PHYSICS

IB1

Examination

Paper 1

Wednesday 31th of March 2021

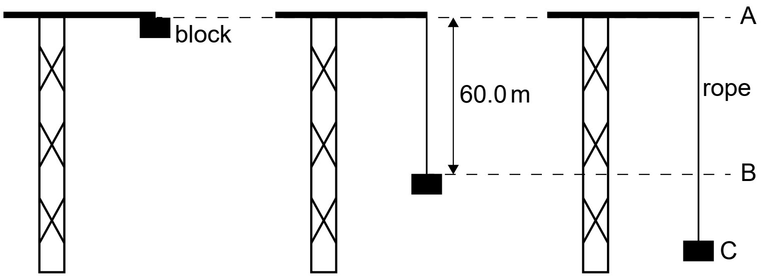
Answers

9 problems   Total: / 62 marks

Problem 1

[12 marks]

An elastic climbing rope is tested by fixing one end of the rope to the top of a crane.
The other end of the rope is connected to a block which is initially at position A.
The block is released from rest. The mass of the rope is negligible.



The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

(a) At position B the rope starts to extend. Calculate the speed of the block at position B. [2]

$\frac{1}{2}mv_B^2 = mgh \Rightarrow v_B = \sqrt{2gh} = \sqrt{1200} = \boxed{34.1 m s^{-1}}$

(b) At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

(i) Determine the magnitude of the average resultant force acting on the block between B and C. [2]

$F = 80\frac{0-34.1}{0.759} = \boxed{3616 N}$

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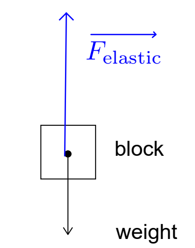
(ii) Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. [2]



(iii) Calculate the magnitude of the average force exerted by the rope on the block between B and C. [2]

$4400N$

(c) For the rope and block, describe the energy changes that take place

(i) between A and B. [1]

gravitational potential energy of block converted into its kinetic energy.

(ii) between B and C. [1]

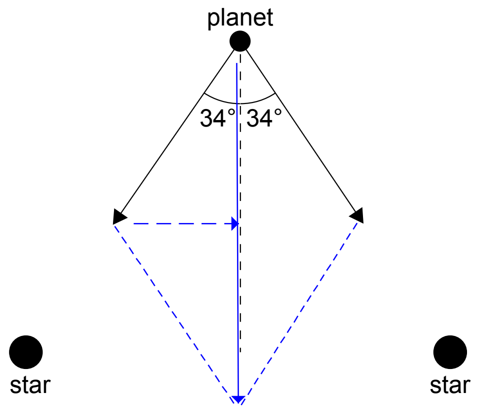
gravitational potential & kinetic energy of block into elastic potential energy of rope

(d) The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. [2]

Using the formula $\frac{1}{2}kx^2$ for the potential elastic energy.

Problem 2 *[5 marks]*

The two arrows in the diagram show the gravitational field strength vectors at the position of a planet due to each of two stars of equal mass *M*.



Each star has mass $M = 2.0 \times 10^{30}$ kg. The planet is at a distance of 6.0×10^{11} m from each star.

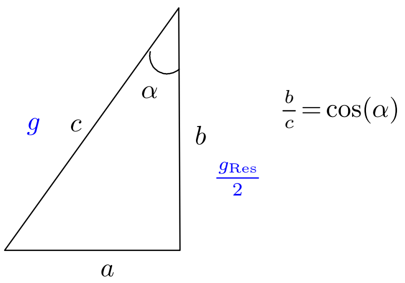
(a) Show that the gravitational field strength at the position of the planet due to **one** of the stars is $g = 3.7 \times 10^{-4}\,\mathrm{N\,kg^{-1}}$. [1]

$$g = G\frac{M}{d^2} = 6.67 \cdot 10^{-11} \times \frac{2 \cdot 10^{30}}{(6 \cdot 10^{11})^2} = 2.7 \cdot 10^{-4} N\,\mathrm{kg}^{-1}$$

(b) Calculate the magnitude of the resultant gravitational field strength at the position of the planet. [2]

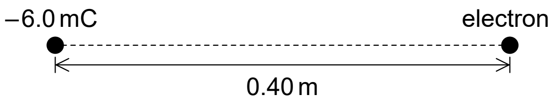
$$\cos(34) = \frac{\frac{g_{\mathrm{Res}}}{2}}{g} \Rightarrow g_{\mathrm{Res}} = 2g\cos(34) = 2 \times 2.7 \cdot 10^{-4} \times 0.83 = \boxed{4.48 \cdot 10^{-4} N\,\mathrm{Kg}^{-1}}$$

some help :



Problem 3 *[5 marks]*

An electron is placed at a distance of 0.40 m from a fixed point charge of –6.0 mC.



(a) Show that the electric field strength due to the point charge at the position of the electron is $3.4 \times 10^8 \, \mathrm{N\,C^{-1}}$. [2]

$$E = k\frac{|Q|}{d^2} = 9 \cdot 10^9 \frac{6 \cdot 10^{-3}}{(4 \cdot 10^{-1})^2} = 3.38 \cdot 10^{9-3+2} \ \mathrm{NC^{-1}}.$$

(b) (i) Calculate the magnitude of the initial acceleration of the electron.

$$F = ma \Rightarrow a = \frac{3.4 \cdot 10^8}{9.11 \cdot 10^{-31}} = \boxed{3.7 \cdot 10^{38} m s^{-1}}$$

(ii) Do you expect this acceleration to be constant ?

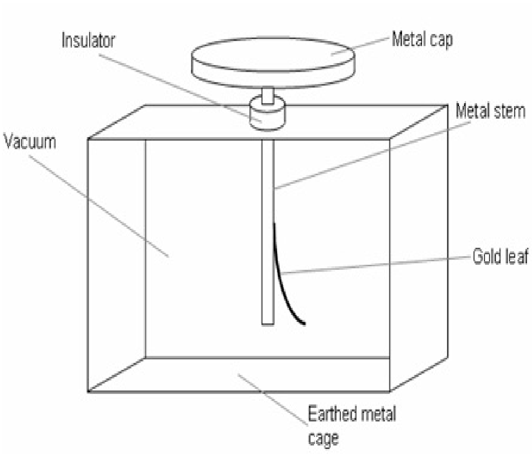
No, because with such a acceleration, the electron would have a speed *greater* than the speed of light (after about 10^{-30} sec only), and that is impossible !

An other reason is that this acceleration depends of the force between the two charges, and that force is not constant (because the distance is decreasing).

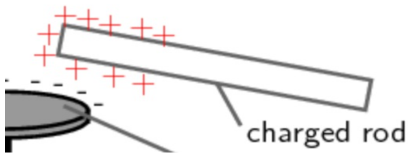
Problem 4 *[5 marks]*

An electroscop is made of a box (cage) in *insulator*. One gold leaf suspended from a metal stem in a vacuumed glass jar and connected to a metal cap, as shown in the picture below.

When no charge is present the metal leaves hang loosely downward.



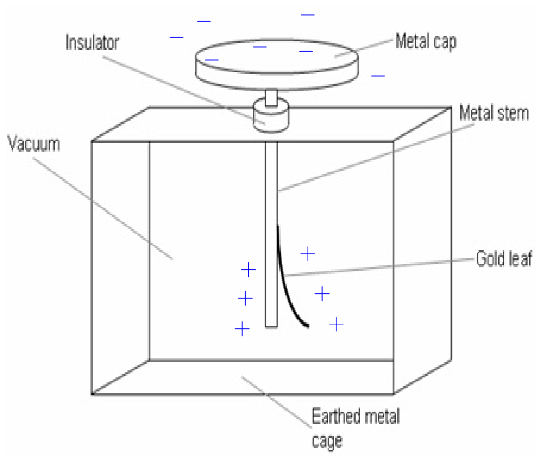
1) Explain what happen to the gold if an rod with a positive charge is brought near the electroscope, *without touching* the metal cap.



cap

Many free electrons will leave the region near the gold leaf, and move along thr metal stem to the plate (that will becomes negative).

Hence the leaf and the metal stem, both *locally* charged + (positive) will repulse each other.



2) Explain what happen to the gold if the rod with a positive charge is brought very close to the electroscope, and touches the metal cap.

Some lectrons of the plate will jump on the road. Hence the metal stem will be g*lobaly* charged +.

Problem 5 *[5 marks]*

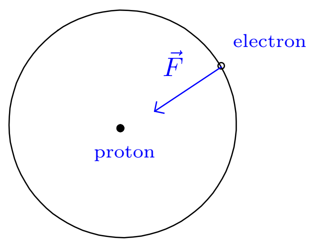
In a simple model of the hydrogen atom, an electron orbits the proton. Both electron and proton are regarded as point charges. The orbital radius of the electron is 5.0×10^{-11} m.

a) Show that the magnitude of the electric force between the electron and the proton is

9.3×10^{-8}N. $\quad E = k\frac{|q_p|}{d^2}$

b) Explain why the motion or the electron is circular

$\vec{F}$ est *constant* and *toward the center*.



c) Find the speed of the electron

$\vec{F} = m\vec{a} \quad$ with $F = k\frac{|q_e\, q_p|}{r^2} \quad$ and $a = \frac{v^2}{r}$

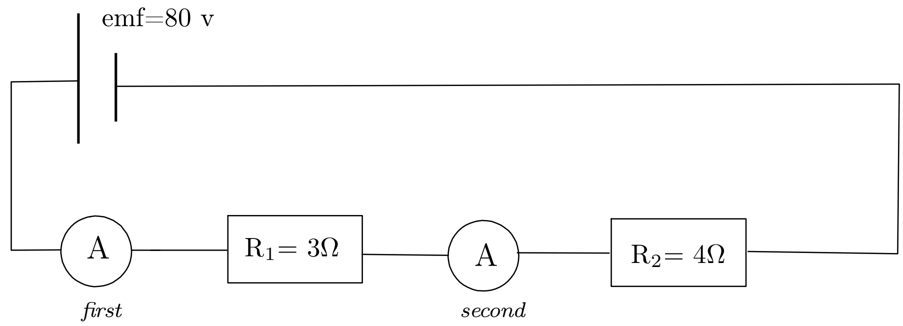
gives $\quad v^2 = k\frac{e^2}{m \times r} \quad$ where $e = 1.6 \cdot 10^{-19}$

$$\Rightarrow v = \sqrt{\frac{k}{m \times r}} \times e = \sqrt{\frac{9 \cdot 10^9}{9,109^{-31} \times 5.29 \cdot 10^{-11}}} \times 1.6 \cdot 10^{-19} = \boxed{1.55 \cdot 10^6 \frac{m}{s}}$$

d) The Kinetic energy of the electron is : $E_k = \frac{1}{2}\text{mv}^2 = \frac{k}{2r}e^2 = \boxed{2.178 \cdot 10^{18} J}$

Problem 6 *[5 marks]*

Let us consider the following situation



1) Describe how the two resistors are disposed. $\boxed{\text{in series}}$

2) The first anmeter measures 10A, what measures the second anmeter ? $\boxed{\text{Both measure 10A}}$

3) Give a definition of *emf* and a definition of i*nternal resistance*.

Electromotive force, abbreviation **E** or **emf**, energy per unit electric charge that is imparted by an energy source, such as an electric generator or a battery.[1]

4) Find the value of the internal resistance of the cell.

$$\text{emf} = (r_{\text{int}} + R_1 + R_2)\text{I} \Rightarrow r_{\text{int}} = \frac{\text{emf}}{I} - (R_1 + R_2) = \frac{80}{10} - 7 = \boxed{1\Omega}$$

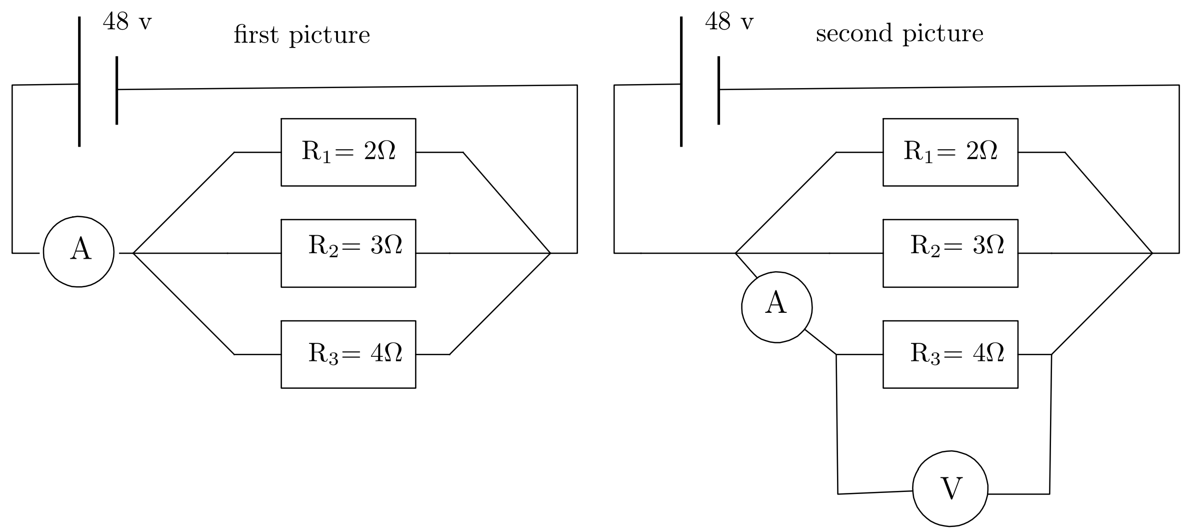
1. britannica.com

Problem 7 *[12 marks]*

1) Show the direction of the current That is always from + to −

2) Show the direction of the displacement of the electrons Electrons always move from − to +

3) What will measure the ammeter ? 52 A



4) What will measure the ammeter if we move it like shown in the second picture ?

The anometer will measure only the current that passes through R_3.

You can show that this current is $I_3 = 12\,A$

Extra questions - What is the current I_1 that passes through R_1 and I_2 that passes through R_2 ?

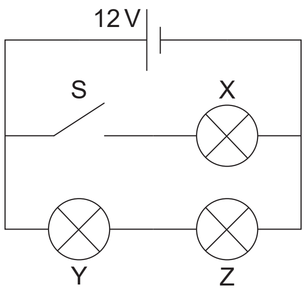
- What is the sum $I_1 + I_2 + I_3$?

5) What is the *tension* measured by the voltemeter ? 48 V.

6) What is the *power* transformed by the resistor R_3 ? 576 Watt. (Joul's law)

Problem 8 *[6 marks]*

Three identical light bulbs, X, Y and Z, each of resistance 4.0 Ω are connected to a cell of emf 12 V. The cell has negligible internal resistance.



(a) The switch S is initially open. Calculate the total power dissipated in the circuit. [2]

$R_{tot} = 4 + 4 = 8\Omega$ $\quad$ $P = \frac{V^2}{R_{tot}} = \frac{144}{8} = \boxed{18W}$

(b) The switch is now closed.

(i) State, without calculation, why the current in the cell will increase. [1]

Without calculation, we can said that if the switch is of, the total resistance decrease because it creates two paths in parallele. Hence as I increase ($I = \frac{V}{R}$)

$\frac{1}{R_{tot}} = \frac{1}{4} + \frac{1}{4+4} \Rightarrow R_{tot} = \frac{8}{3}\Omega$ $\quad$ $P = \frac{V^2}{R_{tot}} = \frac{144}{\frac{3}{8}} = \boxed{384W}$

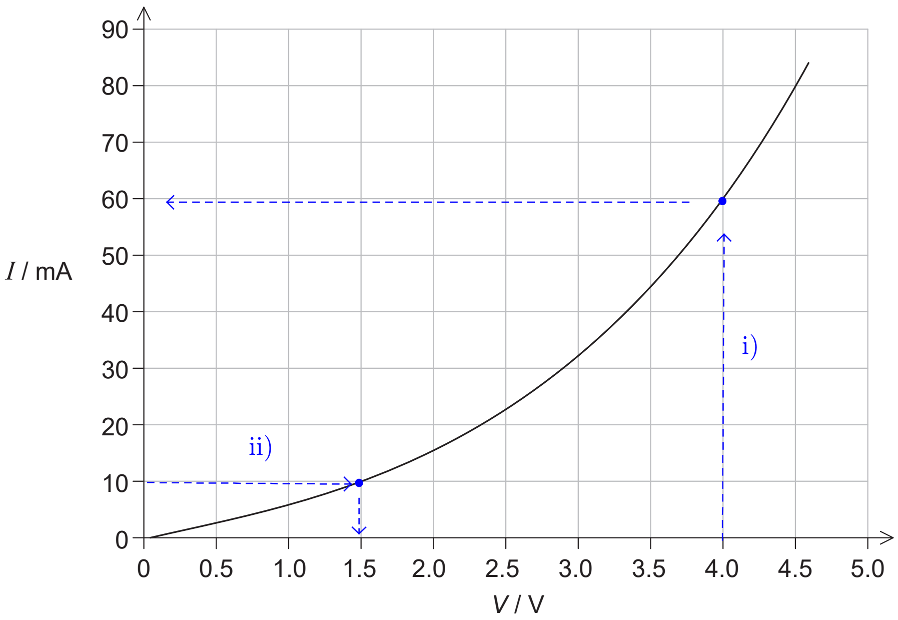
(ii) Deduce the ratio $\dfrac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$. [2]

As Y az Z have the same V in both cases, the thy also have the same I

then the same power dissipated in Y $\Rightarrow$ $\boxed{\text{The ratio is 1}}$

Problem 9 *[7 marks]*

The graph shows how current I varies with potential difference V across a component X.



(a) According to this graph

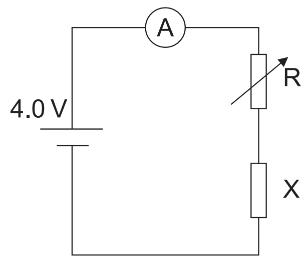
i) What is the currant (I) when the tension (V) is 4V ? $\boxed{60\text{mA}}$

ii) For V=4V, find the resistance of the resistor X is 15mΩ : $V=RI = \boxed{R=\frac{4}{0.06}=66.7\Omega}$

iii) Estimate the voltage (V) when the current (I) is 10mA ? $\boxed{1.5V}$

iv) Estimate the resistance of the resistor when the current (I) is 10mA ? $V=RI = \boxed{R=\frac{1.5}{0.01}=150\Omega}$

(b) Component X and a cell of negligible internal resistance are placed in a circuit.
A variable resistor R is connected in series with component X. The ammeter reads 20 mA.



(i) Determine the resistance of the variable resistor. [3]

As the ammeter reads 20mA, we know that the potential difference across the componant X is 2.3V (using the graph). Hence the tension across the variable resistor X is $4.0 - 2.4 = \boxed{1.6\text{V}}$ and its resistance is $R=\frac{V}{I}=\frac{1.6}{0.02}=\boxed{80\Omega}$