Name: ________________________________ (   )   Class: _______

華僑中學
HWA CHONG INSTITUTION
SPECIMEN PAPER A

HIGHER PHYSICS

Level: Secondary Three
Duration: 1 hour

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your name, index number and class on the top of this page.

Answer the questions in **Section A and B** in the spaces provided. **All workings must be shown**.

In **Section B**, answer only **2 questions** out of the 3 questions.

INFORMATION FOR CANDIDATES

In **Sections A and B** the intended marks for each question or part of a question are given in brackets [ ]. Any working should be done in the space provided.

When necessary, take acceleration due to gravity, **g** to be 10 m s^{-2}.

This question paper consists of 12 printed pages, including this page.

Section A [20 marks]

*Answer **all** the questions in this section.*

1 An elastic collision is defined as one in which there is no loss of kinetic energy in the collision. An inelastic collision is one in which part of the kinetic energy is changed to some other form of energy in the collision. An experiment to investigate collisions has been set up as shown in figure A below. Two motion sensors are set up at each end of the runway. Trolley A is given a sharp push so that it runs along the runway and collides with trolley B. Figure B shows the velocity time graph of the motion of the two trolleys. Both trolleys are of mass 500 g.

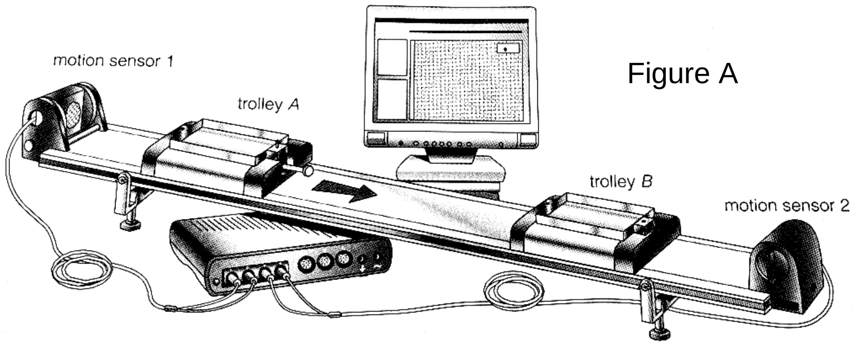


Figure A

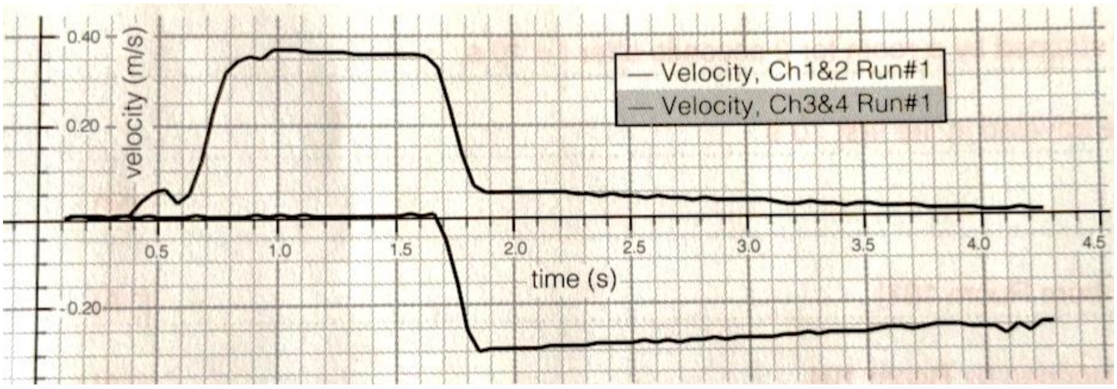


Figure B

(a) Estimate the distance moved by trolley A before collision. [2]

Distance moved = area under the graph from t = 0.40 s to t = 1.60 s[1]
= ½ (1.20 + 0.80)(0.35)
= 0.35 m [1]

(b) Explain why the velocity of one of the graphs is negative. [1]

Trolley B travelled towards motion sensor 2 after the collision. [1]

(c) What is the average force acting on trolley A during the collision? [2]

Change in momentum, Δp	$= F \times \Delta t$	
0.500 (0.05 – 0.35)	$= F \times (0.30)$	[1]
F	$= -0.50$ N	[1]

(d) A student wrote the following observation in his lab report.

Momentum before collision = 0.500 x 0.35 = 0.178 kg m s^{-1}
Momentum after collision = 0.500 x 0.30 = 0.150 kg m s^{-1}
Since momentum before collision is not equal to the momentum after collision, hence momentum is not conserved.

Comment on the student's observation. [2]

Momentum is always conserved in collision. [1]
Momentum after collision was incorrectly determined as momentum of trolley A was not considered. [1]

(e) Explain with evidence if the collision between the trolleys is elastic or inelastic. [3]

KE before collision	$= \frac{1}{2} m v_A^2$	
	$= \frac{1}{2} (0.500)(0.35^2)$	
	$= 3.1 \times 10^{-2}$ J	[1]
KE after collision	$= \frac{1}{2} m v_A^2 + \frac{1}{2} m v_B^2$	
	$= \frac{1}{2} (0.500)(0.05)^2 + \frac{1}{2} (0.500)(-0.30)^2$	
	$= 2.3 \times 10^{-2}$ J	[1]

Since KE after collision after collision is not equal to KE before collision, hence collision is inelastic. [1]

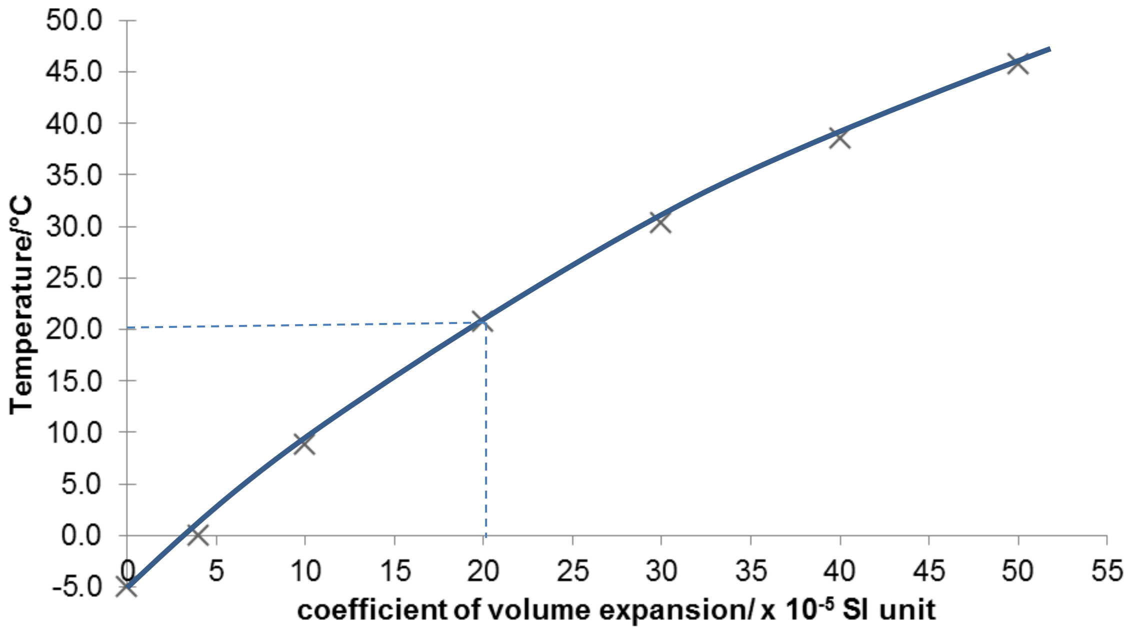
2 Sea level rises provide one of the most immediate and direct consequences of global warming. A major contribution to sea level rise is thermal expansion of sea water. About 70% of the Earth's surface is covered with water and the average depth is about 3800 m.

The coefficient of volume expansion β, is defined as the fractional change in volume per unit change in temperature in Kelvin.

$$\Delta V = \beta V_0 \Delta T$$

where ΔV is the change in original volume V_0 caused by a temperature change ΔT.

Water has a rather unusual expansivity, it contracts when heated from 0°C to 4°C before expanding. Since expansion of sea water is non-linear, the coefficient of volume expansion for water is not constant. The graph below shows the coefficient of volume expansion in SI unit for water at various temperatures.



(a) On the graph above, draw the best-fit line for the data points. [1]
Smooth curve [1]

(b) State if the graph suggests that temperature T and the coefficient of volume expansion β are related by an expression of the form

$$T = a\beta + c$$

where a and c are constants. [1]

No. The graph is non-linear. [1]

(c) Deduce the unit for volume expansivity. [1]

$\Delta V = \beta V_0 \Delta T$

$\beta = \Delta V/(V_0 \Delta T)$

Hence unit of β is K^{-1} or $°C^{-1}$. [1]

(d) Estimate the total volume of water on Earth. [3]

Surface of Earth $= 4\pi r^2$

$= 4\pi(6.37 \times 10^6)^2$ [1] estimating radius of Earth in Mm

Volume of water = surface area x depth

$= 70\% \ (4\pi(6.37 \times 10^6)^2)(3.8 \times 10^3)$ [1]

$= 1.3 \times 10^{18}\ m^3$ [1]

(e) If the temperature of the sea water is currently at 20°C,

(i) calculate the approximate increase in volume of sea water if the average temperature of the sea water rose by just 1.0 °C. [2]

$\Delta V = \beta V_0 \Delta T$

$= 20 \times 10^{-5} \times (1.3 \times 10^{18})$ [1] reading β correctly from graph at 20°C

$= 2.6 \times 10^{14}\ m^3$ [1]

(ii) Predict the rise in sea level which would result from the increase in temperature of just 1.0 °C. [1]

Increase in depth = ΔV/surface area

$= 2.6 \times 10^{14}/(0.70 \times 4\pi(6.37 \times 10^6)^2)$

$= 0.73$ m [1]

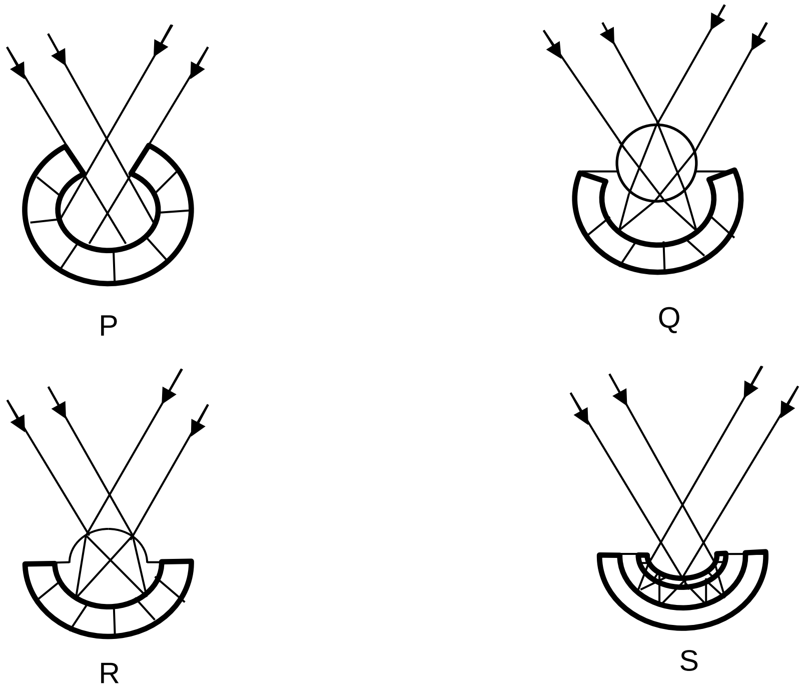
(f) Explain a possible impact on Singapore due to rise in sea level. [1]

Less useable area as low lying coastal regions will be submerged. [1]

Section B [20 marks]

*Answer **two out of three** questions in this section.*

3 Animals have different eye structures to enable them to see and be able to survive in their natural habitat. Several eye structures are shown in the diagram below. Rays of light from two points of a distance object are incident into the eyes.



(a) A snail is only able to tell which direction light is coming from but cannot form an image, which eye structure does the snail have? [1]

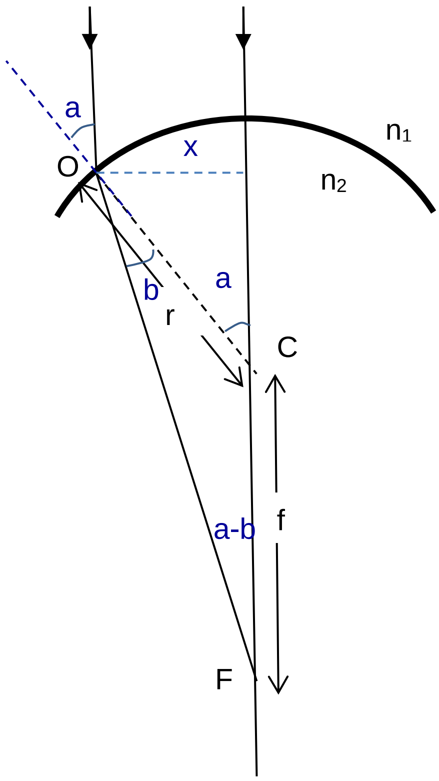
P [1]

(b) Describe the vision of the animal having eye structure Q. [1]

Sharp real image of the distance object formed. [1]

The figure below shows an image formed by a single spherical surface (similar to eye structure R) separating media of refractive index n_1 and n_2. If the radius of curvature of the surface is r, then the focal length f, the distance from the centre of curvature C to the focus F is given by:

$$f = \frac{n_1 r}{(n_2 - n_1)}$$



(c) By applying Snell's law to the refracted ray and given that OF is approximately the same as f+r, show that

$$f = \frac{n_1 r}{(n_2 - n_1)} \qquad [4]$$

$n_1 \sin a = n_2 \sin b$ [1] need to indicate clearly where is angle a and b are

$\sin a = x/r$ [1] basic trigo relation

$[\sin b]/f = [\sin (a-b)]/r = [\sin (180 - a)]/(f+r) = (x/r)/(f+r)$ [1] sine rule

Hence,

$$\begin{aligned}
n_1 \sin a &= n_2 \sin b \\
n_1 (x/r) &= n_2\, (f(x/f+r)/r) \qquad \text{proof [1]} \\
n_1 &= n_2\, (f/(f+r)) \\
n_1\, (f+r) &= n_2 f \\
n_1 f + n_1 r &= n_2 f \\
n_1 r &= f(n_2 - n_1) \\
f &= n_1 r/(n_2 - n_1)
\end{aligned}$$

(d) Explain the difference in the focal length of the eye when light rays enter the eye from air and water. [2]

Focal length of eye when light rays enters the eye **from water is greater** than when light ray enters the eye **from air** [1]
Because **the refractive index of water is greater than refractive index of air** [1]

(e) The material in the eye structure R has a refractive index 1.40 and a focal length of 10 cm in air. Determine the focal length in water when the eye is completely in seawater of refractive index of 1.35. [2]

$$f = \frac{n_1 r}{(n_2 - n_1)}$$

10 = 1.00 r/(1.40-1.00) [1]
r = 4.0 cm

f = 1.35(4.0)/(1.40 – 1.35)
= 110 cm [1]

4 Next to the 3000-year-old Drombeg circle in Ireland is a stone-lined pit known as a Fulacht Fiadh. A fulacht fiadh is the name given to an ancient cooking pit dating from the Bronze Age. Fulachta fiadh is generally located beside a source of water, a pit or hole was constructed and filled with clean water. Archaeology thinks that during that time, water was first heated by placing heated stones in it and fresh meat was then boiled in it.

In an experiment to test this idea, it was found that the 120 kg of clean water in the pit of initial temperature of 18°C started to boil after five heated stones each of average mass 9.0 kg had been added. Specific heat capacities of stone and water are 1.1 J g^{-1} $°C^{-1}$ and 4.2 J g^{-1} $°C^{-1}$ respectively. Fresh meat cut into a cube of 10.0 cm length was then lowered into the boiling water.

Energy is transferred by conduction when the piece of meat comes into contact with the heated water. The basic thermal energy transfer equation for conduction is given by

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

where Q is the amount of energy transferred, t is the time taken, A would be the area of the piece of meat, k the thermal conductivity of the meat 0.496 W $m^{-1}°C^{-1}$, ΔT is the difference in temperature and d is the thickness of the piece of meat.

(a) Determine the minimum temperature for the fire. [2]

Energy lost by stone	= Energy gained by water	
$(mc\Delta\theta)_{\text{stone}}$	$= (mc\Delta\theta)_{\text{water}}$	
$5 \times 9.0 \times 1100 \times (\Theta - 100)$	$= 120 \times 4200 \times (100 - 18)$	[1]
Θ	= 930 ° C	[1]

(b) Explain why the temperature of the fire would be higher than the calculated value. [1]

Energy lost to surrounding once water is being heated up to a temperature greater than surrounding temperature. [1]
OR
Thermal equilibrium has not been reached. [1]

(c) Explain briefly how energy is transferred in the water after the heated stones are added to it. [2]

Conduction when heated stones come into contact with water as they sink into the water. [1]

Convection currents are then set up in the water for water to be heated up to boiling temperature. [1]

(d) Estimate the time needed to raise the temperature of a piece of meat of approximately 2.0 kg in mass from 18°C to the equilibrium temperature of the water, stone and meat. The specific heat capacity of meat is about 3.6 J g^{-1} $°C^{-1}$. State assumptions made clearly in your working. [5]

Energy lost by stone & water = Energy gained by meat
$(mc\Delta\theta)_{stone} + (mc\Delta\theta)_{water} = (mc\Delta\theta)_{meat}$
$5 \times 9.0 \times 1100 \times (100 - \Theta) + 120 \times 4200 \times (100 - \Theta) = 2.0 \times 3600 \times (\Theta - 18)$
$\Theta = 98.9$ °C [1] - Computation of equilibrium temperature

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

$(mc\Delta\theta)_{meat}/t = kA\,\Delta\theta/d$
$[2.0 \times 3600 \times (98.9 - 18)]/t = [0.496 \times (0.100 \times 0.100 \times 6) \times (100 - 18)]/0.050$
$t = 1.2 \times 10^4$ s

[1] - amount of energy gained by piece of meat
[1] - correct substitution of $kA\,\Delta\theta/d$
[1] - answer

Assumptions
1. Energy is not lost to surrounding.
2. Energy is conducted evenly from all surfaces of the piece of meat.
3. Energy transferred is just sufficient for water to reach equilibrium temperature of 100 °C, and no water vaporize.

[1] – for at least 2 assumptions stated

5 Energy can be ‘saved’ in automobiles by reducing a variety of losses.

The two main frictional forces on a moving automobile are air resistance and rolling friction along the road.

Air resistance is a force that affects objects that move through the air. It depends on the density of the air, the area of the object, the velocity it is moving, and a "drag coefficient" that accounts for other properties of the object like the surface roughness, and turbulence. Air resistance is also called "drag".

Air resistance F_D is usually expressed in a formula

$$F_D = \frac{1}{2} CA\rho v^2$$

where v is the velocity of the automobile, A is the cross sectional area, ρ is the density of the air 1.29 kg m^{-3} and C is the drag coefficient.

The following table shows the typical drag coefficient and the frontal area for some automobiles.

Automobile	Drag coefficient	Frontal area/m^2
Motorcycle with rider	0.60	0.80
Sedan car	0.45	3.50
Sports car	0.32	2.00
Bus	0.65	8.00

Rolling friction F_r is due to the contact of the tyres with the road surface and is given by

$$F_r = \mu N$$

where N is the normal reaction force between car and the road and μ is the coefficient of rolling friction.

Rubber tires on different surfaces	Coefficient of rolling friction
Dry asphalt	0.05
Wet asphalt	0.02

Mr Tan is driving a 1500 kg sedan car along a straight asphalt road on a rainy day at a constant speed of 50 km h^{-1}.

(a) Determine the total force resisting the motion of Mr Tan's car. [5]

50 km h^{-1} = 14 m s^{-1} [1]

Total resistive force $= F_D + F_r$
$= ½ CA\rho v^2 + \mu N$
$= ½ (0.45)(3.50)(1.29)(14)^2 + 0.02(1500 \times 10)$
$= 200 + 300$
$= 500$ N

Correct computation of F_D [2]
Correct computation of F_r [2]

(b) How much power is supplied by the car's engine for Mr Tan to travel at 50 km h^{-1}? [2]

Power = Fv
Power = 500 x 14 [1]
= 7000 W [1]

(c) Explain why Mr Tan's car is able to travel about 12 km per litre of fuel, while a bus is able to manage only about 6 km per litre of fuel if both are traveling at same constant velocity. [2]

Total resisting force on bus is **greater** than total resisting force on Mr Tan's car [1] because **mass, drag coefficient and frontal area of bus is greater** than those of Mr Tan's car. [1]
Hence power of bus is greater if they are both travelling with same velocity.

(d) Explain why the speed of the car reduces if Mr Tan's car starts to climb a gentle slope with the same power. [1]

Work has to be done against resisting forces and **gravitational force**, hence with same power velocity of car has to be reduced. [1]