BPhO Practice

Question 1

A particle, mass m, slides down the smooth track, **Figure 1**, from a height H under gravity. It is to complete a circular trajectory of radius R when reaching its lowest point. Determine the smallest value of H.

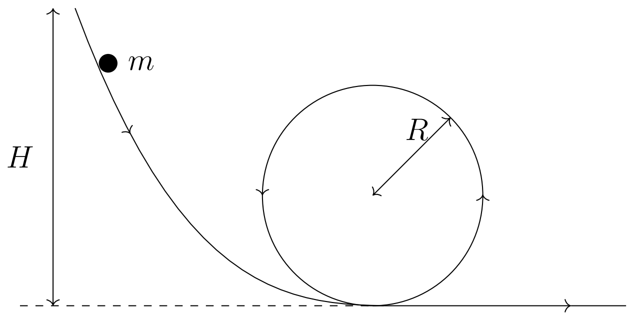

Figure 1

[3]

Question 2

The pulley system in **Figure 2** consists of two pulleys of radii a and b rigidly fixed together, but free to rotate about a common horizontal axis. The weight W hangs from the axle of a freely suspended pulley P, which can rotate about its axle. If section A of a rough rope is pulled down with velocity V:

(i) Explain which way W will move.

(ii) With what speed will it move?

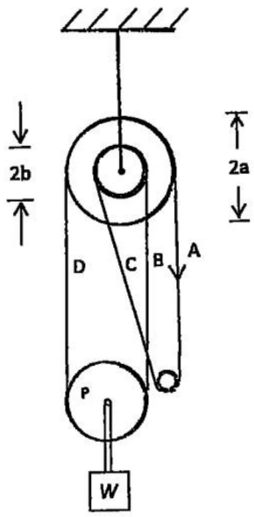

Figure 2

[5]

Question 3

Three boats start at time $t = 0$ from the corners of an equilateral triangle, of side $50\ \mathrm{km}$, and maintain constant speeds of $30\ \mathrm{km\,h^{-1}}$ during the subsequent motion. They each maintain a heading, clockwise, towards the neighbouring boat. They all eventually meet at P.
Determine:

(i) qualitatively, the evolution of the triangle formed by the three boats

(ii) the velocity components of the three boats in the direction of P, as a function of time, t, and in the perpendicular directions

(iii) the time, t_M, at which they all meet

(iv) the distance travelled by each boat, D.

[8]

Question 4

A tank contains water to a depth of $1.0\ \mathrm{m}$. Water emerges from a small hole in the vertical side of the tank at $20\ \mathrm{cm}$ below the surface. Determine:

(i) the speed at which the water emerges from the hole

(ii) the distance from the base of the tank at which the water strikes the floor on which the tank is standing.

[5]

Question 5

Two $1.00\,\mathrm{m}$ lengths of wire, one copper and one tungsten, are joined vertically end to end. The copper wire has a diameter of $0.500\,\mathrm{mm}$. When a $100\,\mathrm{kg}$ block is suspended from one end, the combined length of wire stretches by $6.00\,\mathrm{cm}$. What is the diameter, d, of the tungsten wire if the Young's modulus for copper is $12.4 \times 10^{10}\,\mathrm{Pa}$, and that for tungsten is $35.5 \times 10^{10}\,\mathrm{Pa}$?

[6]

Question 6

A man, on an open wagon of a train travelling along a straight horizontal track at a constant speed of $10\,\mathrm{m\,s^{-1}}$, throws a ball into the air in line with the track, that he judges to be at $60°$ to the horizontal. A woman standing on the ground observes the ball rise vertically.

How high does the ball rise relative to

(i) the man and;

(ii) the woman?

[5]

Question 7

A battery of emf E and internal resistance r drives 3.0 A round a circuit consisting of two $2.0\ \Omega$ resistors in parallel. When these resistors are connected in series the current is 1.2 A. Calculate E, r and the power dissipated, W, in each resistor.

[5]

Question 8

Determine, in **Figure 3**, the total resistances, R_{TBC}, across BC, R_{TBD} across BD and R_{TBA} across AB.

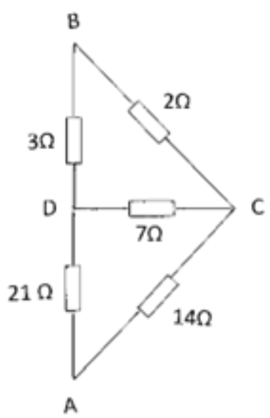

Figure 3

[6]

Question 9

The temperature coefficients of resistance, α, of certain alloys are positive and others are negative. They have resistance per unit length of r. This makes it possible to produce a resistor, using the two wires in series, which does not vary with temperature. The values of r, at 0°C, and α are given in Table 1 for constantan and manganin. These wire have lengths L_c and L_m respectively at 0°C. What values of L_c and L_m are required to produce a $5.0\ \Omega$ resistor?

Wire	r / $\Omega\,\mathrm{m}^{-1}$	α / $^\circ\,\mathrm{C}^{-1}$
Constantan	6.3	-3.0×10^{-5}
Manganin	5.3	$+1.4 \times 10^{-5}$

Table 1

[5]

Question 10

The circuit in **Figure 4** contains a cell of emf E, a known variable resistance R_0, an unknown resistance R and an ammeter. When X and Y are short circuited $E = I_0 R_0$.

When R is inserted the current is αI_0, where α is a constant.

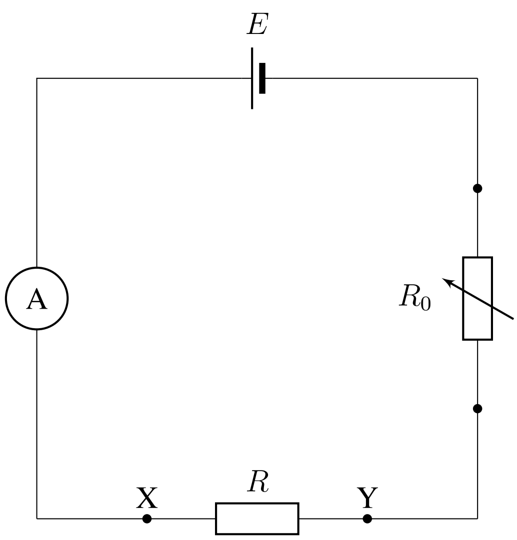

Figure 4

(i) Express R in terms of R_0 and α, giving the range of validity of R and α.

(ii) In order to extend the range of α, modify the circuit by putting R in parallel with R_0. Determine the ranges of R and α for the modified circuit.

[4]

Question 11

A chain of resistors, **Figure 5**, is composed of n units, each consisting of three resistors, each resistor of resistance R, **Figure 6**. A unit is attached to the left hand end of the chain in order to increase the number of units from n to $(n+1)$.

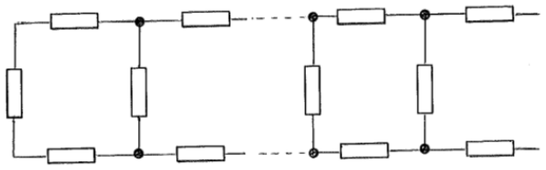

Figure 5

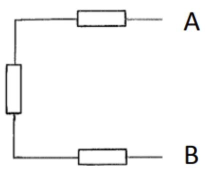

Figure 6

(i) Calculate the resistance (between A and B) across a chain with two units, R_2, and the resistance R_3, across a chain with three units.

(ii) A unit is attached to a long chain. The resistance of the chain, R_T, is not altered by this addition. Determine the resistance of the chain.

[6]

Question 12

A glass block of refractive index $\mu = 1.5$ has an 'L' cross-section, **Figure 7**, and is of constant width and thickness.

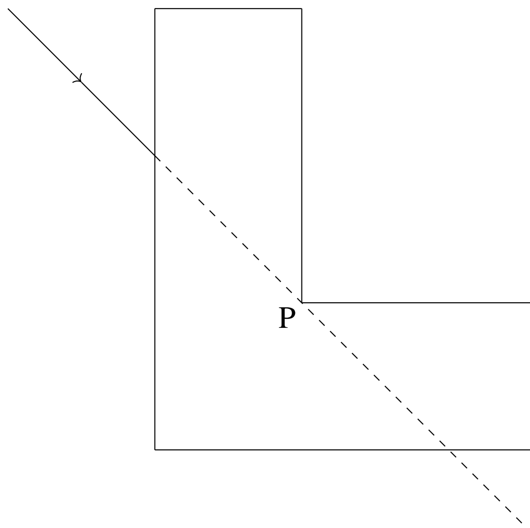

Figure 7

a) A laser beam enters the block from the left, as indicated in **Figure 7**, at an incident angle of $\theta = 45°$. If the block was absent the beam would pass through the point P. Determine the angle at which the beam will emerge from the bottom face after refraction through the block.

b) If this beam enters the block below the horizontal through P, determine its possible subsequent path(s).

[6]

Question 13

A ray of light is incident on a $60°$ glass prism of refractive index 1.500 at an angle of incidence of $48.59°$. Determine:

(i) the angle of emergence, θ, from the prism; i.e. the angle between the emergent ray and the normal to the prism face.

(ii) the angle of deviation of the ray, δ.

[5]

Question 14

In **Figure 8** a fixed mirror, a light source and a light receiver are all $0.30\,\mathrm{km}$ from a rotating mirror, with angular frequency ω. The distance between the light source and the receiver is $0.60\,\mathrm{m}$. What is the lowest value of ω required for detection of the reflected light?

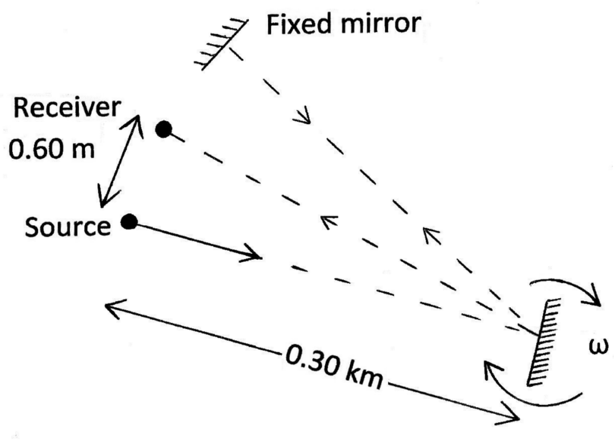

Figure 8

[4]

Question 15

Protons are accelerated from rest through a p.d. of 2.0×10^6 V and fired at a gold ($^{197}_{79}$Au) foil. What is the distance of closest approach of a proton to the gold nucleus?

[4]

Question 16

A lithium surface, with work function energy $W = 3.7 \times 10^{-19}$ J, is irradiated with photons of frequency $f = 6.3 \times 10^{14}$ Hz. The loss of photoelectrons from the surface causes the metal to acquire a positive potential, V. What will this potential be when the metal prevents the loss of further electrons?

[4]

Question 17

A small object of mass m rests on a scale-pan which is supported by a spring. The period of vertical oscillations is $0.50\,\mathrm{s}$. When the amplitude of the oscillations exceeds the value, A, the mass leaves the scale-pan. Determine A.

[3]

Question 18

A calorimeter contains $800\,\mathrm{kg}$ of water at a temperature of $15\,^\circ\mathrm{C}$. The heat capacity of the calorimeter is $42.8\,\mathrm{J}\,^\circ\mathrm{C}^{-1}$. $0.400\,\mathrm{kg}$ of molten lead is poured into the calorimeter. The final equilibrium temperature is $25\,^\circ\mathrm{C}$. What was the initial temperature of the lead?

The specific heat of molten lead is $158\,\mathrm{J\,kg^{-1}\,^\circ C^{-1}}$.
The specific heat of solid lead is $137\,\mathrm{J\,kg^{-1}\,^\circ C^{-1}}$.
The specific latent heat of solid lead is $2.323 \times 10^4\,\mathrm{J\,kg^{-1}}$.
Lead freezes at $327\,^\circ\mathrm{C}$.
The specific heat of water is $4200\,\mathrm{J\,kg^{-1}\,^\circ C^{-1}}$.

[5]

Question 19

To determine the specific heat capacity, s, of a liquid flowing at a constant rate of $0.060\ \mathrm{kg\,min^{-1}}$ down a pipe, heat from an electrical supply is maintained at the rate of 12 W. It produces a temperature rise of 2.0 °C along the flow. Calculate s.

[2]

Question 20

A bicycle tyre has a volume of $1.20 \times 10^{-3}\ \mathrm{m}^3$ when fully inflated. The barrel of the bicycle pump has a working volume of $9.0 \times 10^{-5}\ \mathrm{m}^3$. How many strokes of the pump are needed to completely inflate the flat tyre to a total pressure of 3.0×10^5 Pa? The atmospheric pressure is 1.00×10^5 Pa. Assume the air is pumped in slowly, so that the temperature remains constant.

[4]