

## **TEST 2**

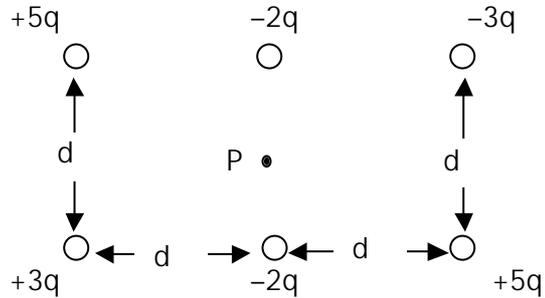
This test is on the final sections of this session's syllabus and should be attempted by all students.

**QUESTION 1**

**[Marks 10]**

Six charged particles are arranged in a rectangle as in the diagram.

- (a) Determine an expression for the electric potential at the point P in the centre of the rectangle.
- (b) Find an expression for the electric field at P and indicate its direction.
- (c) How much work must be done to bring a charge  $q$  from a large distance away and place it at P?



**QUESTION 2**

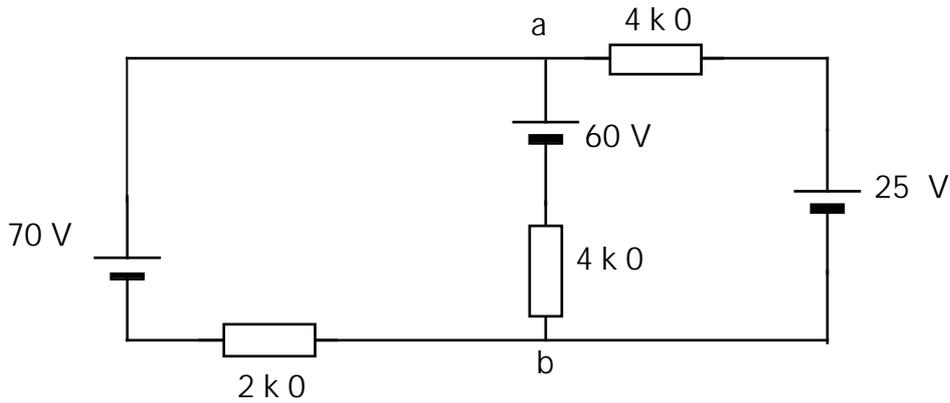
**[Marks 12]**

An isolated, charged parallel plate capacitor has only air between its plates. Initially the plates are 1.0 mm apart and the potential difference between them is  $V_0$ . The plates are then separated to a spacing of 4.0 mm, while the charge on them remains the same, and a slab of dielectric is inserted to fill the space between the plates.

- (a) If the potential difference across the capacitor falls to  $V_0/2$  as a result of these changes, calculate the dielectric constant of the material inserted.
- (b) A second uncharged capacitor with the same capacitance as the altered capacitor is now connected in parallel with it. What will be the potential difference across the combination?

**QUESTION 3**

**[Marks 11]**



- (a) Determine the current in each resistor in the diagram including the direction of flow.
- (b) Calculate the potential difference between *a* and *b*.

**QUESTION 4**

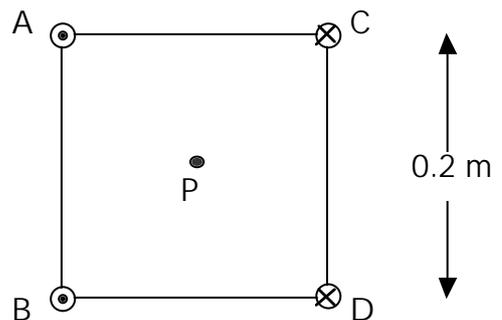
**[Marks 10]**

- (a) Outline the principles of operation of a mass spectrometer. Include a derivation of the diameter of a particle's path  $x$  in the magnetic field as a function of its mass,  $m$ , its charge,  $q$ , the magnetic field strength,  $B$ , and the potential difference through which it has been accelerated,  $V$ .
- (b) If two different carbon isotopes of masses 12 and 14 atomic mass units are introduced into the spectrometer, what will be the distance between the points where they are detected in the spectrometer? Assume each has a single positive charge, the magnetic field is 0.6T and the accelerating voltage is 8 kV.

**QUESTION 5**

**[Marks 7]**

The diagram shows four long parallel wires arranged in a square of side 0.2 m, each carrying a current of 3.0 A. At A and B the current is out of the page (indicated by the dots) and at C and D the current is into the page (indicated by the crosses). Determine the magnitude and direction of the magnetic field at the point P at the centre of the square.

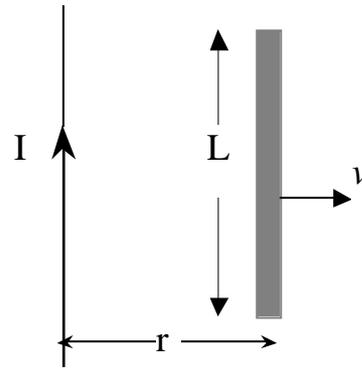


**QUESTION 6**

**[Marks 10]**

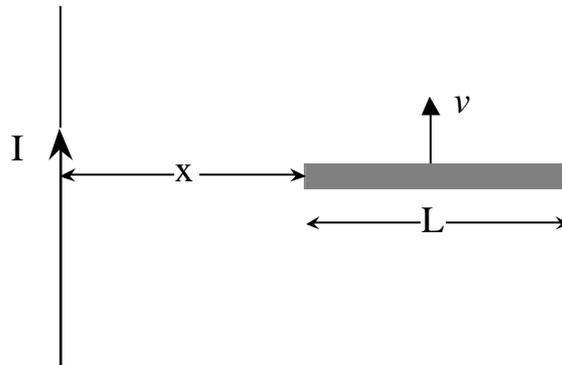
- (a) A rod of length  $L$  is moving at a constant velocity  $v$  away from a long wire carrying a current  $I$  as in diagram (a). Determine the emf induced in the rod when it is at a distance  $r$  from the wire.

*diagram a*



- (b) Determine the emf induced in the same rod when it is moving parallel to the wire as in diagram (b).

*diagram b*



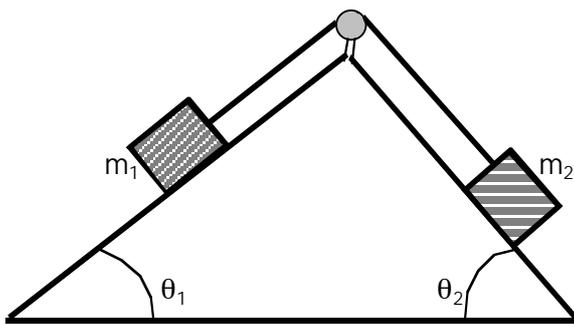
## TEST 1R

### QUESTION 7

[Marks 11]

- (a) A skater travelling initially at a speed of 12 m/s comes to a halt in a distance of 95 m. Calculate the coefficient of kinetic friction between the skates and the ice.

(b)



Two objects of masses  $m_1$  and  $m_2$  are located on a frictionless double incline, as shown in Figure. They are connected by a fixed-length, mass-less rope passing over a smooth, mass-less pulley. The two sides of the incline make angles of  $\theta_1$  and  $\theta_2$  with the horizontal, respectively.

- (i) draw a diagram showing all the relevant forces acting in this problem,
- (ii) derive a simple relationship between the masses and the angles when the system is in equilibrium.

**QUESTION 8**

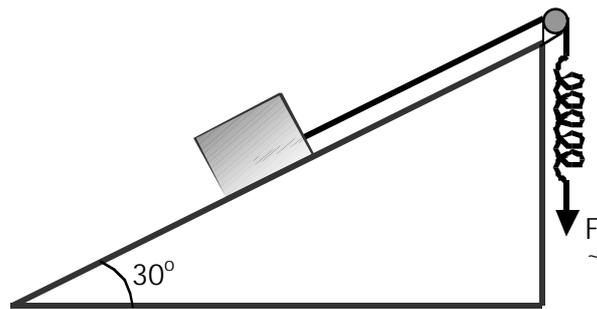
**[Marks 8]**

A certain fish called an Archer catches its food by projecting (i.e. 'spitting') a drop of water at its target. The Archer can project a drop of water to a maximum horizontal distance of 1 m. Calculate the angles (there are 2 values) at which the Archer should aim, relative to the horizontal, in order for the drop of water to hit an insect on the surface of the water 0.5 m away. Assume that the speed of projection is the same in all cases and ignore any drag forces.

**QUESTION 9**

**[Marks 10]**

A 5 kg block rests on an inclined plane (angle  $\theta = 30^\circ$ ) as shown in Figure. It is attached to a spring via a special, mass-less pulley. The spring is being pulled downwards with a gradually increasing force and has a spring constant  $k = 200 \text{ N/m}$ . The coefficient of static friction between the block and the incline is  $\mu_s = 0.4$ .

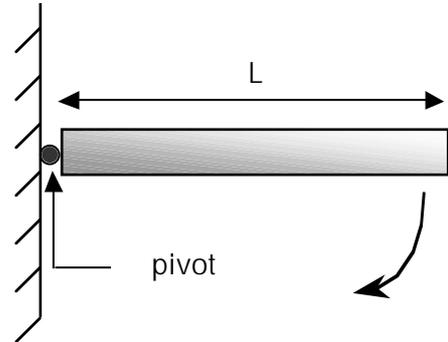


Calculate the extension of the spring at the moment when the block just begins to move.

**QUESTION 10**

**[Marks 10]**

- (a) A uniform rod of length  $L$  and mass  $M$  is free to rotate about a frictionless pivot at one end in a vertical plane, as shown in the figure. The rod is released from rest in the horizontal position. The rotational inertia  $I$  of the rod about the pivot is  $ML^2/3$ .



- (i) calculate the initial angular acceleration of the rod just after release,
- (ii) calculate the initial linear acceleration of the right-hand end of the rod.

- (b) A uniform, solid disk of mass 120 kg and radius 1.4 m rotates initially with an angular speed of 1100 revolutions/minute.

- (i) a constant, tangential force is applied at a radial distance of 0.6 m. Calculate the amount of work this force must do to stop the disk.
- (ii) If the disk is brought to rest in 2.5 minutes, calculate the torque produced by the tangential force and also calculate the magnitude of this force.
- (iii) How many revolutions will the disk make during this 2.5 minute period, before it stops?  
[note: Rotational Inertia:  $I(\text{disk})= MR^2/2$ ].

**QUESTION 11**

**[Marks 13]**

- (a) A ladder rests against a frictionless, vertical wall. The coefficient of static friction between the ladder and the floor is 0.3.
- (i) draw a diagram showing all the forces acting on the ladder and
  - (ii) calculate the smallest angle between the ladder and the horizontal at which the ladder will remain stationary.
- (b) You place a ladder against a vertical wall. Now, there **is** friction between the ladder and the wall.
- (i) Draw a diagram showing all the forces acting on the ladder before you start to try to climb it.
  - (ii) If there were no friction between the ladder and the floor would you be able to climb the ladder, even though there is friction at the wall ? Explain your answer (a simple “yes” or “no” answer will not suffice!)

**QUESTION 12**

**[Marks 8]**

- (a) The Earth completes an orbit around the Sun in 365.25 days. Assuming that the orbit is circular with a radius of  $1.49 \times 10^{11}$  m, calculate the mass of the Sun. [Note: the Gravitational constant  $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$ ].
- (b) A star of radius  $1.0 \times 10^4$  km rotates about its axis with a period of 30 days. The star explodes and then collapses into a neutron star of radius 3 km. Assuming that the star remains spherical and its mass remains constant, calculate the period of the neutron star.

$$[I_{\text{sphere}} = \frac{2}{5} MR^2]$$