RADLEY

Academic Scholarship 2019

PHYSICS

Time allowed – 30 minutes

Calculators are not to be used

Total marks available = 33

Most of the marks in these questions are for showing how well you think. Your final answers are less important than demonstrating a logical and systematic approach.

You **must show your working out** at all stages and state any assumptions that you make.

Where you can, use powers of ten to show very big or very small numbers. For example "1,000,000" can be written: 1.0×10^6

1. It is easy to walk along on a dry flat surface such as a pavement. However, it is very difficult to walk along on ice due to the fact that the friction forces are very much reduced on ice.

   Explain why friction is necessary for us to walk along on a surface.

[5 marks]

2. A cable that hangs vertically has a maximum possible length beyond which it can no longer support its own weight.

(a) For a steel cable with a diameter of 4 cm and a length of 1 m, show that the mass of the cable is approximately 10 kg.

d = 4 cm
L = 1 m
density of steel = 8000 kg / m^3

[2 marks]

(b) What is the weight force on this 1 m cable if it hangs downwards

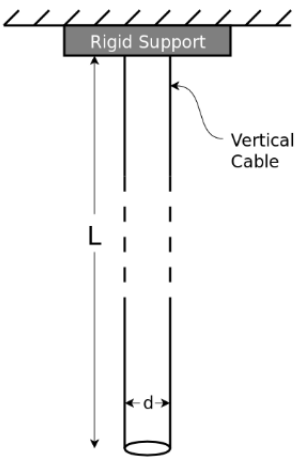
$W = m\,g$, where m is the mass and g = 10 N/kg

[1 mark]

(c) Stress (σ) is defined as Force ÷ Cross sectional Area and the unit is Pascal (Pa).

Stress = F / A i.e. $\sigma = F / A$

Calculate the stress at the top of the 1 m cable (shown right) where it is joined to the rigid support.



[2 marks]

(d) The maximum stress that a steel cable under tension can withstand, before it breaks, is 400 MPa.

This is often referred to as the ultimate tensile strength of the material.

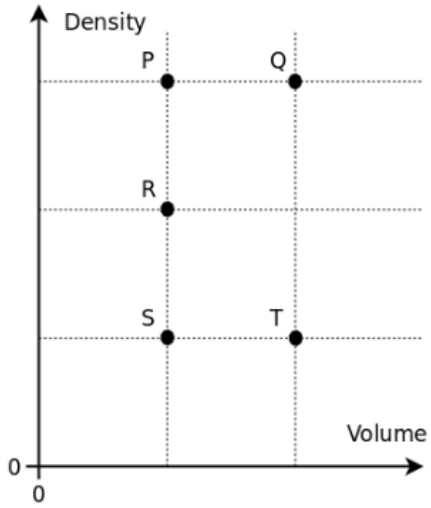
Calculate the maximum length of a steel cable with a diameter of 4 cm that can be hung vertically from a suitable rigid support such that it can support its own weight.

[2 marks]

(e) Explain what effect increasing the diameter of the cable would have on the maximum length of the cable calculated in part (d).

[2 marks]

3. The graph shows the Volume and Density of several different objects.



Which two objects have the same mass? Justify your answer.

[3 marks]

4. In the circuit shown, the power supply is a fixed voltage *V* and the resistor is a fixed value *R*.

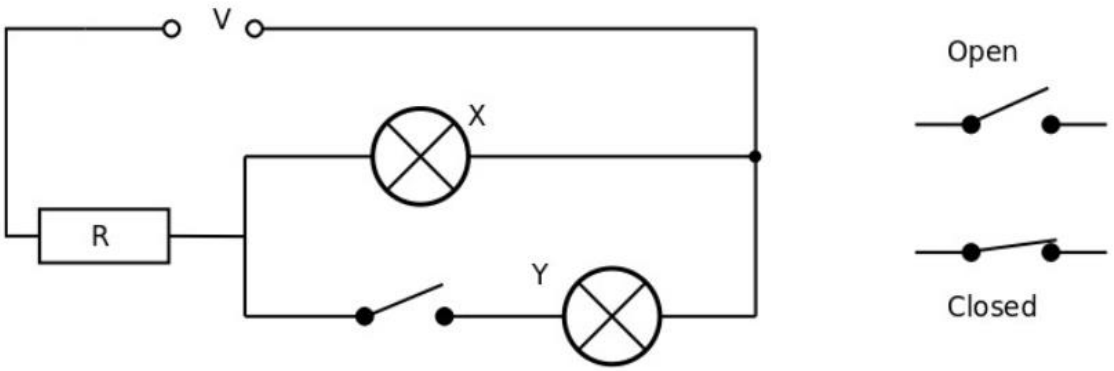
   The two bulbs are identical.

   When the switch is open just bulb X is lit.

   When the switch is closed both bulb X and bulb Y are lit.

   State **and explain** whether the brightness of bulb X will increase, decrease or stay the same when the switch is changed from open to closed.

[5 marks]



5. **Estimate** the volume of a £ 10 note. Show your thinking clearly – it may help to draw a diagram.

[5 marks]

6. The 2017 Nobel Prize in Physics was awarded for detecting gravitational waves from two colliding black holes.

(a) The gravitational waves were detected by two detectors 3000 km apart with a time difference of 6.9 ms.

What speed does this give?

Comment on what this tells us about the gravitational waves.

[3 marks]

(b) The mass of the Sun is sometimes given the symbol $M_\odot$ in astronomy. The initial black hole masses are 36 $M_\odot$ and 29 $M_\odot$. The final larger black hole mass is 62 $M_\odot$. How much mass was lost when the black holes collided to form one larger one?

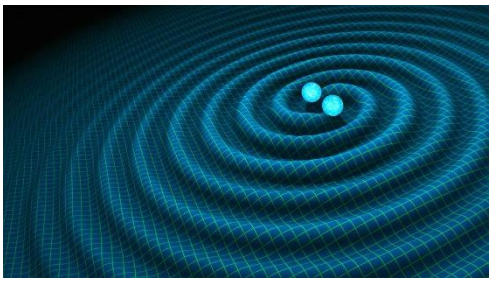
[1 mark]

(c) If $M_\odot = 1.989 \times 10^{30}$ kg, how much energy is given off as gravitational waves, coming from the loss of mass of the black holes?

(Hint: use Einstein's equation $E = m\,c^2$.)

As you may know, the speed of light, $c = 3.0 \times 10^8$ m/s.

[2 marks]



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