HONG KONG ADVANCED LEVEL EXAMINATION
AL PHYSICS
1982 Structural Question

1. The data in the table below is from the Apollo 11 space fight (which resulted in the first manned moon landing). The velocity of the spacecraft is given for various distances from the centre of the Earth. During the period to which this data applied there was no rocket propulsion and the total mass of the spacecraft was $m = 44 \times 10^3$ kg.

Distance from centre of Earth $r/10^6$ m	Velocity v/ms^{-1}
11.0	8406
26.3	5374
54.4	3653
95.7	2619
169.9	1796
209.2	1532
240.6	1356

At the distances from the Earth's centre given in the table the influence of the moon's gravitational field on the motion of the spacecraft is negligible, and you should ignore it when answering the following questions:

(a) Why does the velocity of the spacecraft decrease?

(b) Using the data in the above table, determine the change in gravitational potential energy of the spacecraft as it moves from a distance of 11.0×10^6 m to a distance of 240.6×10^6 m from the Earth's centre.

(c) When the data from the table is used to plot the kinetic energy of the spacecraft as a function of its distance from the Earth's centre, the graph in Figure 1 is obtained (the kinetic energy for $r = 11 \times 10^6$ m has not been plotted since it falls outside the scale chosen).

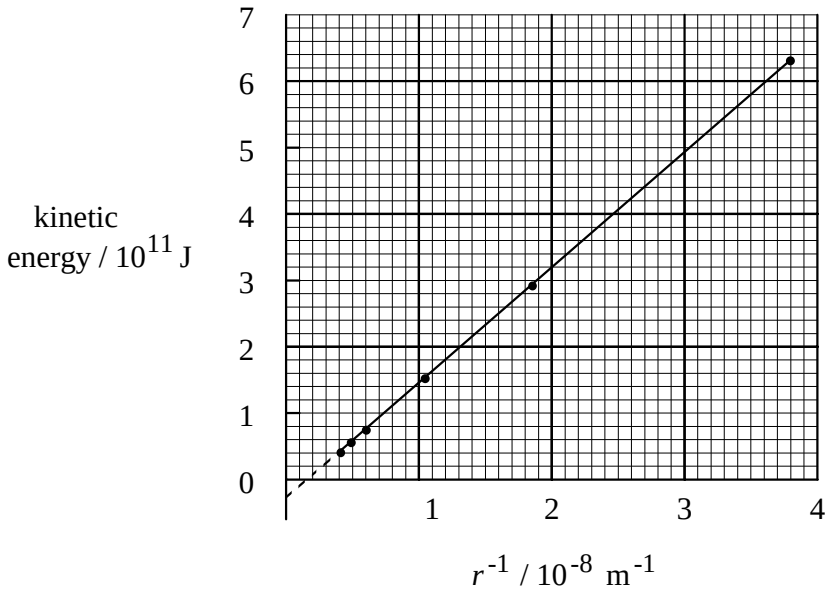


Figure 1

(i) What is the physical significance of the intercept on the kinetic energy axis?

(ii) Write down an expression for the gradient of the line in terms of the gravitational constant G, the Earth's mass M, and the total mass of the spacecraft m. (8 marks)

2. (a)

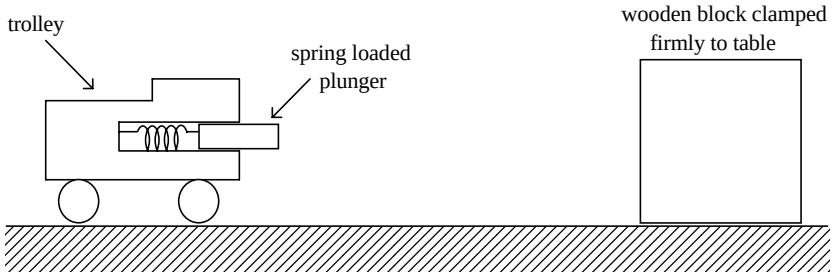


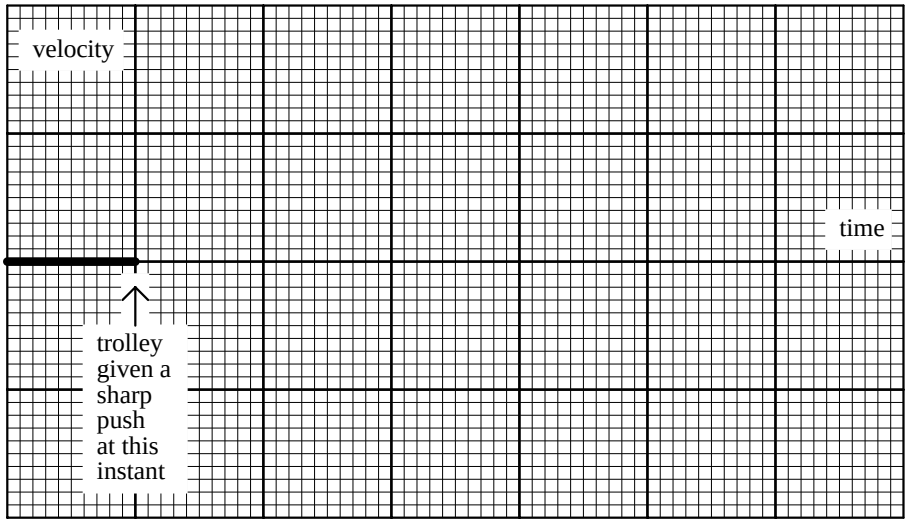
Figure 2

A trolley fitted with a spring-loaded plunger (see diagram above) is initially at rest on a horizontal table. The trolley is given a sharp push and after travelling for some distance it rebounds from a wooden block clamped firmly to the table.

(i) In the space below, sketch the velocity of the trolley as a function of time assuming that

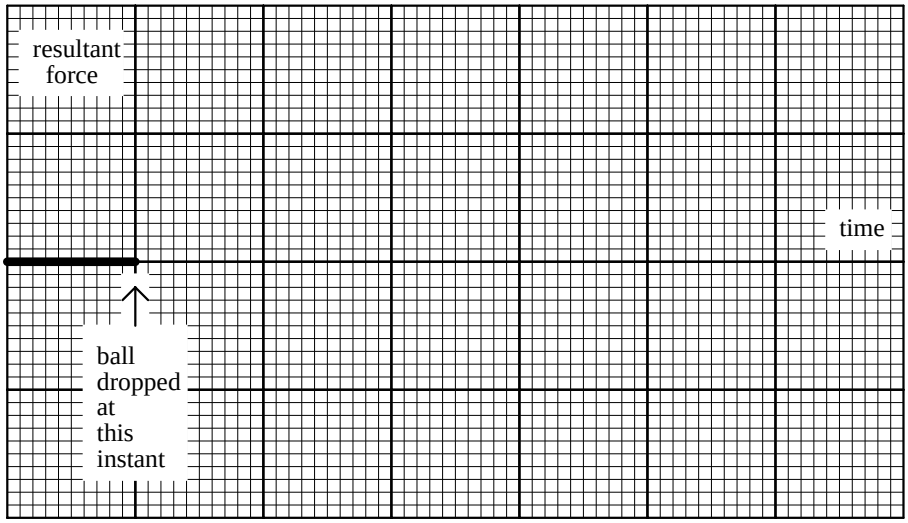
(1) friction in the wheel bearings and between the wheels and the table is negligible, and

(2) during impact there is a 20% energy loss.



(ii) A student argues that this experiment violates the principle of conservation of momentum because the momentum of the trolley before the collision is not equal to its momentum after the collision. Is the student right or wrong? Explain.

(b) A student drops a tennis ball so that it falls vertically onto the ground. The ball bounces several times and eventually comes to rest. In the space provided, sketch the resultant force on the ball as a function of time for the first three bounces.



(7 marks)

3. (a) 60 J of energy is supplied to 2 moles of helium gas placed inside an insulated container.

(i) Explain, in terms of the behaviour of the gas molecules, why the temperature of the gas will increase.

(ii) Given that the molar gas constant is 8.31 J mol^{-1} K^{-1}, estimate the rise in temperature of the gas.

(b) If 2 moles of nitrogen gas were placed in the container instead of the helium gas, would you expect the temperature rise to be (i) smaller than, (ii) equal to, or (iii) greater than that for the helium? Give a brief explanation for your answer.

(7 marks)

4. A satellite moving in an orbit near the Earth's surface and emitting radio waves at a frequency of 40 MHz passes over a ground station in Hong Kong. When the signal is received, it is superposed with another signal output from an oscillator at the receiving station, the frequency of which is very close to 40 MHz. The resulting beat frequency is measured and Figure 3 shows the change in beat frequency as the satellite passes over the station.

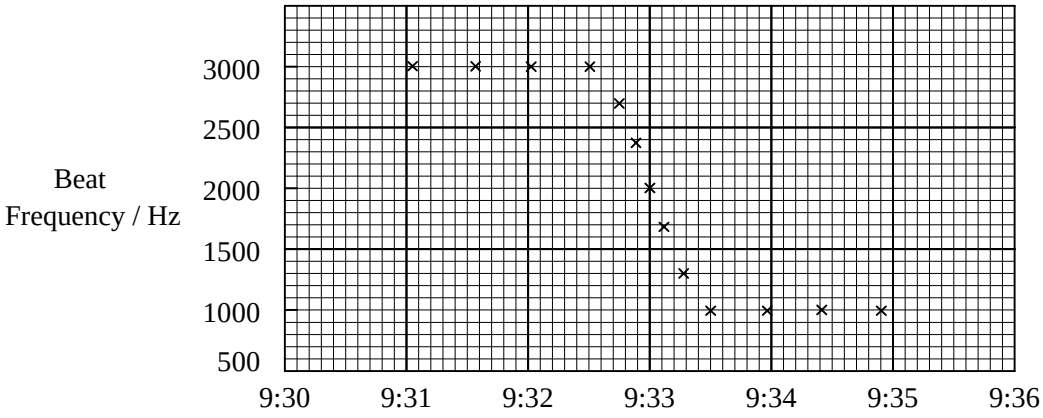


Figure 3

(a) Deduce the velocity of the satellite v. (You may assume that the velocity of radio waves = $c = 3 \times 10^8$ m/s and that $v << c$.)

(b) What is the frequency of the oscillator at the receiving station?
The frequency of the oscillator is _____ Hz above/below (delete as appropriate) the signal frequency of the satellite.

(c) Explain briefly why it is preferable to measure the beat frequency rather than to directly measure the received frequency of the oscillator. (8 marks)

5.

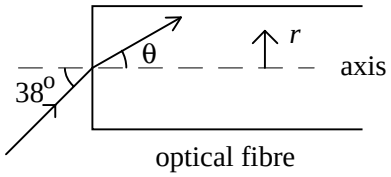


Figure 4

A ray of light is incident centrally at the end face of a cylindrical-shaped optical light-guiding fibre, at an angle of incidence of 38° with the central axis. The refractive index n of this optical fibre varies with the radial distance r from the axis as

$$n = 1.45 - 0.09\, r,$$

where r is expressed in mm.

(a) Calculate the angle of refraction θ of the incident light ray at the first end face.

(b) At a certain point within the optical fibre, the light ray turns back towards the central axis. Find the distance of this point from the axis.

(c) Explain why it is more suitable to use an optical fibre to convey a ray of light than to use a hollow tube of small cross-section with a reflective inner surface.

(7 marks)

6. A circular wire ring is dipped into soap solution and held vertically. When viewed in a dark room with monochromatic light of wavelength 6.5×10^{-7} m reflected normally from the film, a series of interference fringes are seen. The pattern of fringes at a particular instant is shown in Figure 5.

(The refractive index of soap solution = 1.33)

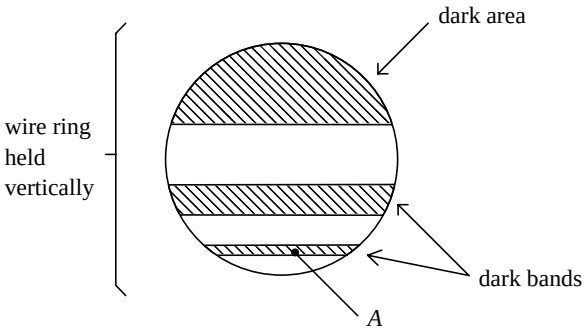


Figure 5

(a) What colour are the fringes?

(b) Why is there a dark area at the top of the ring?

(c) What is the thickness of the film at point *A*?

(d) As time goes on and if the film drains downwards and does not break, the fringe pattern changes from that shown in Figure 5. Describe the changes you would expect to see (explanations are not required). (9 marks)

7.

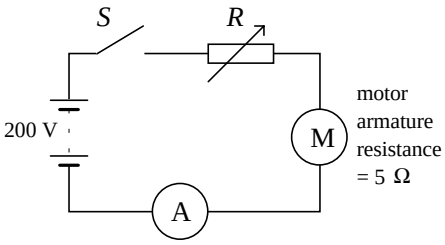


Figure 6

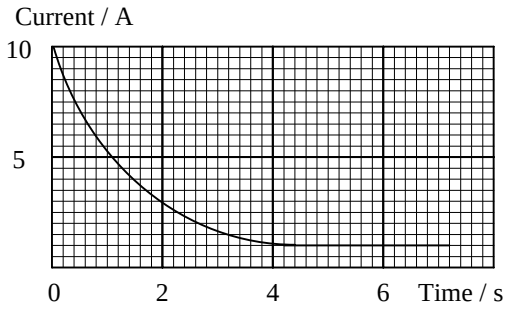


Figure 7

A d.c. source of 200 V supplies power to a circuit containing a motor with armature resistance 5 Ω, a switch *S*, a rheostat *R* and an ammeter *A*, all connected in series. After the switch *S* is closed, the reading on the ammeter changes with time as shown by the curve in Figure 7.

(a) Calculate the resistance of the rheostat *R*.

(b) After the motor has reached constant speed, calculate

(i) the back e.m.f. of the motor,

(ii) the mechanical power output of the motor, and

(iii) the power dissipated as heat in the armature. (7 marks)

8.

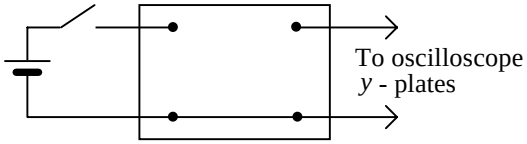


Figure 8

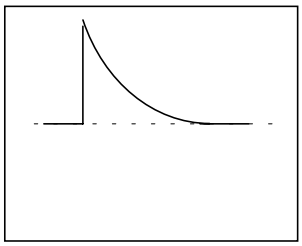


Figure 9

In Figure 8 a battery is connected through a switch to the two input terminals of a four-terminal box. The box contains a resistor and a capacitor, and a wire joins its bottom two terminal as shown.

(a) The output terminals are connected to the y-plates of a cathode ray oscilloscope with its time-base running 'slow'. When the switch is closed a single pulse with the shape shown in Figure 9 is observed as the oscilloscope spot sweeps from left to right across the screen. In the space below, draw a diagram of the circuit arrangement inside the box. You may assume that the input resistance of the oscilloscope is very large.

(b) Draw a diagram of what you think will be seen on the screen when the switch in opened again. Explain briefly.

(c) If a wire is now connected between the two input terminals, draw what you think will be seen on the screen. Explain briefly. (7 marks)

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