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PHYSICS
STANDARD LEVEL
PAPER 3

SPECIMEN PAPER

1 hour

Candidate session number

Examination code

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[35 marks]*.

Option	Questions
Option A — Relativity	4 – 5
Option B — Engineering physics	6 – 7
Option C — Imaging	8 – 9
Option D — Astrophysics	10 – 11

27 pages
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Paper 3 - Specimen Paper

SECTION A

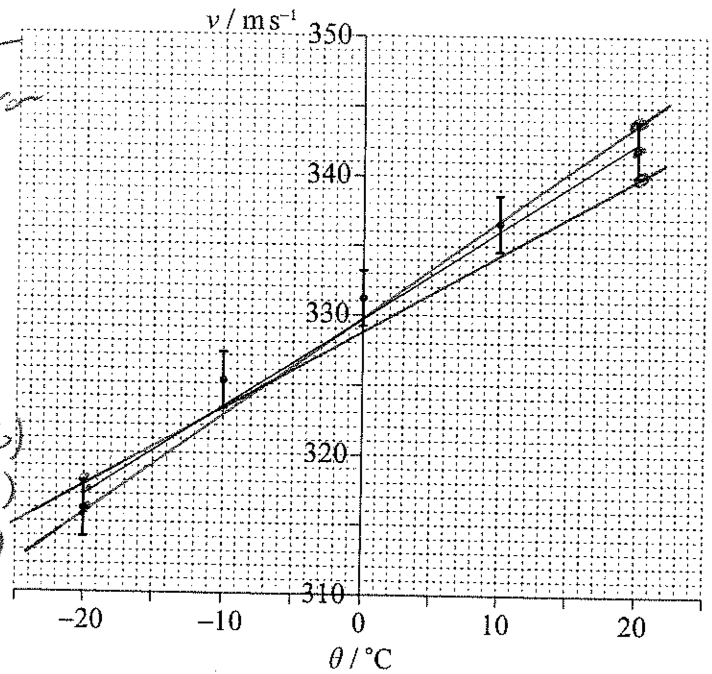
*Answer **all** questions. Write your answers in the boxes provided.*

1. The speed of sound in air, v, was measured at temperatures near 0°C. The graph shows the data and the line of best-fit. The error bars for temperature are too small to be shown.

- Max Slope & Min Slope Must go through all Error Bars

- Lines should pivot around a point.

(-20°C, 318 m/s)
(-20°C, 317 m/s)
(-20°C, 316 m/s)



(20°C, 344 m/s)
(20°C, 342 m/s)
(20°C, 340 m/s)

Slope Line of Best Fit

$\frac{342\text{ m/s} - 317\text{ m/s}}{20°C - (-20°C)} = \frac{25}{40}$

$= .63\text{ m/s/°C}$

A student suggests that the speed of sound v is related to the temperature θ in degrees Celsius by the equation

$$v = a + b\theta$$

$y = mx + b$
$v = b\theta + a$
slope   y-intercept

where a and b are constants.

(a) (i) Determine the value of the constant a, correct to two significant figures. *[1]*

a = 330 m/s

(This question continues on the following page)

(Question 1 continued)

(ii) Estimate the absolute uncertainty in b. *[3]*

b is Slope

Max Slope Min Slope

344m/s − 316m/s / 20°C − (−20°C) = 28/40 = .70   340m/s − 318m/s / 20°C − (−20°C) = 22/40 = .55

Max Slope − Min Slope

.70 − .55 = .15/2 = .075 = .08 m/s/°C

(iii) A student calculates that $b = 0.593\,\text{m}\,\text{s}^{-1}\,°\text{C}^{-1}$. State, using your answer to (a)(ii), the value of b to the correct number of significant figures. *[1]*

b = .59 ± .08 m/s/°C

(b) (i) Estimate the temperature at which the speed of sound is zero. *[1]*

v = bθ + a

0 = .59θ + 330   −330/.59 = .59θ/.59   θ = −556°C

(ii) Explain, with reference to your answer in (b)(i), why the student's suggestion is not valid. *[2]*

Absolute 0K is −273K

– It is not possible to have a temp below absolute 0

2. A student uses an electronic timer in an attempt to estimate the acceleration of free-fall g. She measures the time t taken for a small metal ball to fall through a height h of 0.50 m. The percentage uncertainty in the measurement of time is 0.3 % and the percentage uncertainty height is 0.6 %.

(a) Using $h = \frac{1}{2}gt^2$, calculate the expected percentage uncertainty in the value of g. *[1]*

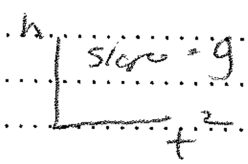
Solve for g $\frac{\Delta g}{g} = \frac{\Delta h}{h} + \frac{\Delta t}{t} + \frac{\Delta t}{t}$

$g = \frac{2h}{t^2}$ $\frac{\Delta g}{g} = .6\% + .3\% + .3\% = 1.2\%$

Multiplication & Division

(b) State and explain how the student could obtain a more reliable value for g. *[3]*

- Increase sample size
- Drop from a higher height (
- Determine g from another method



3. In an experiment to measure the specific heat capacity of a metal, a piece of metal is placed inside a container of boiling water at 100 °C. The metal is then transferred into a calorimeter containing water at a temperature of 10 °C. The final equilibrium temperature of the water was measured. One source of error in this experiment is that a small mass of boiling water will be transferred to the calorimeter along with the metal.

(a) Suggest the effect of the error on the measured value of the specific heat capacity of the metal. *[2]*

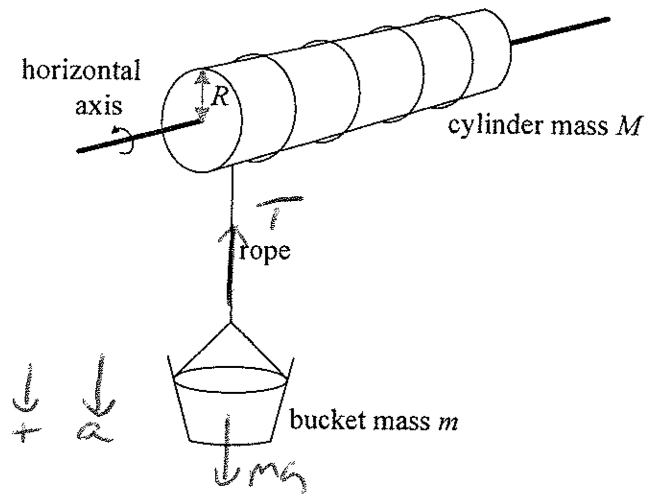
- Some heat lost by the cold water will be gained by the unwanted hot water
- Volume determined will be the specific heat of the metal will be lower than the actual volume

(b) State **one** other source of error for this experiment. *[1]*

- Energy released to the surroundings while moving the hot metal

Option B — Engineering physics

6. A bucket of mass m is held above a water well by a rope of negligible mass, as shown. The rope is wound around a cylinder of mass M and radius R. The moment of inertia of the cylinder about its axis is $I = \frac{1}{2}MR^2$.



(not to scale)

The bucket is released from rest. Resistance forces may be ignored.

(a) Show that the acceleration a of the bucket is given by the following equation.

$$a = \frac{mg}{m + \frac{M}{2}}.$$ *[4]*

$\Gamma = I\alpha$ $F_{net} = ma$

Need $a = r\alpha$ or $\alpha = \frac{a}{r}$

$\Gamma_{net} = I\alpha$

$I_{solid\ cylinder} = \frac{1}{2}Mr^2$ Pg 352 → Text or above

$\Gamma = Fr$

$Tr = I\alpha$

$Tr = \frac{1}{2}Mr^2 \frac{a}{r}$

$T = \frac{1}{2}Ma$

$mg - T = ma$

$mg = ma + T$

$mg = ma + \frac{1}{2}Ma$

$mg = (m + \frac{1}{2}M)a$

$\frac{mg}{m + \frac{1}{2}M} = a$

(Option B continues on the following page)

(Option B, question 6 continued)

(b) The following data are available.

Bucket mass m = 24 kg
Cylinder mass M = 36 kg
Radius R = 0.20 m

$v_f = ??$ $v_i = 0$ m/s $d = 16$ m

(i) Calculate the speed of the bucket when it has fallen a distance of 16 m from rest. *[2]*

① Find a

$a = \frac{mg}{m + \frac{M}{2}}$

$a = \frac{24\,kg(9.8\,m/s^2)}{24\,kg + \frac{36\,kg}{2}} = 5.6\,m/s^2$

② Find v_f

$v_f^2 = v_i^2 + 2ad$

$v_f^2 = 2(5.6\,m/s^2)(16\,m)$

$\sqrt{v_f^2} = \sqrt{179.2}$

$v_f = 13$ m/s

(ii) Calculate the rate of change of the angular momentum of the cylinder. *[3]*

Angular Momentum $L = I\omega$

Rate of change: Divide both sides by t: $\frac{\omega}{t} = \alpha$

$\frac{\Delta L}{t} = I\alpha$

$\alpha = \frac{a}{r}$

$\frac{\Delta L}{t} = \frac{Ia}{R} = \frac{\frac{1}{2}MR^2 a}{R}$

$= \frac{1}{2}MRa = \frac{1}{2}(36\,kg)(.20\,m)(5.6\,m/s^2)$

$\frac{\Delta L}{t} = 20.2$ Nm

(c) The bucket in (b) is filled with water so its total mass is now 45 kg. The bucket is raised at a constant speed of 2.0 m s^{-1} using an electric motor attached to the cylinder. Calculate the power output of the motor. *[1]*

$P = FV$

① $F = mg = 45\,kg(9.8\,m/s^2) = 441\,N$

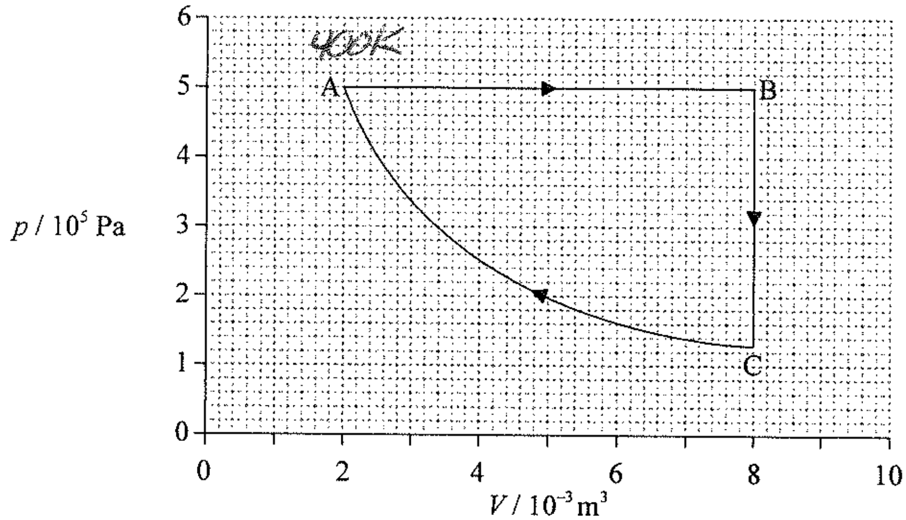
② $P = FV = 441\,N(2\,m/s)$

882 W

(Option B continues on the following page)

(Option B continued)

7. The pressure volume (pV) diagram shows a cycle ABCA of a heat engine. The working substance of the engine is a fixed mass of an ideal gas.



The temperature of the gas at A is 400 K.

(a) Calculate the maximum temperature of the gas during the cycle. *[1]*

eB $\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T_B}$ $\frac{2\times10^{-3}\,m^3}{400K} = \frac{8\times10^{-3}\,m^3}{T_B}$

Pressure same $T_B = 1600K$

(Option B continues on the following page)

(Option B, question 7 continued)

(b) For the isobaric expansion AB, calculate the

(i) work done by the gas. [2]

B A

V_f − V_i

Work = $P \Delta V$

= 5×10^5 Pa (8×10^{-3} m^3 − 2×10^{-3} m^3)

= 3000 J

(ii) change in the internal energy of the gas. [1]

From Reference Table

Sub in

$\Delta U = \frac{3}{2} nRT$ ($PV = nRT$)

$\Delta U = \frac{3}{2} P \Delta V$

From part i $P\Delta V = 3000$ J

$\Delta U = \frac{3}{2}(3000\text{ J}) = 4.5 \times 10^3$ J

4500 J

(iii) thermal energy transferred to the gas. [1]

$Q = \Delta U + W$ Q = Thermal Energy

From part i & ii

4500 J + 3000 J = 7500 J

(Option B continues on the following page)

(Option B, question 7 continued)

(c) The work done on the gas during the isothermal compression is 1390 J. Determine the change in entropy of the gas for this compression. *[2]*

$\Delta S = \frac{\Delta Q}{T} = \frac{1390\text{ J}}{400\text{ K}} = -3.48\ \frac{\text{J}}{\text{K}}$

Negative Answer - Gas is compressed then expanded

(d) Determine the efficiency of the cycle ABCA. *[2]*

Refer Table Pg 11

η - Efficiency $\eta = \frac{\text{useful work done}}{\text{energy input}}$

i. $W = 3000\text{ J}$

iii. $Q = 7500\text{ J}$ $\eta = \frac{3000\text{ J} - 1390\text{ J}}{7500\text{ J}} = .21$

(e) State whether the efficiency of a Carnot engine operating between the same temperatures as those operating in cycle ABCA on page 14, would be greater than, equal to, **or** less than the efficiency in (d). *[1]*

Carnot Cycle efficiency is greater

End of Option B