = \frac{1}{2}kx^2$ $\qquad x = A\sin(\omega t + \alpha)$

$y = A\sin(kx - \omega t + \phi)$ $\qquad y = 2A\sin kx \cos \omega t$

$c = f\lambda$ $\qquad c = \sqrt{\frac{F}{\mu}}$

$n_1 \sin i = n_2 \sin r$ $\qquad n_1 c_1 = n_2 c_2$ $\qquad d_a = \frac{d}{n}$

$P = 2\pi^2 A^2 f^2 \mu c$ $\qquad I = 2\pi^2 A^2 f^2 \rho c$

$c = \sqrt{\frac{\gamma P}{\rho}}$

$\beta = 10\log_{10}\left(\frac{I}{I_0}\right)$

$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$ $\qquad \frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\qquad m = -\frac{i}{o}$

$d\sin\theta = m\lambda$ $\qquad a\sin\theta = m\lambda$ $\qquad a\sin\theta = 1.22\lambda$

$m_l = \frac{250}{f} + 1$ $\qquad \alpha = \frac{\pi a \sin\theta}{\lambda}$ $\qquad \beta = \frac{\pi d \sin\theta}{\lambda}$

$I = \frac{I_{\text{max}} \sin^2\alpha \cos^2\beta}{\alpha^2}$ $\qquad I = I_0 \cos^2\theta$

$m_\theta = \frac{f_o}{f_e}$ $\qquad R = \frac{\lambda}{\Delta\lambda} = mN$ $\qquad D = \frac{d\theta}{d\lambda}$

$$\sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$$

Properties of Matter / Fluids Equation Sheet

$$Y = \frac{F/A}{\Delta l/l_0} \qquad B = \frac{-\Delta p}{\Delta V/V_0} \qquad S = \frac{F/A}{d/y} \qquad \sigma = \frac{-\Delta b/b_0}{\Delta l/l_0}$$

$$p = p_0 + \rho g h \qquad p + \tfrac{1}{2}\rho v^2 + \rho g y = \text{const.} \qquad v = \sqrt{2gh}$$

$$\gamma = \frac{F}{l} = \frac{W}{\Delta A} \qquad h = \frac{2\gamma\cos\theta}{\rho g R} \qquad \Delta p = \frac{2\gamma}{R} \text{ or } \frac{4\gamma}{R}$$

$$Q = Av = \text{const.} \qquad Q = \frac{\pi R^4 \Delta p}{8\eta l} \qquad v_1^2 = \frac{2(p_1 - p_2)}{\rho\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}$$

$$\eta = \frac{F/A}{\Delta v/\Delta y} \qquad F = 6\pi\eta R v$$

$$N_R = \frac{\rho v D}{\eta} \qquad v_t = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta}$$

Electricity and Magnetism Equation Sheet

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} \qquad V = \frac{q}{4\pi\varepsilon_0 r} \qquad E = \frac{q}{4\pi\varepsilon_0 r^2}$$

$$U = \frac{q_1 q_2}{4\pi\varepsilon_0 r} \qquad E = -\frac{dV}{dx} \qquad Q = CV$$

$$C = \frac{\varepsilon_0 A}{d} \qquad U_\mathrm{E} = \tfrac{1}{2}CV^2 \qquad W = \tfrac{1}{2}QV$$

$$W = VIt \qquad R = \rho\frac{l}{A} \qquad R_\mathrm{T} = R_0\left[1 + \alpha(T - T_0)\right]$$

$$V = IR \qquad P = VI$$

$$\oint \mathbf{E}\cdot d\mathbf{A} = \frac{q}{\varepsilon_0} \qquad \mathbf{F} = q\mathbf{v}\times\mathbf{B} \qquad \mathbf{F} = i\mathbf{l}\times\mathbf{B}$$

$$\mathbf{M} = i\mathbf{A} \qquad \mathbf{\Gamma} = \mathbf{M}\times\mathbf{B} \qquad \frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

$$\oint \mathbf{B}\cdot d\mathbf{l} = \mu_0 I \qquad dB = \frac{\mu_0 i dl \sin\theta}{4\pi r^2} \qquad \phi_\mathrm{B} = \int \mathbf{B}\cdot d\mathbf{A}$$

$$\varepsilon = -\frac{d}{dt}(N\phi_\mathrm{B}) \qquad \varepsilon = -L\frac{di}{dt} \qquad \varepsilon = -M\frac{di}{dt}$$

$$U_\mathrm{B} = \frac{1}{2}Li^2 \qquad u_\mathrm{B} = \frac{B^2}{2\mu_0} \qquad B = \frac{\mu_0 I}{2\pi r}$$

$$\tau = \frac{L}{R} \qquad \tau = RC$$

$$X_\mathrm{L} = \omega L \qquad X_\mathrm{C} = \frac{1}{\omega C}$$

$$Z^2 = R^2 + (X_\mathrm{L} - X_\mathrm{C})^2 \qquad \tan\phi = \frac{X_\mathrm{L} - X_\mathrm{C}}{R}$$

Tear off this sheet and use it for the graph required in Q1. Use the grid on the reverse of this page if you need a second sheet.

Family name: ____________________

Other names: ____________________

Student ID: ____________________

END OF EXAMINATION PAPER