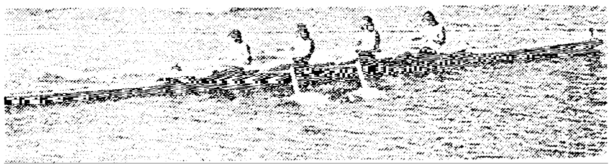
1997

Question 1 *[14 marks]*

(a) The speed of a rowing boat (skiff) increases as the number of rowers increases. The data below, recorded by the fastest crews at a recent Olympic competition, show the effect.

rowers per skiff *(n)*	1	2	4	8
maximum speed (m/s)	4.487	4.852	5.265	5.678



(four-person skiff)

From a knowledge of fluid physics one can predict that the relationship between the maximum speed, v, and the number of rowers, n, should have the form 1

$$v = A\, n^{1/9}$$

A is a constant which depends on the skiff s shape. All Olympic skiffs have similar shape and, therefore, the same A.

(i) Use the data in the table above to construct a linear graph which will test the predicted 9 power law. Is the prediction confirmed? [6 marks]

(ii) Determine a value for A. [1 mark]

(iii) How many rowers are required to produce a speed of 6 m/s? [2 marks]

(b) The power P required to displace force F along its direction with speed v is given by $P = F\,v$ .This is useful in what follows.

(i) A superbly fit rower can work at the rate of about 400 W for a few minutes. Use this fact, the data in the table and the power equation stated above to determine the drag force on the one-rower skiff when at full speed. [1 mark]

(ii) In general, the drag force on a skiff's hull is proportional to the square of the speed, that is

$$F_{drag} = B\, v^2$$

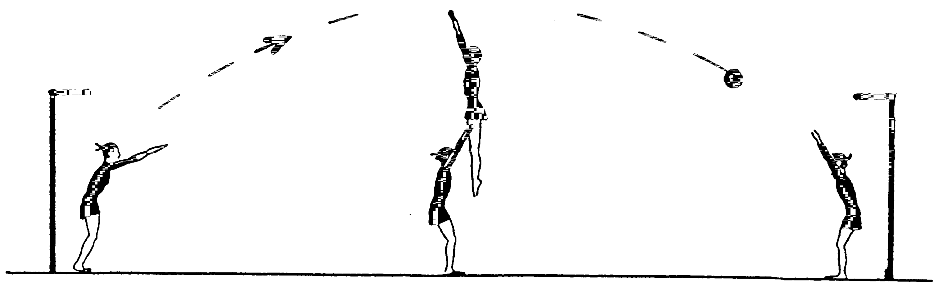
where B is a constant

What is the drag force on the one-rower skiff when moving at 3 m/s? [1 mark]

(iii) Hence determine the instantaneous acceleration of the one-rower skiff if, at some moment, the speed of the skiff is 3 m/s and the rower is working at full power. Assume the mass of the skiff plus rower is 110 kg. [3 marks]

Question 2 *[15 marks]*

(a) In a 1998 netball test match the NZ team reveals a new and revolutionary move in which the NZ `Goal Keep' makes a huge throw of 29 m from the goal she defends to the NZ `Goal Shoot' attacking the opposition goal.



< ---------------------------------- 29 m ------------------------------------ >

Because the rules require the ball to be touched in mid-court, one NZ mid-court player is, prior to the throw, lifted and supported by a team member, so that as the ball flies past she can lightly brush it with her finger without impeding its motion.

Assuming the ball is thrown from a height of 2 m and reaches a height of 4 m determine:

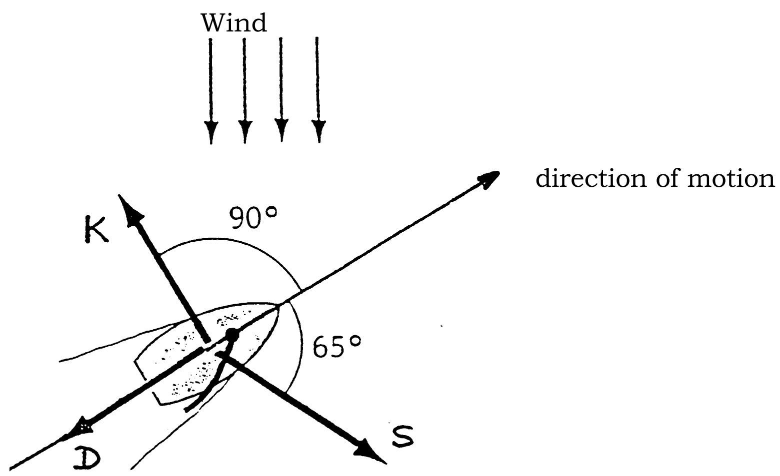
(i) the time of flight [3 marks]

(ii) the horizontal component of velocity [1 mark]

(iii) the initial vertical component of velocity [3 marks]

(iv) the angle to the horizontal at which the ball must be thrown. [2 marks]

(b) To a first approximation the forces on a yacht can be represented by three vectors representing, respectively, the sail force (S), the drag (D) and the keel force (K). These are drawn below, though not to scale.

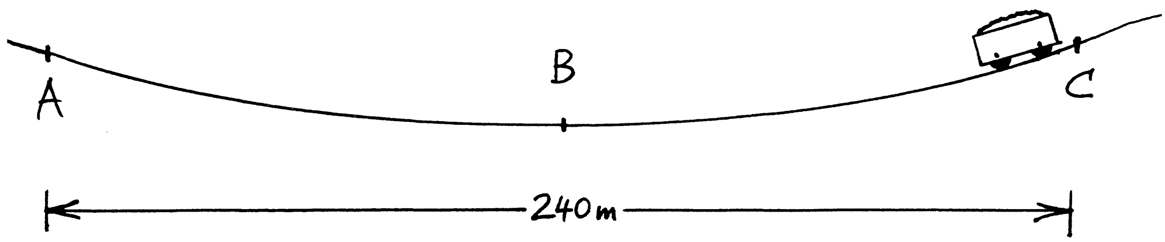


If the yacht's velocity is constant and *K* is 2000 N calculate *D* and *S*. [4 marks]

Captain Cook's ship Endeavour had no keel and for that reason could not sail into the wind. Briefly explain, with the help of the force diagram above, why all flat-bottomed boats are so restricted. [2 marks]

Question 3 *[18 marks]*

A goods train descends at A (see figure) into a hollow section of track. As it climbs out the other side the last wagon snaps its coupling and breaks free, reaching and coming to rest at point C, before rolling back into the hollow.



Trapped in the 240m distance between A and C the wagon, of mass 2000 kg, oscillates in simple harmonic motion about B with a period of 40 s. Friction is relatively slight, so that the wagon oscillates for some time.

(i) Determine the angular frequency, co, for the motion. [1 mark]

(ii) What is the value of the maximum speed attained by the wagon and where does it occur? [2 marks]

(iii) What is the total energy of oscillation? [1 mark]

(iv) What is the height difference between B and C? [1 mark]

(v) What is the height difference, half-way between B and C? [3 marks]

(vi) Sketch a displacement /time graph for one cycle of the motion. Let the wagon be at A when $t = 0$ and let $x = 0$ be at B. Consider displacements to the right to be positive and attach scales to the aces. [3 marks]

(vii) Write down the displacement /time equation which matches your graph above. [2 marks]

(viii) A small hole in the bottom of the oscillating wagon allows sand to trickle out onto the track. Would the distribution of sand along the track be even or not? Briefly explain with the aid of a sketch; assume the loss of sand does not significantly alter the wagon's mass. [2 marks]

(ix) Suppose that when the wagon was at C, the sides suddenly burst open and much of the sand was suddenly lost from the wagon. Briefly explain whether or not the energy of the wagon plus the remaining sand would be more than, less than, or the same as before. Likewise, what would happen to the amplitude of oscillation? [3 marks]

Question 4 *[l4 marks]*

(a) A solid disc of mass m and rotational inertia I rolls from rest down a ramp. After falling height h the disc has acquired translational speed v and angular velocity ω.

(i) Write mathematical expressions for:

(1) the gravitational potential energy lost by the disc

(2) the translational kinetic energy gained by the disc

(3) the rotational kinetic energy gained by the disc

(ii) Use the expressions obtained in (i) and the Principle of the Conservation of Mechanical Energy to obtain the energy equation governing the disc's motion. [1 mark]

(iii) The rotational inertia of a solid disc, radius r, about its axis, is $I = mr^2 /2$. Show that after losing height h the disc translates with speed $v = \sqrt{(4gh/3)}$ [2 marks]

(iv) The speed in (iii) above refers to the centre of the disc. What are the speeds of the top and the bottom of the disc? [2 marks]

(v) Show that, at any instant, the linear kinetic energy is twice the rotational kinetic energy. [2 marks]

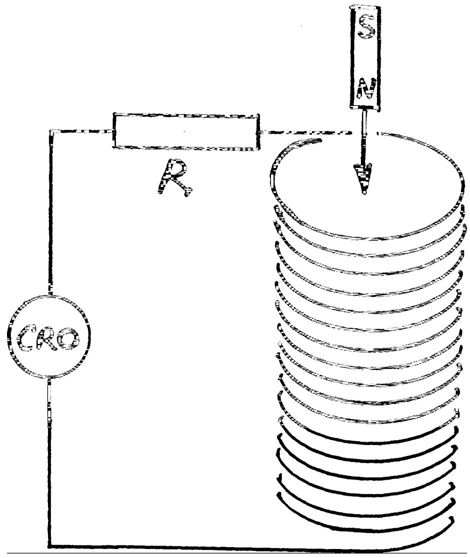
(b) A uniform block of polished wood, into which two small marker pens have been inserted, lies on a large slippery floor, as shown.

One end of the block is struck hard with a hammer and the block moves off, sliding for some distance along the floor. One pen traces the path of the block's centre while the second pen traces the path near one end.

Sketch the nature of pattern left by the pens and, in a few sentences, explain why the shapes are so. [4 marks]

Question 5 *[17 marks]*

(a) A magnet is dropped through a long vertical coil, as shown schematically in the diagram. The coil is connected to an oscilloscope from which a graph of the coil voltage *versus* time is obtained.



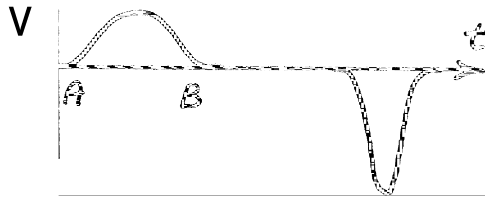
(i) Explain in physical terms the origin of the first pulse. [1 mark]

(ii) Why are there two pulses and why of opposite polarity? [2 marks]

(iii) The second pulse has a larger peak voltage than the first although the pulses seem to have the same 'area'. Explain both features. [2 marks]

(iv) What is the direction of current through the resistor ***R*** during the time interval AB - from left to right or right to left ? [1 mark]

(v) The coil is now replaced by a relatively close-fitting long aluminium tube and the magnet again dropped in the top. What happens and why? [2 marks]



(b) In the circuit below the 12 V and 5 V cells establish currents *1* and I_1 as shown.

(i) Apply Kirchhoff s voltage rule to the left-hand loop of the circuit and obtain the associated equation relating *I* and *I~*. [1 mark]

(ii) Apply Kirchhoff s voltage rule to the outer loop of the circuit and show that

$$SI = 7+ 21_1$$ [2 marks]

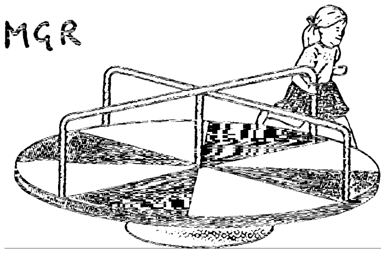
(iii) Solve for the currents *I* and I_1. (They have integer and half-integer values) [2 marks]

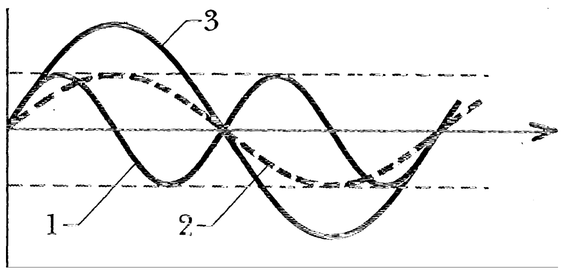
(iv) How much energy is dissipated in the 4 S2 resistor in 60 s? [3 marks]

(v) Which, if either, cell is being charged? [1 mark]

Question 6 *[I6 marks]*

(a) A friend rides, in turn, the rims of three fast Merry-Go-Rounds (MGR's) while holding a sound source that emits equally, in all directions, at frequency L. You stand far from the MGR's and, as each MGR rotates, listen to the frequency variation of the sound. The graphs below, marked 1, 2 and 3, show this frequency variation with time for the three MGR's.



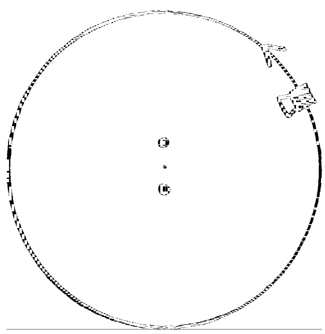


(i) List the MGR's according to their linear speed (v) of the sound source, fastest first. [2 marks]

(ii) List the MGR's according to their the angular velocity (0)) of rotation, highest first. [2 marks]

(iii) List the MGR's according to their radius, largest first.. [2 marks]

(b) Two radio-frequency point sources, separated by 2.0 m, radiate in phase with X.=O.SOm.



A detector D moves once around a circular path which is centred on the two sources, and in a plane containing them, as shown. without calculation, how many maxima will be detected? Illustrate with a sketch. [4 marks]

Question six continued over the page ....

(c) The picture below shows a stretched string of length L and four pipes (a,b,c,d) of lengths L, $2L$, $L / 2$ and $L / 2$ respectively.

The string's trension is adjusted until the speed of sound on the string equals the speed of sound waves in air. The string is vibrating in its fundamental mode. One of the pipes will resonate with the sound from the string. Identify the pipe, explain why it is resonant, and sketch the oscillation mode established within it.

[6 marks]

Question 7 *[17 marks]*

(a) The diagram below, which relates to an electron accelerator, shows the `race-track' path of an electron in a region totally filled with a uniform magnetic field and partially filled with electric field. The magnetic field is perpendicular to the page and it covers the whole diagram; electric fields, however, exist only between the top pair and the bottom pair of plates.

The path consists of two straight sections and two half circles of radius R.

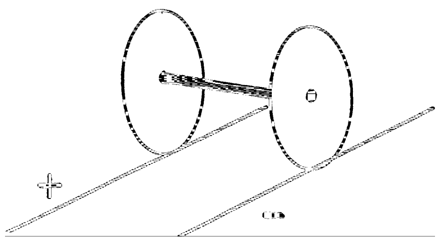
(i) Must the magnetic field be directed into, or out of, the page? [1 mark]

(ii) Given that the electron has mass m, charge q and velocity v, write an equation for B, the strength of the magnetic field required. [2 marks]

(iii) Indicate, with a + or -sign, how the top two metal plates (A, B) must be charged and sketch the electric field lines -and their direction -between them. [2 marks]

(iv) Deduce an equation relating the electric field E, the magnetic field B and the velocity v. [2 marks]

(b) A new design for an electric train is as follows: The engine is driven by the force on the conducting axle due to the vertical component of the Earth's magnetic field. Current from a source passes down one rail, through the axle, and back to the source through the other rail.



(i) If the vertical component of the Earth's field is 10μT and the ale length is 1.8 m, what current is needed to provide a 10 k• force? [2 marks]

(ii) Calculate the resistance of 1 km of iron rail, resistivity $9.0 \times 10^{-\$}$ S2 m and cross-section 40×10^{-4} m^2. [2 marks]

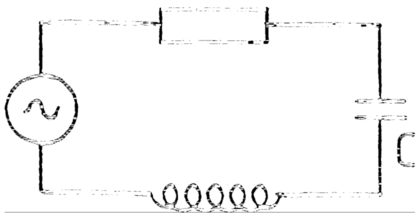
(iii) How much power would be dissipated in each km of rail? [2 marks]

(iv) Using $B = 2\ 10^{-7} I/d$,calculate the force on lkm of rail due to the other. Assume a separation of 1.8m. [2 marks]

(v) Is such a train totally unrealistic or marginally so? Why? [2 marks]

Question S *[19 marks]*

(a) The *LCR* circuit below is driven by an AC source, of negligible resistance, at angular frequency *co* .



Such a circuit has impedance given by

(i) Sketch a typical phasor diagram showing the phase angle *9* between the source voltage V_{een} and the circuit current *I*. [1 mark]

(ii) Write an expression for *tamp*. [1 mark]

(iii) Show in a sketch what happens to the angle *9* if *L* is increased. [1 mark]

(iv) What happens to the angle *tp* if *C* is increased? [1 mark]

(b) Consider the circuit below which consists of an *LCR* circuit driven by an AC source of 240 V rms and negligible resistance.

(i) With the switch in position 1 the rms current is 2 A. Calculate the numerical value of the reactance, *X*. [1 mark]

(ii) With the switch open, as shown, the resistance is included in the circuit. Given that the source voltage lags the current by 20°, determine *R*. [1 mark]

Question eight continued over the page ....

(iii) Using your results for (i) and (ii) deduce that

[1 mark]

(iv) When the switch is in position 2 the phase angle changes to a new value. The source voltage is now found to lead the current by 10°.

Show that

(vi) Given that w = 400 s^{-1}, combine the results from (iii) and (iv) to determine *C* and *L*. [3 marks]

(c) The figure below shows the circuit of a flashing lamp, like those used to warn car drivers of roadworks. A fluorescent lamp of negligible capacitance is connected across the capacitor of an *RC* circuit charged by a battery of emf *Vban.*

The lamp conducts only when the voltage across it has risen to its breakdown voltage, V ~lash• Then the lamp flashes as the capacitor discharges - completely - through it.

(0 Write an equation describing the rise of voltage across the capacitor in the time interval following one flash and up to the next. [2 marks]

(ii) Illustrate the equation with a sketch. [2 marks]

(iii) Determine *R* if the capacitor is 0.150 μF, the battery emf is 95.0 V (negligible internal resistance), the flash voltage is 72V and two flashes per second are required. [3 marks]

Question 9 *[20 marks]*

(a) Satellites can become charged by the photoelectric effect when sunlight acts upon the metal cladding of the capsule. A platinum metal coating, with its work function of 5.32 eV, inhibits the effect.

(i) Calculate the longest wavelength of incident light that will eject an electron from a platinum surface. [3 marks]

(ii) What danger, if any, is there for the crew working inside the charged capsule? [1 mark]

(iii) Perhaps the capsule should be painted black? Comment. [2 marks]

(b) A 100.0 g sample of wood from a Kauri log uncovered in a Northland swamp has a radiocarbon activity of 2.99 decays / min. A 2.00 g sample from a living tree has a radiocarbon activity of 30.6 decays /min.

(i) State the main assumptions of the radiocarbon dating technique. [2 marks]

(ii) Calculate the number of half-lives that have passed since the Kauri died. (The decay equation is not required to do this.) [2 marks]

(iii) If the half-life of ^{14}C is 5730 years determine when the Kauri died. [1 mark]

(c) The Bohr model predicts that the energy levels of the hydrogen atom are given (in electron-Volt units) by

$$E\ (eV) - \_\ \frac{1326}{n}$$

(i) What name is given to `n'? [1 mark]

(ii) State, verbally and mathematically, the one quantum condition Bohr assumed. [2 marks]

(iii) For what reason is the energy, in the above energy formula, negative? [2 marks]

(iv) A hydrogen discharge lamp glows red because of the dominant red line. This line is the lowest energy transition in the Balmer series. Use the formula above to calculate the energy (in eV) of this transition. [2 marks]

(v) In 1996, for the first time, physicists managed to create a cluster of a few hundred anti-hydrogen atoms. Such atoms consist of a positive electron orbiting a negative proton. Briefly, how would you expect the spectrum of anti-hydrogen to compare with that of normal hydrogen? [2 marks]

Question 10 *[10 marks]*

This question is concerned with the magnitude of the various physical phenomena within our environment. Select ANY TEN of the following and write the approximate value of the physical property, as directed, including the appropriate unit.

(i) the cruising speed of a Jumbo jet aircraft

(ii) the frequency with which TV 1 transmits

(iii) the maximum height to which blood would rise in a vertical tube inserted into the blood supply of a living adult human (blood pressure)

(iv) the mass of a car

(v) the cost of 1 kWh of energy

(vii) the depth in the sea at which the pressure on your immersed body has increased by one atmosphere

(viii) the maximum solar power incident on a 1 m^2 surface in the middle of a hot summer's day

(ix) the track spacing on a standard music CD

(x) the easiest wavelength to see

(xi) the density of air

(xiii) the temperature, in °C, in an oven cooking a large joint of meat

(xiv) the clock speed (MHz) of a Pentium computer chip

(xv) the total electric power capacity of NZ's generating system

(xvi) the highest frequency you can hear

(xvii) the maximum magnetic field from an iron electromagnet

END OF EXAMINATION