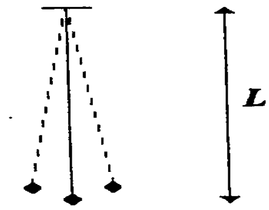
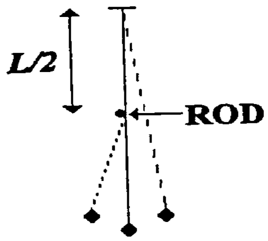
Second Round Question (45 or 60 minutes) / 50 marks

Show all your work in the pages provided. Don't forget to write your name and your academic institution

1. A Simple pendulum as shown in the figure has a period T of 1.00 s



a) Calculate the length L of the pendulum.
b) A small horizontal rod is now placed at a distance L/2 below the point of suspension of the pendulum.

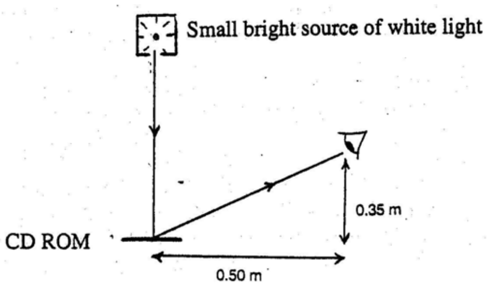


The string collides with the rod once in each oscillation. Calculate the new period T' of the pendulum.

[7 points]

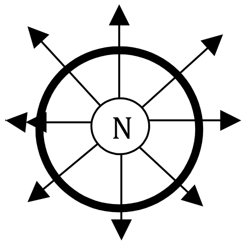
2. A white light shines vertically down on a horizontal CD ROM disc. A person whose eye is at a horizontal distance 0.50 m from the disc and 0.35 m vertically above its horizontal plane views the disc. A yellow light of wavelength 590 nm is observed due to first order diffraction.

a) Deduce the spacing *d* between adjacent tracks of the CD ROM. The CD ROM is tilted, clockwise through an angle of 5_{o}.
b) Determine the wavelength now observed.



(12 points)

3. A metal ring of mass m, radius r with a small radius of the cross sectional area, and resistance R falls, symmetrically, from rest, at time t = 0, in a horizontal radial magnetic field of magnitude B. At time t it has a vertical velocity v, an acceleration a and a current I.



a) Show that, due to the rate at which the magnetic flux is cut, the current induced on the ring is

$$I = 2\pi\, r\, Bv / R$$

b) Deduce that

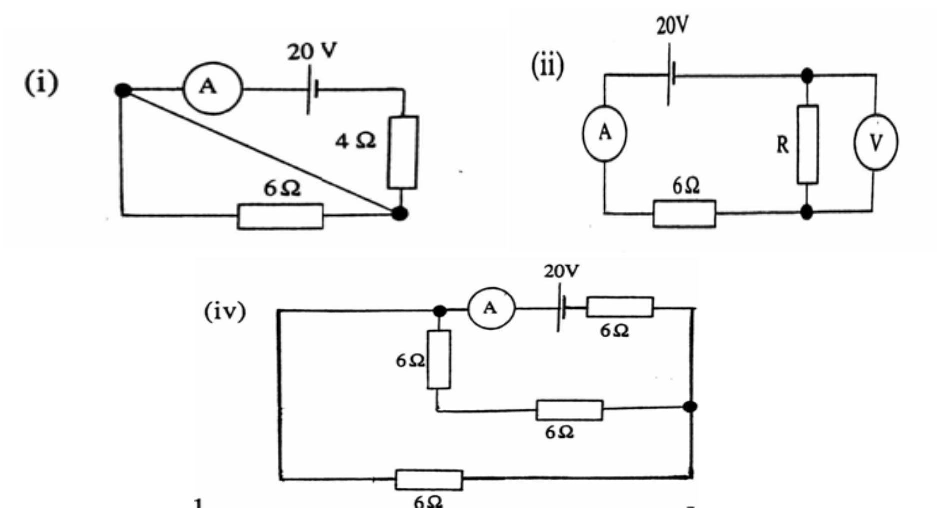
$$ma = mg - (2\pi\, r\, B)^2 v/R$$

c) Derive the initial variation of v with t. Also find the terminal velocity of the ring.

d) Sketch graphically the variation of a and v with t.

(10 points)

4. Determine the current I through the ammeter A in each of the four circuits in the figures below . The ammeter has zero resistance. The voltmeter, in (ii), has infinite resistance and a reading 8V. The resistance R has not been specified.



(6 points)

5. This question comprises of several independent parts.

A star, which is more massive than our sun, typically collapses under its own gravity to form neutron stars. In this case the electrons collapses into the nucleus and form neutrons after fusing with protons. Stars that are initially rotating will rotate faster after the collapse due to the conservation of angular momentum. Let us recall that angular momentum is given by $J = R^2\Omega$ (omitting some constants) where R is the radius of the star and Ω is the angular rate of rotation in radians per second.

a) If the volume of the star decreases by 15 orders of magnitude, and the shape of the star remains the same then what is the ratio of the final to initial radii, $R_{final} / R_{initial}$?

b) If the rotation period of star before the collapse was 20 days, calculate the new period of rotation in seconds and also Ω_{final}.

c) When the core of the star collapses to form neutron star, the electrical conductivity becomes very high. In this case the star's magnetic field becomes frozen into the material of the star and collapse down with the star, increasing the flux density. The resulting neutron stars therefore have very strong magnetic field associated with them. If the magnetic field for the star before the collapse is 10^{-2} T, determine the final magnetic field strength near the surface of the resulting neutron star.

d) If the neutron star spins too fast, it will start losing material from its equatorial region. Show that this implies a minimum period, T_{min} given by

$$T_{min} = \frac{2\pi}{\sqrt{G}} M^{-1/2} R^{2/3}$$

Taking M = 1.4 Solar Masses and R= 10 km, find T_{min} .
(Note Solar Mass=2.0×10^{30} kg)

e) The binding energy of a neutron star is the gravitational potential energy lost when it is formed from a cloud of atom all separated at far distances apart. The binding energy of a star of mass, M and radius R is given by $U= k_1 \frac{GM^2}{R}$ where k_1 is a numerical constant. The behavior of the neutron stars is quite different from ordinary matter and they satisfy the mass-radius relationship given by $RM^{1/3}= k_2$, with k_2 being another numerical constant. Now assume two neutron stars of identical mass fuse and form another more massive star. Assuming the mass-radius relationship to be valid in this process, what is the ratio of the final binding energy of the star to the total initial binding energy?

(15 marks)