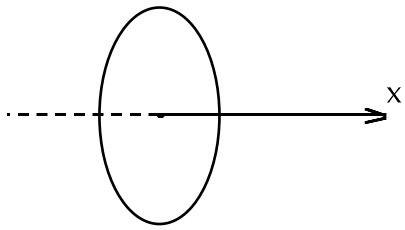
TEST 2

QUESTION 1 **[Marks 11]**

(a) Show that the electric field at a distance *x* from the centre of a circular ring, radius *R*, of charge *Q* and along the axis of the ring is

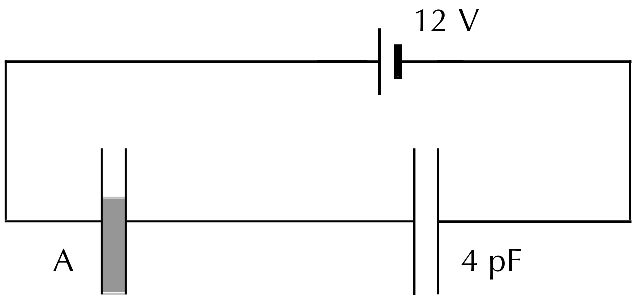
$$\frac{Qx}{4\pi\varepsilon_0\left(x^2+R^2\right)^{3/2}}$$



(b) A point charge *Q* with mass *M* is place at the centre of the ring. When it is displaced slightly the point charge accelerates along the x axis to infinity. Show that the final speed of the point charge is

$$v=\left(\frac{Q^2}{2\pi\varepsilon_0 MR}\right)^{1/2}$$

QUESTION 2 **[Marks 15]**



Capacitor A in the diagram consists of square plates with side length 2 cm. separated by 0.5 cm. Capacitor A is filled with a non-conducting liquid, dielectric constant 3.0, to a height of 1.5 cm.

(a) Determine the capacitance of capacitor A.

(b) Capacitor A is connected in series with a 4 pF capacitor and a 12 V emf. Determine the charge on capacitor A and the potential difference across it.

(c) If all the liquid were suddenly drained out of capacitor A, explain whether the total capacitance of the circuit will increase or decrease and what has happened to any energy gained or lost.

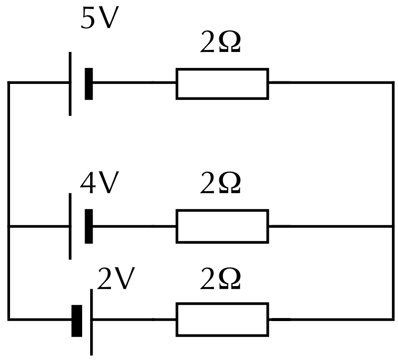
QUESTION 3 **[Marks 11]**

A copper wire has a length 2 m, diameter 1 mm and resistivity 1.7 x 10^{-8} ohm m.

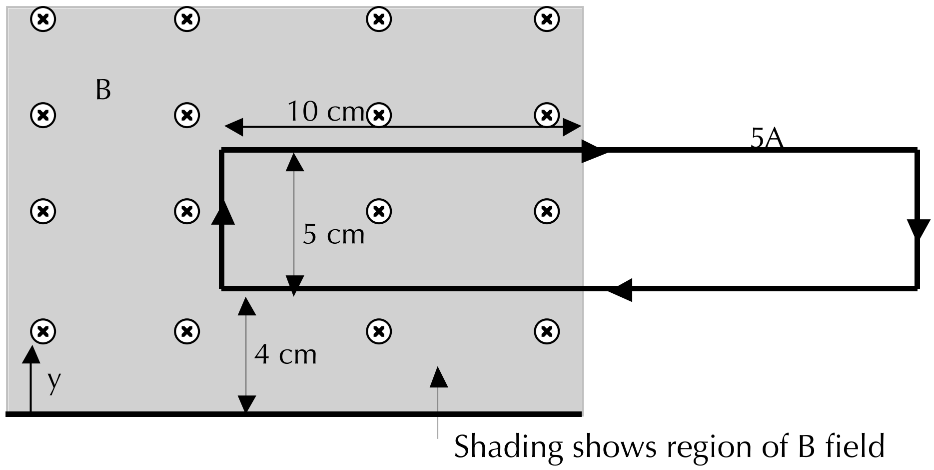
(a) Calculate the resistance of the wire.

(b) A mass of 4.4 kg is suspended from the wire so that its length increases by 1.0 mm. Neglecting any change in diameter, calculate the change in resistance.

(c) Calculate the current flowing through the 4 V emf in the circuit shown.

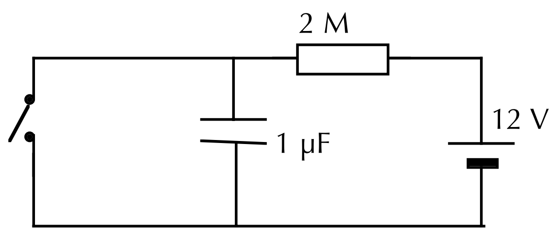


QUESTION 4 **[Marks 10]**



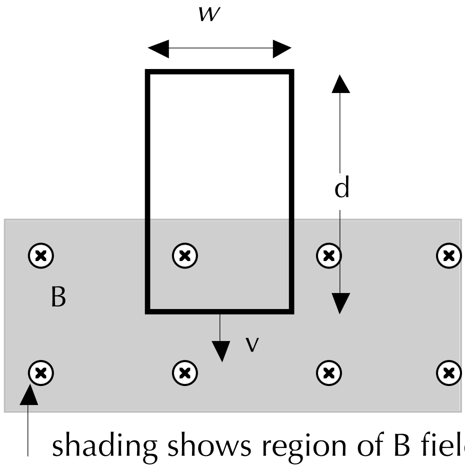
QUESTION 5 **[Marks 7]**

In the circuit shown at right the switch is mechanically operated to be periodically on for 0.5 second, then off for 0.5 second, then on for 0.5 second and so on.
Starting with the switch ON at t = 0, sketch a graph of the potential difference of the capacitor against time for t = 0 to 2 seconds. Include the values of any maximum or minimum voltages.



QUESTION 6 **[Marks 6]**

A conducting rectangular loop of wire of mass M, resistance R, and dimensions w by d falls from rest into a magnetic field B as shown in the diagram. The loop of wire accelerates until it reaches a terminal speed v.



shading shows region of B field

(a) Why does it accelerate no further?

(b) Determine an expression for v in terms of quantities given.

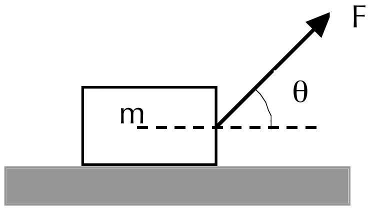
TEST 1R

This is the repeat version of TEST 1, which was held during Session.

This repeat test should be attempted by those students who missed Test 1, or who wish to improve their mark in Test 1.

QUESTION 7 **[Marks 10]**

A block of mass m rests on a rough horizontal surface (coefficients of static and kinetic friction μ_s, μ_k) and is acted on by a force at an angle θ above the horizontal (as shown in the diagram).



(a) With the aid of a sketch clearly show all of the forces acting on the block.

(b) Show that the block will not move, unless

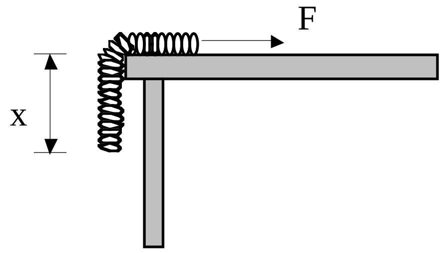
$$F \geq \frac{\mu_s\, mg}{\cos\,\theta + \mu_s\,\sin\,\theta}$$

(c) Calculate the force required to pull the block along the surface at constant speed.

(d) Obtain an expression for the magnitude of the normal force in case (c) above. Check that your expression gives the correct results for the special cases $\theta = 0$, $\theta = \frac{\pi}{2}$.

QUESTION 8 **[Marks 10]**

A uniform heavy rope of total mass m and length l is pulled onto a smooth table at a slow, constant speed as shown in the diagram.



(a) Calculate the magnitude of the applied forces required when a length x of the rope remains hanging.

(b) Sketch F as a function of x.

(c) Calculate the total work needed to pull all of the rope onto the table, if initially it is all hanging.

(d) Calculate the change in potential energy of the rope, from when it is all hanging to when it is all on the table.

QUESTION 9 **[Marks 8]**

(a) Show that the escape velocity for a projectile fired from the Earth's surface is given by

$$v = \sqrt{\frac{2\,G\,M_e}{R_e}}$$

Clearly explain all steps in your derivation.

(b) A meteor of mass 20 kg, moving with negligible speed in deep-space, is captured by the Earth's gravitational field. Neglecting air resistance, calculate the speed of the meteor when it strikes the Earth's surface.

QUESTION 10 **[Marks 12]**

Two objects, of masses 1 kg and 2 kg, move along the *x*- axis. At time t = 0 the objects have positions $x_A = -1$, $x_B = 2$ and constant velocities $v_A = +1.0$, $v_B = -0.5$ (all quantities in SI Units).

(a) Write down expressions for the positions as functions of time, t.

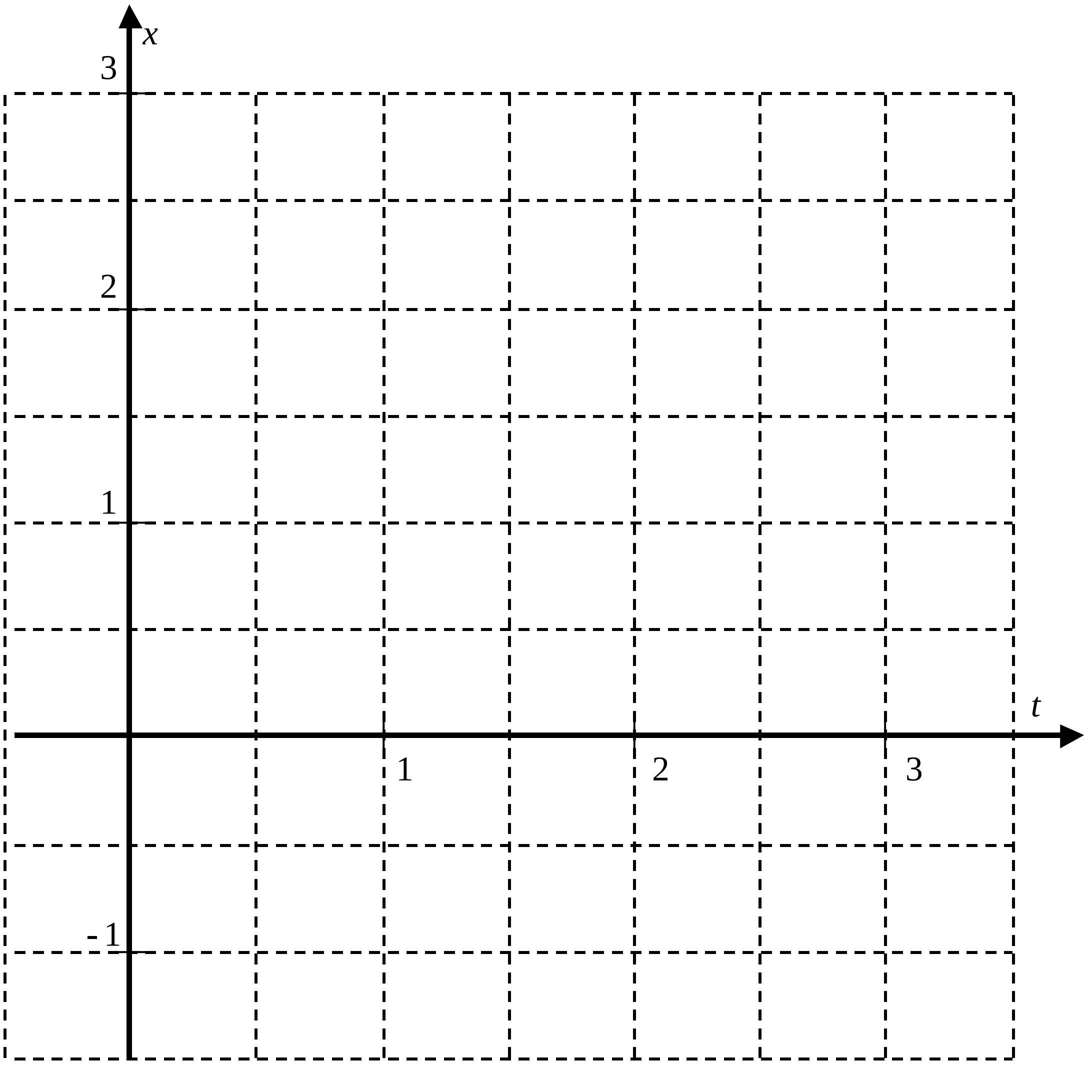
(b) On the graph paper provided below, sketch the position time graph for $0 \le t \le 2$ for each particle (clearly label all curves!).

(c) Calculate the position of the centre-of-mass for $0 \le t \le 2$ and show this on the sketch.

(d) Show that the particles collide at t = 2 and find where the collision occurs.

(e) Assuming the collision is completely inelastic, find the velocity of the combined mass after the collision.

(f) Draw on your sketch the position-time graph of the combined mass after the collision.

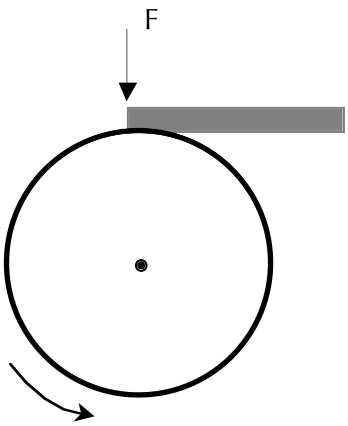


QUESTION 11 **[Marks 10]**

A grinding wheel, in the form of a uniform disk of radius 0.15 m and thickness 0.03 m is mounted on a horizontal axle with frictionless bearings. The wheel is driven by an electric motor which can provide a maximum torque of 6.75 kg m^2s^{-2}. The wheel has a mass of 40 kg.

(a) Calculate the angular acceleration of the wheel, and its angular velocity after 2.0 seconds, if it is run freely at maximum torque, starting from rest.

(b) The grinding wheel is used to sharpen a tool which is pressed onto the wheel with a normal force F. The coefficient of friction is 0.4.



(i) Calculate the magnitude of F, which will result in the wheel turning with constant angular speed, if the motor is providing maximum torque.

(ii) If the motor is providing 500 watts of power to the wheel, what will be its angular velocity?

[The rotational inertia (moment of inertia) of a uniform disk is $^1/_2\ MR^2$]

QUESTION 12 **[Marks 10]**

(a) (i) Define the angular momentum of a rigid body, rotating about a fixed axis. Clearly explain the meaning of all terms and symbols.

(ii) State the conditions under which the angular momentum of a body or system of bodies will be conserved.

(b) Assume that all of the planets in the solar system move in circular orbits.

(i) Derive an expression for the orbital angular velocity of a planet in terms of the radius of the orbit and other parameters.

(ii) Hence show that the angular momentum of a planet is proportional to $mr^{1/2}$, where m and r are the mass and orbit radius respectively.