AS COMPETITION PAPER 2008
SOLUTIONS

Total Mark/50

Marking

The mark scheme is prescriptive, but markers must make some allowances for alternative answers.

A value quoted at the end of a section must have the units included. Candidates lose a mark the first time that they fail to include a unit, but not on subsequent occasions except where it is a specific part of the question.

Significant figures are related to the number of figures given in the question. A single mark is lost the first time that there is a gross inconsistency (more than 2 sf out) in the final answer to a section. One question does require many sf and that is noted in the mark scheme.

Ecf: this is allowed in numerical sections provided that unreasonable answers are not being obtained. Ecf can not be carried through for more than one section after the first mistake (e.g. a mistake in section (d) can be carried through into section (e) but not then used in section (f)). This applies to Question 11 in particular.

Section A: Multiple Choice

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

5. **B**
6. **D**
7. **C**

1. Half of the hole diameter will reduce the power through the hole to ¼ . This power is spread out to twice the width (not uniformly but we are looking at the centre of the beam before and after) and so to four times the area. Hence 1/16 of the power on the same area at the centre compared with previously.

2. A full earth will be seen when the sun, moon and earth are lined up, which is when you would see a new moon from the earth. The next occasion that this occurs is when the moon has gone through a whole cycle, and so the periods for the phases observed from each body are the same.

3. From 0 to t_1 there is a constant acceleration, which would require a constant force. Added to this there is a force proportional to v. After t_1 there is a constant frictional force alone (no acceleration after t_1). Thus A or C. It is A because the constant force of the acceleration adds to the 0 to t_1 force line (from where it would link the origin to the horizontal force line after t_1).

4. If the room has an identical shape, ten times the length will mean 1000 times the volume and 100 times the surface area. Other factors remain the same.

5. From the fishes eye to the rim of the tank makes an angle of 48° with the vertical. The emerging ray is horizontal (which is the requirement to see the horizon). Hence the depth of the fish is, $d \times \tan 48° = 15.0$, giving d.

6. Friction will produce heat energy and so the total energy will not be PE + KE (or all of the PE will not turn into KE). At a constant velocity there is no gain of KE. On a horizontal surface there is no change of PE. Falling freely, the PE turns solely into KE.

7. A quick mental check can be made on a couple of the data points and then confirmed with a calculator. Laborious working through all of the possibilities for all four data points is not necessary.

Section B: Written Answers

Question 8.

A fibre optic cable is used to transmit signals. When a short pulse of light passes along a fibre, it spreads out, which limits the rate of transmission of signals down the fibre.

a) Suggest two reasons why the pulse of light might spread out.

Variation of refractive index/ speed of light/dispersion with colour/wavelength (of light) ✓

Reflections off the sides/ zigzag path taken by some rays/ some rays take a longer distance to travel (not time, as this is the question) ✓

[2]

b) A fibre of length 10.0 km is illuminated with red light from an led which is turned on and off repeatedly for equal amounts of time. The speed of the pulse of light ranges from 1.95×10^8 m/s to 2.05×10^8 m/s. Calculate the range of times taken for the pulse to travel down the fibre optic.

$t_{long} = 10^4 / 1.95 \times 10^8 = 5.13 \times 10^{-4}$ s (2 or 3 sf)

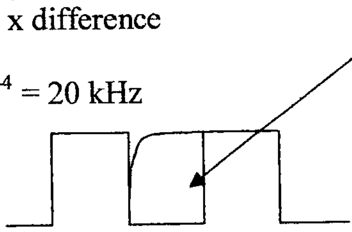
$t_{short} = 10^4 / 2.05 \times 10^8 = 4.88 \times 10^{-4}$ s ✓

(both t needed)

[1]

c) What is the maximum frequency of the led so that the pulses arrive without overlapping?

Difference in times is 0.25×10^{-4} s ✓
This corresponds to the pulse being spread out to fill the space
So period of signal is 2 x difference ✓
Frequency = 1/period
$= 1/ 0.5 \times 10^{-4} = 20$ kHz ✓



[3]

d) The wavelength the LED emits is 1310 nm in air. Calculate the frequency of the light used.

($c = 3.0 \times 10^8$ m/s)

$f = 2.3 \times 10^{14}$ Hz ✓

[1]

e) The frequency of light at the red end of the spectrum is 4 x 10^{14} Hz. Explain in what part of the spectrum the 1310 nm of part (d) is to be found.

(Lower frequency → longer wavelength →) ✓

IR (answer only) ✓ [2]

/9

Question 9.

A gas consists of particles moving around in random directions. Air molecules move with an average speed of 500 m/s at room temperature. In a balloon filled with hydrogen gas at the same room temperature, the hydrogen molecules would have the same average kinetic energy as the air molecules.

average relative molecular mass of air molecule = 29
relative molecular mass of hydrogen molecule = 2.0

a) Calculate the average speed of a hydrogen molecule.

$$\frac{1}{2}m_{air}v_{air}^2 = \frac{1}{2}m_H v_H^2$$ ✓

$$v_H = v_{air}\sqrt{\frac{m_{air}}{m_H}} = 500\sqrt{\frac{29}{2}}$$ ✓ correct substitution

$$v_H = 1900\,m/s$$ (2 or 3 sf) ✓

[3]

b) What is the average velocity of the hydrogen molecules in the balloon?

zero ✓

[1]

c) Comment on how the speed of sound in hydrogen would compare with the speed of sound in air at the same temperature?

Faster in H ✓ because the pressure variations are transferred by the moving molecules ✓
(not just that the molecules move faster but a link between speed of molecules and of sound)
[2]

d) If the mass of all the molecules of the hydrogen gas in the balloon is 1.0 g, calculate the sum of the kinetic energies of all the molecules in the balloon.

$$\frac{1}{2}mv^2 = \frac{1}{2} \times 10^{-3} \times 1900^2$$
$$= 1810\,J \quad ✓$$

[1]

e) If a balloon was filled with an identical number of air molecules at the same temperature, how would the sum of the kinetic energies of the air molecules compare with the value calculated in part (d) for hydrogen?

Air and hydrogen molecules have the same av ke at the same temperature (given)

1810 J or same total ke ✓ [1]

f) If one of the hydrogen molecules was directed upwards from the surface of a planet which had no atmosphere, but was similar in size and mass to the earth and had the same gravitational field strength, to what height would the molecule go? (assume that g is independent of height)

$$\frac{1}{2}mv^2 = mgh \quad ✓ \quad \text{(or without m)}$$

$$h = \frac{v^2}{2g} = \frac{1900^2}{2 \times 9.8} = 184\,km \quad ✓$$

[2]

g) How does this height, calculated in part (f), compare with the height reached by an air molecule directed upwards from the planet in an identical manner? (A numerical answer is not required)

The height reached by the air molecule is (**much**) less ✓ (not slightly less)
(must be clear which molecule is discussed)
($h \propto v^2$ as the mass of the molecule cancels out) [1]

h) This height is not enough to get away from the earth's gravitational pull, and yet the hydrogen molecules at the top of the atmosphere do escape completely from the earth's gravitational field. Explain how this could be so.

The molecules in a gas have a range of speeds ✓

So the faster ones have more ke and can gain more pe (owtte) ✓ [2]

/13

Question 10.

a) The power dissipated as heat in a resistor in a circuit is given by $P = VI$. Show that this may also be expressed as $P = I^2 R$ and $P = \frac{V^2}{R}$.

R=V/I must be explicitly made clear for a mark ✓

[1]

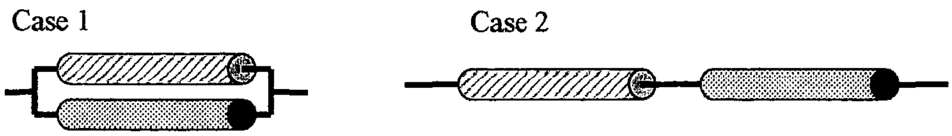
b) A student goes out to purchase an electric heater for his flat. The salesman says that, to get more heat, he should purchase a heater with a high resistance because $P = I^2 R$, but the student thinks that a low resistance would be best, because $P = \frac{V^2}{R}$. Explain who is correct.

Fixed V applied to the heater ✓

(so use V^2/R) and hence low R needed ✓

[2]

c) Copper is a better conductor than iron. Equal lengths of copper and iron wire, of the same diameter, are connected first in parallel, and then in series. A potential difference is applied across the ends of each arrangement in turn, and the p.d. is gradually increased from a small value until, in each case, one of the wires begins to glow. Explain this, and state which wire will glow first in each case.



Case 1: same pd across each wire

So V^2/R implies smaller R for a larger power ✓ EITHER THIS

So copper glows first (lower R value) ✓ (needed)

Case 2: same current through each wire ✓

So I^2R implies larger R for a larger power ✓ OR THIS

So iron glows first (larger R value) ✓ (needed) [4]

d) A surge suppressor is a device for preventing sudden excessive flows of current in a circuit. It is made of a material whose conducting properties are such that the current flowing through it is directly proportional to the fourth power of the potential difference across it. If the suppressor dissipates energy at a rate of 6 W when the applied potential difference is 230 V, what is the power dissipated when the potential rises to 1200 V?

Expression $I = kV^4$ may be implicit in calculation ✓

$P = VI = kV^5$ ✓

So $6 = k \times 230^5 \rightarrow k = 9.3 \times 10^{-12}\ W/V^5$ or $P_{1200} = 6 \times (1200/230)^5$

$P_{1200} = 23\ kW$ ✓ [3]

/10

Question 11.

When a metal rod is heated, it expands uniformly with temperature. The coefficient of linear thermal expansivity, α (alpha), is equal to the fractional increase in length per unit temperature rise.
If a rod of length ℓ expands by an amount $\Delta\ell$ when the temperature rises by $\Delta\theta$ in °C, α is given by,

$$\alpha = \frac{\Delta\ell}{\ell}\frac{1}{\Delta\theta}$$

a) What are the units of α?

$^{o}C^{-1}$ ✓ [1]

A pendulum clock has a metal pendulum. The period of oscillation, T, of the pendulum is given by,

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

where ℓ is the length of the pendulum and g is the acceleration due to gravity. The period of the pendulum is exactly 1 second when the room temperature is such that the clock gives the correct time. On days when the room temperature is 15.0 °C the clock runs 5s fast per day. When the room temperature is 30.0 °C, the clock runs 10s slow per day.

b) When the clock gives the correct time, how many oscillations will occur in a day?

24 x 3600 = 86,400 ✓

[1]

c) For the two temperatures quoted, write down the number of oscillations that would occur in one day.

At 15 °C 86,405 ✓

At 30 °C 86,390 ✓ [2]

d) Calculate the periods of the pendulum, T_{15}, and T_{30}, at the two temperatures.

$T_{15} = 1.000\ 058$ s (6 or 7 sf) ✓

$T_{30} = 0.999\ 884$ s ✓

[2]

e) Calculate the corresponding values of lengths, ℓ_{15} and ℓ_{30}.

$\ell_{15} = 0.248\ 266$ m ✓

$\ell_{30} = 0.248\ 179$ m ✓

[2]

f) Calculate the value of α for the metal of the pendulum.

$\Delta\ell = 0.000\ 087$ m ✓

$$\alpha = \frac{\Delta\ell}{0.248} \times \frac{1}{15}$$ ✓

$= 2.34 \times 10^{-5}\ ^{\circ}C^{-1}$ (2 or 3 sf) ✓

[3]

/11