Cover Type A

University of Technology, Sydney

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AUTUMN SEMESTER EXAMINATION, 2010
FACULTY OF SCIENCE

SUBJECT NAME: Foundations of Physics

SUBJECT NO.: 68101

DAY/DATE: Tuesday 22nd June, 2010

TIME ALLOWED: 3 hours + 10 minutes optional 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 this time 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.

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

$$
\begin{aligned}
g &= 9.81 \ \mathrm{m/s^2} \\
\sigma &= 5.670\times10^{-8}\,\mathrm{W/(m^2\,K^4)} \\
R &= 8.314\,\mathrm{J/(mole\,K)} \\
N_A &= 6.022\times10^{23}\ \text{molecules/mole} \\
k_B &= 1.381\times10^{-23}\,\mathrm{J/(K\,molecule)} \\
c &= 3.00\times10^{8}\,\mathrm{m/s} \\
h &= 6.626\times10^{-34}\,\mathrm{J\,s} \\
I_0 &= 1.0\times10^{-12}\,\mathrm{W/m^2} \\
\varepsilon_0 &= 8.854\times10^{-12}\,\mathrm{F/m} \\
\frac{1}{4\pi\varepsilon_0} &= 9\times10^{9}\,\mathrm{N\,m^2/C^2} \\
\mu_0 &= 4\pi\times10^{-7}\,\mathrm{H/m} \\
e &= 1.602\times10^{-19}\,\mathrm{C} \\
m_e &= 9.110\times10^{-31}\,\mathrm{kg} \\
&= 0.00055\,\mathrm{u} \\
m_p &= 1.673\times10^{-27}\,\mathrm{kg} \\
&= 1.00728\,\mathrm{u} \\
m_n &= 1.675\times10^{-27}\,\mathrm{kg} \\
&= 1.00866\,\mathrm{u} \\
1\mathrm{u} &= 1.661\times10^{-27}\,\mathrm{kg} \\
G &= 6.673\times10^{-11}\,\mathrm{N\,m^2/kg^2} \\
\text{Rydberg's constant} &= 1.097\times10^{7}\ \mathrm{m^{-1}} \\
\text{Temperature of Ice Point} &= 273.15\,\mathrm{K} \\
1\ \text{atmosphere} &= 1.013\times10^{5}\ \mathrm{Pa} \\
\text{Mass of Earth} &= 5.974\times10^{24}\ \mathrm{kg} \\
\text{Radius of Earth} &= 6.37\times10^{6}\ \mathrm{m} \\
1\ \text{curie} &= 3.70\times10^{10}\ \text{becquerel} \\
\text{Specific heat capacity of water} &= 4.186\times10^{3}\,\mathrm{J/(kg\,K)} \\
\text{Latent heat of fusion of ice} &= 3.336\times10^{5}\,\mathrm{J/kg} \\
\text{Density of water} &= 1.000\times10^{3}\,\mathrm{kg/m^3} \\
\text{Density of ice} &= 0.917\times10^{3}\,\mathrm{kg/m^3} \\
\text{Density of mercury} &= 13.596\times10^{3}\,\mathrm{kg/m^3}
\end{aligned}
$$

THIS QUESTION IS COMPULSORY

Write you answers in a separate answer booklet, NOT on this question paper.

Question 1 (20 marks)

[1] (a) i. A brass cube is found to displace $8.00 \pm 0.3\,\text{cm}^3$ of water when immersed in a full glass. The length of the cube edge is therefore closest to:

A. (2.00 ± 0.013) cm
B. (2.00 ± 0.10) cm
C. (2.00 ± 0.04) cm
D. $(2.00 \pm 0.027$ cm
E. (2.00 ± 0.025) cm [1]

[1] ii. A vector of magnitude 21 is added to a vector of magnitude 24. The magnitude of their sum could be:

A. 0
B. 2
C. 44
D. 46
E. 50

[1] iii. Suppose object C is in thermal equilibrium with object A and with object B. The zeroth law of thermodynamics states:

A. that C will always be in thermal equilibrium with both A and B
B. that C must transfer energy to both A and B
C. that A is in thermal equilibrium with B
D. that A cannot be in thermal equilibrium with B
E. nothing about the relationship between A and B

[1] iv. As the volume of an ideal gas is increased at constant pressure the average molecular speed:

A. increases
B. decreases
C. increases at high temperature, decreases at low
D. decreases at high temperature, increases at low
E. stays the same

[1] v. Several containers of different sizes and shapes are all filled to the same depth with water. Then:

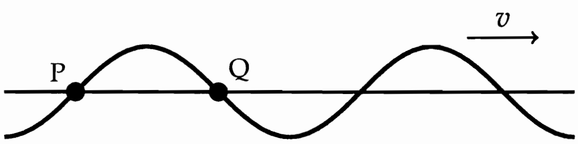
A. the weight of the water is the same for all cases
B. the force of the water on the bottom of each container is the same
C. the least pressure is at the bottom of the container with the largest bottom area
D. the greatest pressure is at the bottom of the container with the largest bottom area
E. the pressure on the bottom of each container is the same

Q1 continues on next page . . .

[1] vi. A body on a spring is undergoing simple harmonic motion (SHM). Which one of the following statements is correct?

A. The velocity and acceleration of the body at any instant always point in the same direction.
B. The displacement and acceleration of the body at any instant always point in the same direction.
C. The potential energy and the kinetic energy of the body both reach a maximum at the same instant in time.
D. The total mechanical energy of the body is constant.
E. The total mechanical energy of the body is independent of its mass.

[1] vii. The diagram shows a transverse wave which is travelling to the right. P and Q are particles of the medium in which the wave is travelling. How are the particles P and Q moving at the instant shown in the diagram?



A. Both are moving to the right.
B. Both are moving upwards.
C. P is moving downwards and Q upwards.
D. P is moving upwards and Q downwards.
E. Both are momentarily stationary.

[1] viii. When a light wave travels from air into glass:

A. the velocity of the wave decreases
B. the velocity of the wave increases
C. the frequency of the wave decreases
D. the frequency the waves increases
E. the wavelength of the wave does not change

Q1 continues on next page ...

(b) Some students conducted systematic measurements on water flowing through horizontal tubes of different diameters. They started off by writing down the Poiseuille equation,

$$Q = \frac{\Delta P \pi R^4}{8\eta L}$$

where Q is the volume flow rate (in m^3/s), ΔP is the pressure difference across a tube or length L and radius R, and η is the viscosity of water ($\eta_{water} = 8.90 \times 10^{-4}$ Pa·s).
They obtained 6 tubes of the same length but different diameters and set up a large elevated tank to drain water into one end of the tube being tested, thus maintaining a pressure difference of 10^4 Pa across the tube.
Finally, they measured the rate at which water flowed out of each tube and recorded their results as indicated in the table below.

Radius, R ±0.05 (mm)	Q ±0.5 (ml)	$R^4 (10^{-12}\,m^4)$	$\Delta R^4\ (10^{-12}\,m^4)$
0.50	1.3	0.0625	0.025
0.60	3.3	0.130	0.043
0.70	5.5	0.240	0.069
0.80	10	0.410	0.102
0.90	16	Ⓐ	0.146
1.00	24	1.000	Ⓑ

[2] i. Two values have been left out of the table (designated Ⓐ and Ⓑ). Calculate these missing values.

[5] ii. α) Tear off the graph paper provided on page 11 and plot on it a fully-labelled graph of Q versus R^4 for the full set of data.

[1] β) Is the data consistent with the predictions of Poiseuille's law? Justify your answer.

[4] iii. Using the graph, estimate the value of L and its uncertainty.

Write your name on the graph paper and put it inside your Q1 answer booklet.

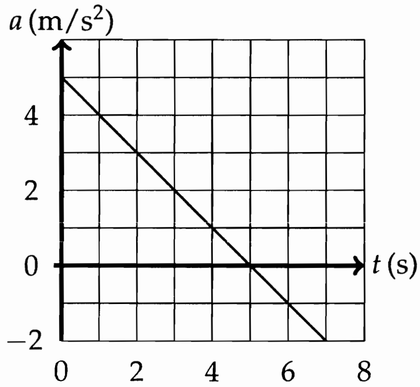
Total Q1= 20

Question 2 (20 marks)

[3] (a) i. The equation $s = At^4 + Bt + C$ describes the motion of a certain projectile, where s has the dimension of length and t is time. State the dimensions of the constants A, B and C.

[2] ii. It takes 3.4 minutes to fill a 55 litre fuel tank with petrol. Calculate the average filling rate, in cubic metres per second.

[3] (b) A particle moves in one dimension. Its acceleration as a function of time is plotted below.



At $t = 0\,\text{s}$ the particle's velocity is $3.0\,\text{m/s}$. Calculate its velocity at $t = 7.0\,\text{s}$.

(c) A vector, $\vec{A}$, points 150° counterclockwise from the positive direction of the $x-$axis and has magnitude 8.2 m.

[3] i. Write $\vec{A}$ in unit vector notation.

ii. A second vector, $\vec{B}$, when added to $\vec{A}$ produces a null resultant vector. Determine:

[2] α) The components (B_x, B_y) of $\vec{B}$.

[2] β) The direction of $\vec{B}$.

(d) A ball is thrown vertically from ground level and rises to a maximum height of 40.0 m.

[3] i. Assuming no air resistance acts on the ball, what is its initially speed?

[2] ii. How long is the ball in the air?

Total Q2= 20

Question 3 (20 marks)

[2] (a) i. State the work-energy principle.

[3] ii. The only force, F, acting on a 3.5 kg block moving in an xy plane has a magnitude of 7.2 N. The block initially has a velocity of 5.8 m/s in the positive x-direction; some time later it has a velocity of 3.9 m/s in the positive y-direction. How much work is done on the block by F during this time?

[5] (b) A 10.0 kg block is at rest on a rough plane inclined at 30° to the horizontal when a force of 15.0 N directed downwards along the plane is applied to it. It is observed that 1.45 seconds later the block has slid 4.6 m down the plane.

Determine the coefficient of kinetic friction between the block and the plane.

[1] (c) i. A particle moves at constant speed along a circular path. Describe the forces acting on the particle.

[4] ii. A bus rounds a flat circular curve of radius 12.00 m at 18.0 km/h. Determine the angle (with respect to the vertical) made by a hand-strap hanging loosely from the ceiling.

[3] (d) i. A space vehicle is travelling at 4 100 km/h relative to Earth when the spent (used-up) rocket motor of mass $4m$ is separated and sent backwards with a speed of 80 km/h relative to the command module (mass m). Calculate the speed of the command module relative to Earth just after the separation.

ii. A 57.7 g tennis ball collides horizontally with a brick wall, hitting it with a speed of 25.0 m/s. It rebounds with an initial speed of 10.5 m/s.

[1] α) What impulse acts on the ball during its contact with the wall?

[1] β) The ball is in contact with the wall for 23 ms. What is the magnitude of the average force on the wall from the ball?

Total Q3= 20

Question 4 (20 marks)

A diatomic gas contained in the piston of a car engine is initially at a temperature of 300 K, a pressure of 1.000 atm and occupies a volume of 900 cm^3. The gas is compressed adiabatically in the piston to 0.1000 of its initial volume.

[4] (a) Calculate the final pressure of the gas in the cylinder.

[4] (b) Calculate the final temperature of the gas.

[4] (c) Calculate the change in internal energy of the gas in the cylinder when it is compressed.

[4] (d) Calculate the work done by the gas.

[2] (e) Draw a p-V diagram showing this compression process.

[2] (f) What is the area underneath this graph?

Total Q4= 20

Question 5 (20 marks)

A research scientist is testing his new device for cooling water at night. The device consists of a 150.0 g container of water. The top surface of the container has an area of 0.7500 m^2 and is coated with a special thin film that allows the container, on a cloudless night, to see the sky as a blackbody radiator at a temperature of $-25.0°$ C. The heat capacity of the container is 840 J/(kg·K).

[4] (a) Calculate the amount of energy the container alone would need to lose to cool to 0.00° C if it is initially at 2.00° C.

[4] (b) Calculate the amount of energy 1 litre of water would need to lose to completely freeze if it is initially at 2.00° C.

[4] (c) If the temperature of the device is the same as its surroundings, 2.00° C, and the emissivity of the special thin film is 0.8 calculate the power that the device is radiating into the night sky.

[4] (d) Calculate how many litres of water the sky cooler could freeze overnight (i.e. in 8 hours).

[2] (e) What assumptions have you made in the above calculations?

[2] (f) Explain whether you think these are valid assumptions and how closely the scientist's experiment will adhere to these assumpations.

Total Q5= 20

Question 6 (20 marks)

(a) A body of mass 60 g moving towards a fixed point is attracted by a force of 0.55 N when its displacement from the fixed point is 60 mm.

[2] i. Assuming that the motion is simple harmonic, find the period of the motion.

[2] ii. If the amplitude of the oscillation is 120 mm find the speed of the mass 0.15 s after the instant it passes through the equilibrium position.

[2] iii. Calculate the maximum kinetic energy of the body.

[2] (b) i. Describe, with the aid of diagrams, the difference between a longitudinal wave and a transverse wave.

[2] ii. Write an equation for a progressive wave moving along the positive $x-$axis and having amplitude 0.05 m, frequency 600 Hz and velocity 340 m/s.

[2] (c) With the aid of a diagram, explain the circumstances under which a wave will undergo total internal reflection.

(d) An object of height 5 mm is placed 20 cm in front of a concave lens with focal length of 40 cm.

[3] i. Sketch a ray diagram showing the object, lens and image (your diagram does not need to be to scale) '

[2] ii. Determine the image distance.

[2] iii. Determine the height of the image.

[1] iv. Is the image real or virtual?

Total Q6= 20

Question 7 (20 marks)

(a) An ice cube is floating in a glass of water.

[6] i. Calculate the percentage of the total volume of the ice cube that is above the water. (Hint:— write an expression for the weight of the ice cube and use Archimedes principle to relate this to the buoyant force on the submerged volume of the ice cube.)

[2] ii. When the ice cube finally melts does the water level in the glass rise, fall, or stay the same? Justify your answer.

(b) The mercury barometer is a simple instrument for measuring pressure and consists of a glass tube filled with mercury that is then inverted into a dish of mercury. Some the mercury flows out of the tube into the dish leaving essentially a vacuum above the mercury column in the tube (see Fig. 1).

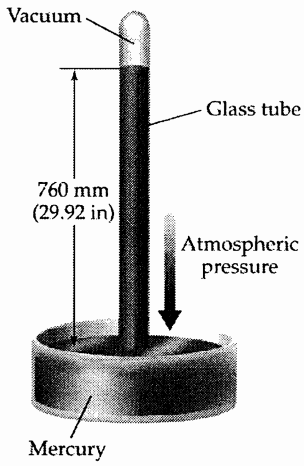


Figure 1: Simple mercury barometer

[4] i. If the height of the mercury column is 760 mm, calculate the pressure.

[4] ii. If the barometer is filled with water rather than mercury, calculate the height of the water column supported by this same pressure.

[2] iii. Why is the space above the mercury (or water) column not an absolute vacuum?

[2] iv. Is it reasonable to ignore this (i.e. part (iii) in the calculations above)?

Total Q7= 20

Mechanics Equations

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

$F = ma$

$F = \mu N$

$F = -kx$

$W = Fs$

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

$P = Fv$

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

$p = mv$

$J = Ft$

$J_\theta = \int T dt$

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

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

$v = u + at$

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

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

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

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

$U = mgy \qquad U = \frac{1}{2}kA^2$

$I = Mk^2$

$I_\mathrm{d} = I_\mathrm{c} + md^2$

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

$J = \int F dt$

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

$\omega = \omega_0 + \alpha t$

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

$s = R\theta$

$v = R\omega$

$a_\mathrm{t} = R\alpha$

$a_\mathrm{n} = \dfrac{v^2}{R} = \omega^2 R$

$\vec{T} = \vec{r} \times \vec{F} \qquad \vec{v} = \vec{\omega} \times \vec{r}$

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

$L = I\omega \qquad L = mvr$

$T = I\alpha \qquad W = T\theta$

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

$P = T\omega$

Thermal Equations

$\Delta l = l_0 \alpha \Delta T$ $\quad \Delta V = V_0 \beta \Delta T$ $\quad \Delta A = (2\alpha) A \Delta T$ $\quad \Delta V = (3\alpha) V_0 \Delta T$

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

$P = \frac{dQ}{dt} = -kA\frac{dT}{dx}$ $\quad P = \sigma \varepsilon A \left(T_{\text{env}}^4 - T_0^4\right)$ $\quad \frac{dQ}{dt} = \frac{\Delta T}{R}$

$R = \frac{L}{k}$ $\quad \frac{dT}{dt} = -k(T_0 - T_S)$ $\quad N = nN_A$

$pV = nRT$ $\quad pV = NkT$ $\quad pV^\gamma = \text{const.}$ $\quad TV^{\gamma-1} = \text{const.}$ $\quad n = \frac{m}{M}$

$pV = \frac{Nm\overline{v^2}}{3}$ $\quad \frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$ $\quad v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$ $\quad v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$

$P = -qA(T - T_S)$ $\quad C_p - C_v = R$

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

$\Delta E_{\text{int}} = Q - W$ $\quad \Delta E_{\text{int}} = nC_v\Delta T$ $\quad W = \int_{V_i}^{V_f} p\,dV$

Waves / Optics Equations

$$F = -kx \qquad a = -\omega^2 x \qquad \omega = \sqrt{\frac{k}{m}}$$

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

$$T = \frac{2\pi}{\omega} \qquad T = 2\pi\sqrt{\frac{\ell}{g}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

$$y = A\sin(kx - \omega t + \phi) \qquad v = f\lambda \qquad k = \frac{2\pi}{\lambda} \qquad v = \sqrt{\frac{F}{\mu}}$$

$$y = 2A\sin(kx)\cos(\omega t) \qquad v = \sqrt{\frac{\gamma P}{\rho}} \qquad v = \frac{\omega}{k}$$

$$v_{\text{max}} = \omega A \qquad P = 2\pi^2 \mu v A^2 f^2 \qquad I = 2\pi^2 \rho v A^2 f^2$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad n = \frac{c}{v} \qquad n_1 v_1 = n_2 v_2$$

$$d_{\text{app}} = \frac{d}{n} \qquad \beta = 10\log_{10}\frac{I}{I_0} \qquad I = \frac{P}{A}$$

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

$$m_\theta = -\frac{f_\text{o}}{f_\text{e}} \qquad d = f_\text{o} + f_\text{e} \qquad m_\theta = \frac{250}{f}$$

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

Properties of Matter / Fluids Equations

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

$$R_\text{V} = Av = \text{ const.} \qquad F_\text{g} = m_\text{F} g \qquad F = \rho V g$$

Family name: ____________________

Other names: ____________________

Student ID: ____________________

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.

END OF EXAMINATION PAPER