Centre No.						Paper Reference	Surname	Initial(s)
Candidate No.						6 7 3 6 / 0 1	Signature	

Paper Reference(s)

6736/01
Edexcel GCE
Physics
Advanced Level
Unit Test PHY6

Friday 26 January 2007 – Morning

Time: 2 hours

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1	
2	
3	
4	
Total	

ND0040007290

Materials required for examination
Nil

Items included with question papers
Insert for use in Question 1

Instructions to Candidates
In the boxes above, write your centre number, candidate number, your signature, your surname and initial(s).
Answer **ALL** questions in the spaces provided in this question paper.
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

Information for Candidates
This question paper is designed to give you the opportunity to make connections between different areas of physics and to use skills and ideas developed throughout the course in new contexts. You should include in your answers relevant information from the whole of your course, where appropriate.
The marks for individual questions and the parts of questions are shown in round brackets.
There are four questions in this paper. The total mark for this paper is 80.
The list of data, formulae and relationships is printed at the end of this booklet.
The passage for use with Question 1 is on the enclosed insert. The insert is NOT to be returned with the paper.

Advice to Candidates
You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.

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SECTION I

1. Read the passage on the Insert and then answer the questions.

(a) Use information from the passage to support the statement in line 3 that 'diamond feels colder to the touch than glass'.

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(3)

(b) Construct an algebraic relationship relating k, the thermal conductivity of a material, to the physical quantities Q, t, ΔT, A and d described in paragraph 2.

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Use your expression to confirm that k has the unit $\text{W m}^{-1}\,\text{K}^{-1}$.

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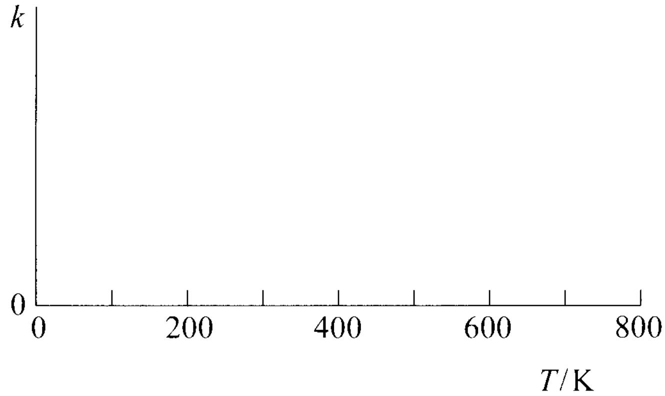
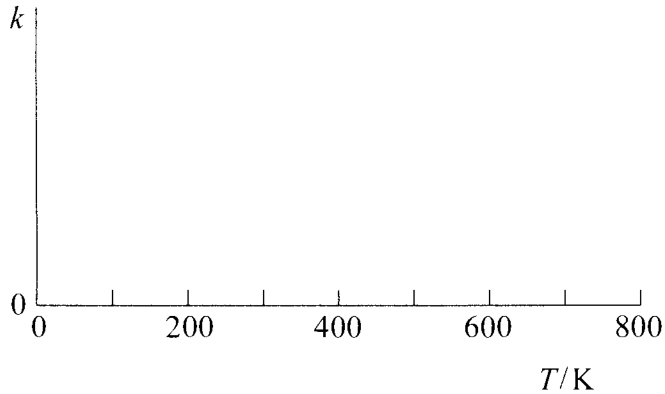
(3)

(c) Sketch three graphs on the axes below to show how the thermal conductivity k of copper, ice and air are said to vary with kelvin temperature T.

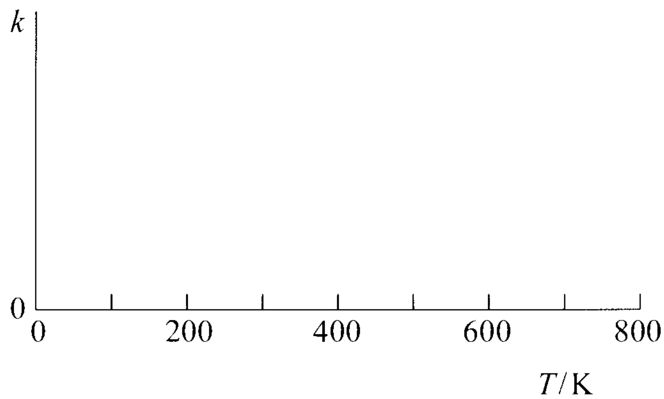
Copper



Ice



Air



(6)

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(d) (i) Assuming air to be an ideal gas, show that 2.00 mol of air at 18.0 °C and 102 kPa has a volume of about 0.05 m^3.

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Deduce the heat capacity of 2.00 mol of air at 18.0 °C and 102 kPa.

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(4)

(ii) Two statements in the passage tell you that air is not an ideal gas. Identify the statements and explain why they mean that air is not an ideal gas.

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(4)

Leave blank

(e) (i) Draw a sketch to show the volume a gas particle sweeps out between two consecutive collisions (paragraph 4).

For a gas with a fixed number of particles per unit volume, explain why the average distance between collisions gets smaller as the scattering cross-section gets bigger.

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(3)

(ii) The thermal conductivity of air and the mean speed of air particles at 18.0 °C and 102 kPa are 0.024 W m^{-1} K^{-1} and 510 m s^{-1} respectively. Calculate the average distance between collisions for air particles under these conditions. How does your value compare with the size of a typical gas molecule?

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(3)

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(f) Explain what is meant by a heat current in a gas (paragraph 3). You may be awarded a mark for the clarity of your answer.

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(4)

(g) The thermal conductivity of air can be found by measuring the rate of heat loss from an electrically heated straight wire. The heat loss is determined by placing the wire along the centre of an air-filled metal tube that runs through a water bath.

Suggest two problems associated with such a method.

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2. ....

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(2)

Q1

(Total 32 marks)

TOTAL FOR SECTION I: 32 MARKS

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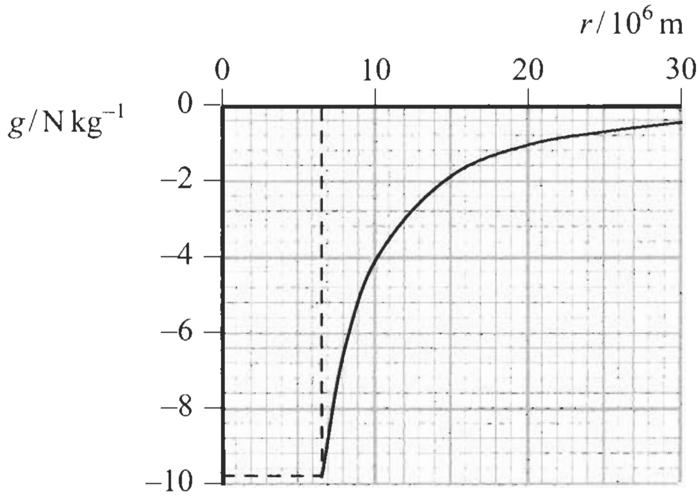
SECTION II

(Answer ALL questions)

2. (a) The graph shows how, above its surface, the Earth's gravitational field strength g varies with distance r along a radius from the Earth's centre.



(i) Use the graph to show that $g \propto r^{-2}$, i.e. that there is an inverse square relationship between g and r.

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Determine the base units of the constant in this relationship.

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(4)

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(ii) Sketch a graph to show how the electric field E produced by a positive point charge varies with distance r along a radius.

Electric fields act on charges. Gravitational fields act on masses. In what other ways do electric and gravitational fields differ?

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(4)

Leave blank

(b) Figure 1 shows a car in a multi-storey car park where the gravitational field strength is $9.8\ \text{N kg}^{-1}$. The gravitational potential difference between each level is $24.5\ \text{J kg}^{-1}$.

Figure 1

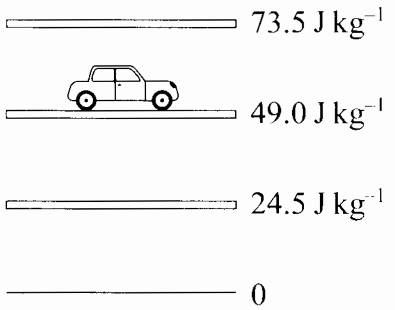
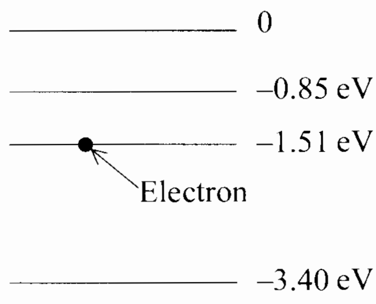


Figure 2



(i) How much gravitational potential energy would a car of mass 1600 kg lose as it moves down one level?

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Deduce the vertical distance between the levels.

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(4)

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(ii) Figure 2 shows an electron and some of the energy levels of atomic hydrogen (the –13.6 eV level is omitted). List **three** ways in which the analogy between electrons in atomic energy levels and cars in multi-storey car parks is a poor analogy.

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2. ....

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3. ....

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Give **one** way in which the analogy is a good one.

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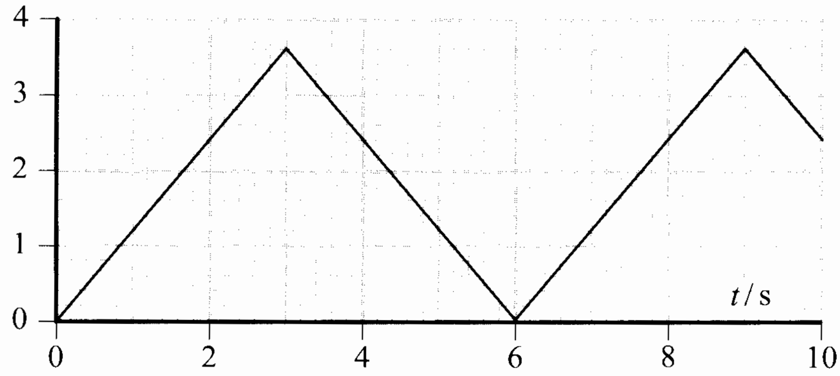
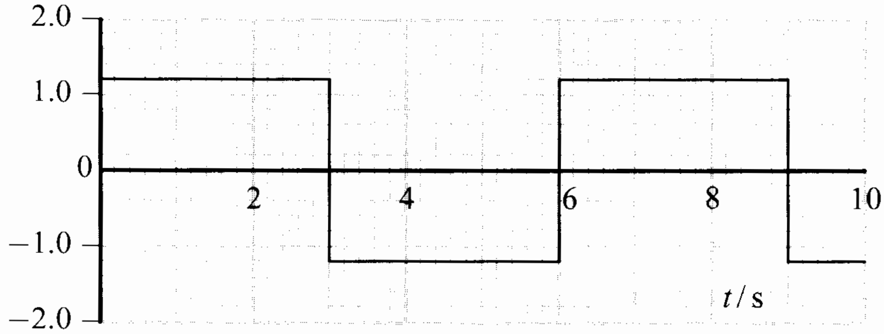
(4)

Q2

(Total 16 marks)

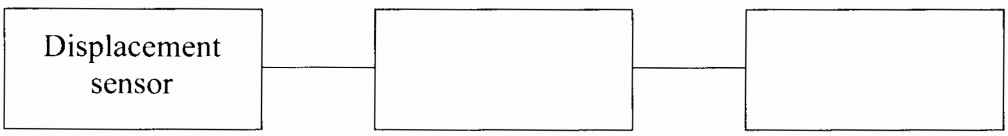
3. Two students, A and B, see related graphs from a datalogging system. The graphs show horizontal time scales but there is no indication of what type of sensor or transducer has been used to capture the numbers 1 to 4 on the vertical axis of the first graph.





(a) Student A suggests that the vertical axis on the first graph is giving the displacement of an object in metres.

(i) Complete the block diagram to indicate how data about displacement can be captured and displayed.



(ii) Explain, using appropriate calculations, what the second graph represents if student A's suggestion is correct.

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(6)

(iii) Outline how student A could use laboratory apparatus to produce motion of the sort recorded by his datalogging system.

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(2)

(b) Student B thinks that the vertical axis on the first graph is giving the electric current in a coil in amperes. The second graph, she deduces, is the e.m.f. in volts induced in a second coil i.e. the vertical axis goes from -2.0 V to $+2.0$ V.

(i) Draw a sketch to show how the two coils would be arranged if she is correct. Explain how an e.m.f. is induced in the second coil in these circumstances.

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(5)

(ii) If the current induced in the second coil is ± 25 mA, calculate the average power transferred to the second coil.

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(2)

Q3

(Total 15 marks)

4. An isotope of thorium, $^{228}_{90}Th$, decays by α-emission to an excited state of radium. The half-life of the decay process is 1.9 years.

(a) (i) Complete the nuclear equation for this decay:

$$^{228}_{90}Th \rightarrow \quad Ra + \alpha$$

(ii) What fraction of a sample of thorium-228 will remain after 5.0 years?

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(5)

(iii) The masses of the particles in the decay are:

Thorium 227.9793 u; Radium 223.9719 u; Alpha 4.0015 u

Calculate the mass loss in the decay and hence deduce the speed of the emitted alpha-particle. State any assumption you make.

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(4)

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(b) The radium nucleus decays almost immediately to its ground state by emitting a 217 keV photon.

(i) Show that the photon has a wavelength of about 6×10^{-12} m and state where such photons are found on the electromagnetic spectrum.

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(4)

(ii) Suggest how, in principle, you would demonstrate (1) the wave-like nature of such photons, and (2) the particle-like nature of such photons.

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2. ....

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(4)

Q4

(Total 17 marks)

TOTAL FOR SECTION II: 48 MARKS

TOTAL FOR PAPER: 80 MARKS

END

List of data, formulae and relationships

Data

Speed of light in vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\ m^{2}\ kg^{-2}}$	
Acceleration of free fall	$g = 9.81\ \mathrm{m\ s^{-2}}$	(close to the Earth)
Gravitational field strength	$g = 9.81\ \mathrm{N\ kg^{-1}}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$	
Electronvolt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$	
Unified atomic mass unit	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$	
Molar gas constant	$R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$	
Coulomb law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^{9}\ \mathrm{N\ m^{2}\ C^{-2}}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N\ A^{-2}}$	

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

$$x = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

Forces and moments

Moment of F about O = $F \times$ (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $$F = m\frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$$

Impulse $$F\Delta t = \Delta p$$

Mechanical energy

Power $$P = Fv$$

Radioactive decay and the nuclear atom

Activity $$A = \lambda N$$ (Decay constant λ)

Half-life $$\lambda t_{\frac{1}{2}} = 0.69$$

Electrical current and potential difference

Electric current $I = nAQv$

Electric power $P = I^2R$

Electrical circuits

Terminal potential difference $V = \mathcal{E} - Ir$ (E.m.f. $\mathcal{E}$; Internal resistance r)

Circuit e.m.f. $\Sigma\mathcal{E} = \Sigma IR$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Heating matter

Change of state: energy transfer $= l\Delta m$ (Specific latent heat or specific enthalpy change l)

Heating and cooling: energy transfer $= mc\Delta T$ (Specific heat capacity c; Temperature change ΔT)

Celsius temperature $\theta/°\mathrm{C} = T/\mathrm{K} - 273$

Kinetic theory of matter

Temperature and energy $T \propto$ Average kinetic energy of molecules

Kinetic theory $p = \frac{1}{3}\rho\langle c^2\rangle$

Conservation of energy

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Energy transferred thermally ΔQ; Work done on body ΔW)

Efficiency of energy transfer $= \dfrac{\text{Useful output}}{\text{Input}}$

Heat engine maximum efficiency $= \dfrac{T_1 - T_2}{T_1}$

Circular motion and oscillations

Angular speed $\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r}$ (Radius of circular path r)

Centripetal acceleration $a = \dfrac{v^2}{r}$

Period $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$ (Frequency f)

Simple harmonic motion:

displacement $x = x_0 \cos 2\pi ft$

maximum speed $= 2\pi f x_0$

acceleration $a = -(2\pi f)^2 x$

For a simple pendulum $T = 2\pi\sqrt{\dfrac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\dfrac{m}{k}}$ (Spring constant k)

Waves

Intensity $I = \frac{P}{4\pi r^2}$ (Distance from point source r; Power of source P)

Superposition of waves

Two slit interference $\lambda = \frac{xs}{D}$ (Wavelength λ; Slit separation s; Fringe width x; Slits to screen distance D)

Quantum phenomena

Photon model $E = hf$ (Planck constant h)

Maximum energy of photoelectrons $= hf - \varphi$ (Work function φ)

Energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p}$

Observing the Universe

Doppler shift $\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$

Hubble law $v = Hd$ (Hubble constant H)

Gravitational fields

Gravitational field strength $g = F/m$

for radial field $g = Gm/r^2$, numerically (Gravitational constant G)

Electric fields

Electric field strength $E = F/Q$

for radial field $E = kQ/r^2$ (Coulomb law constant k)

for uniform field $E = V/d$

For an electron in a vacuum tube $e\Delta V = \Delta(\frac{1}{2}m_e v^2)$

Capacitance

Energy stored $W = \frac{1}{2}CV^2$

Capacitors in parallel $C = C_1 + C_2 + C_3$

Capacitors in series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Time constant for capacitor discharge $= RC$

Magnetic fields

Force on a wire $F = BIl$

Magnetic flux density (Magnetic field strength)

in a long solenoid $B = \mu_0 nI$ (Permeability of free space μ_0)

near a long wire $B = \mu_0 I / 2\pi r$

Magnetic flux $\Phi = BA$

E.m.f. induced in a coil $\varepsilon = -\dfrac{N\Delta\Phi}{\Delta t}$ (Number of turns N)

Accelerators

Mass-energy $\Delta E = c^2 \Delta m$

Force on a moving charge $F = BQv$

Analogies in physics

Capacitor discharge $Q = Q_0 e^{-t/RC}$

$$\frac{t_{\frac{1}{2}}}{RC} = \ln 2$$

Radioactive decay $N = N_0 e^{-\lambda t}$

$$\lambda t_{\frac{1}{2}} = \ln 2$$

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

$$\sin(90° - \theta) = \cos\theta$$

$$\ln(x^n) = n \ln x$$

$$\ln(e^{kx}) = kx$$

Equation of a straight line $y = mx + c$

Surface area cylinder $= 2\pi rh + 2\pi r^2$

sphere $= 4\pi r^2$

Volume cylinder $= \pi r^2 h$

sphere $= \frac{4}{3}\pi r^3$

For small angles: $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

$\cos\theta \approx 1$

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This passage accompanies the question paper and forms an integral part of Question 1.

The conduction of heat

At room temperature diamond is the best-known thermal conductor. This is a surprise to most physicists, because they tend to remember (correctly for the most part) that metals conduct heat better than electrical insulators like diamond or glass. Diamond feels colder to the touch than glass – a poor thermal conductor – as it conducts heat away from the skin a thousand times faster than glass does, which is why diamonds are known in underworld slang as 'ice'.

The thermal energy or heat Q passing through a region of material in a time t is proportional to the temperature difference ΔT and the surface area A of the region, but inversely proportional to the thickness d of the region. The constant of proportionality k is called the thermal conductivity of the material through which the energy is passing. For diamond k is about 2000 W m^{-1} K^{-1}, for glass it is 1.7 W m^{-1} K^{-1}. For metals above room temperature the thermal conductivity is independent of temperature, but for crystalline electrical insulators like real ice (frozen water) k is inversely proportional to the kelvin temperature T.

The mechanism of heat transport in gases results from the free motion of atoms or molecules. Thermal energy spreads because particles with higher kinetic energy diffuse into regions where the particles have lower kinetic energy. There is thus a 'kinetic energy current' that in a gas is the same thing as a heat current. The kinetic theory of gases gives the following formula for the thermal conductivity of a gas:

$$k = \tfrac{1}{3} h v l$$

where h is the heat capacity per unit volume of the gas, v is the mean molecular speed and l is the average distance between particle collisions. For air at 18.0 °C and 102 kPa, $h = 870$ J m^{-3} K^{-1}.

The volume an air particle of radius r sweeps out between collisions is $\pi r^2 l$. The distance l is thus inversely related to the size of the scattering cross section $4\pi r^2$, the 4 arising as the centre-to-centre distance between colliding particles is $2r$. Experiment shows that the thermal conductivity for gases such as air depends upon $T^{\frac{3}{4}}$. This dependence is not exactly as theory predicts, the discrepancy coming from the fact that the effective scattering cross-section decreases at high T when air particles move faster and are less affected by intermolecular forces.

[Adapted from 'The conduction of heat' by Philip B. Allen in *The Physics Teacher*, December 1983]