AS COMPETITION PAPER 2011

Name	
School	
Town & County	

Total Mark/50

Time Allowed: ***One hour***

Attempt as many questions as you can.

Write your answers on this question paper.

Marks allocated for each question are shown in brackets on the right.

You may use any calculator.

You may use any public examination formula booklet.

Allow no more than ***10 minutes*** *for* ***section A.***

The gravitational field strength on the earth is 9.8 Nkg^{-1}

Section A: Multiple Choice

Circle the correct answer to each question. There is only one correct answer.

Each question is worth 1 mark.

1. A toy boat floats in a tank of water which is rather carefully balanced on a block of wood. If the boat slowly drifts to the right across the tank in the diagram below, what would likely happen to the tank of water in which it is floating?

A. The tank will tip so that the right hand side drops down

B. The tank will remain balanced

C. The tank will tip so that the left hand side drops down

D. It depends on how slowly the boat drifts across

2. A spherical mass *m* of uniform density has a weight *W*. If a second mass of similar density but with double the radius of the first is compared, the weight of the second mass is

A. the same B. $2W$ C. $4W$ D. $8W$

3. A parsec is a unit of length used by astronomers to measure distance. If a parsec is 3.26 light years, and a light year is the distance that light travels in a year, how many metres are there in a parsec?

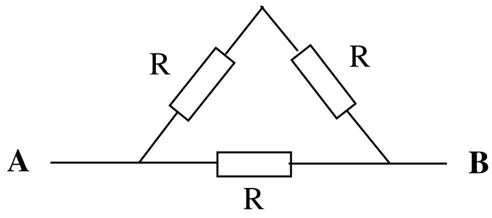
Speed of light is 3×10^8 ms^{-1}

A. 3×10^7 B. 5×10^{14} C. 9×10^{15} D. 3×10^{16}

4. When light passes through a prism and is split into the colours of the spectrum, this is an example of :

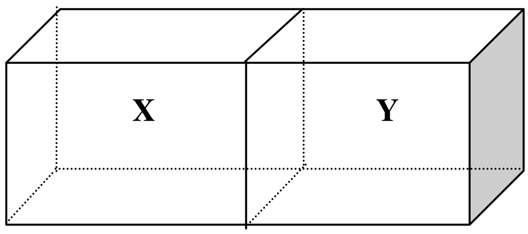
A. Dispersion B. Diffraction C. Reflection D. Refraction

5. If the potential difference between **A** and **B** on the diagram below is V, then what is the current between **A** and **B**? All three resistors are identical.



A. $\frac{V}{3R}$ B. $\frac{2V}{3R}$ C. $\frac{3V}{2R}$ D. $\frac{3VR}{2}$

6. A container of helium gas shown below has two identical sections with a common wall between them which does not allow gas to leak through. The two sections contain helium gas with 2 g in compartment **X** and 1 g in compartment **Y**. The two halves of the container are at the same temperature. Which of the following is the same for the gas in the two sections **X** and **Y**?



A. The number of collisions per second on the common wall

B. The average speed of the atoms

C. The density of the helium

D. The pressure exerted by the helium

7. A high power laser produces a 20 TW pulse of radiation but for the short duration of only 3 fs. How much energy is contained in a single laser pulse?

tera = 10^{12}

femto = 10^{-15}

A. 0.006 J B. 0.06 J C. 0.6 J D. 60 J

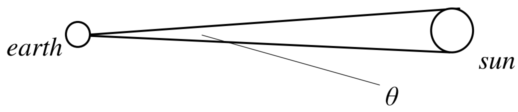
8. A Big Mac from McDonalds has an energy content of 2.3 MJ (McDonalds Nutrition Guide) and a mass of 214 g whilst a tonne of TNT will release 4.7 x 10^9 J when detonated. Comparisons can be made by calculating the energy density, which is the amount of energy released in a reaction per unit mass.

   What is the ratio $\dfrac{\textit{energy density of Big Mac}}{\textit{energy density of TNT}}$

   1 tonne = 10^3 kg

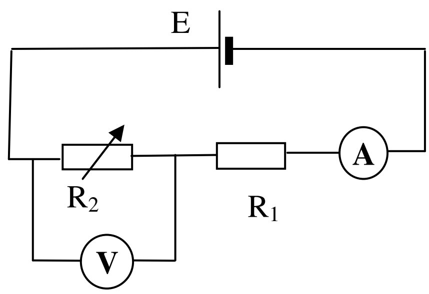
   A. 2.3x 10^{-3} B. 0.23 C. 0.44 D. 2.3

9. The best estimate for the angle θ of the sun subtended at the eye when viewed from the earth is



   A. 0.05° B. 0.5° C. 5° D. 25°

10. A cell which produces a potential E (called an emf) is shown in the diagram below and is connected to two resistors in series, a fixed resistor R_1 and a variable resistor R_2. The current I in the circuit is measured by the ammeter **A** and the potential difference V across resistor R_2 is measured with the voltmeter **V**.
   The relation between the potential E and the current I is given by
   $$E = IR_1 + IR_2$$
   Which of these graphs would produce a straight line fit?

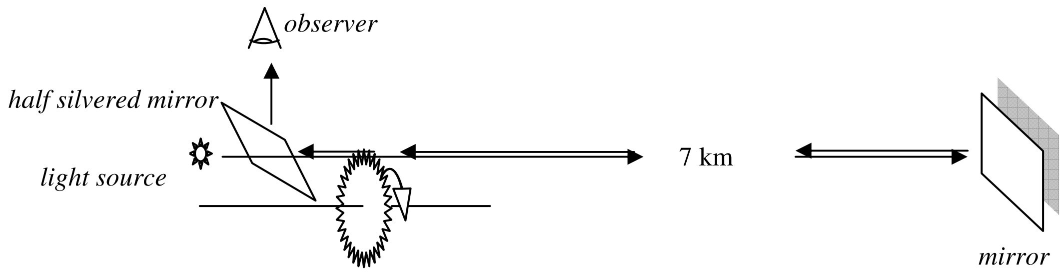


   A. V against I B. V against $1/I$ C. $1/V$ against $1/I$ D. I against $1/V$

Section B: Written Answers

Question 11.

In one of the original experiments to measure the speed of light, carried out by Fizeau in 1849, a beam of light was sent to a distant mirror 7 km away and reflected back, passing through the teeth of a rapidly rotating cogwheel. It is easy to detect when the light is obscured by a tooth on its return path and a reduction in intensity is observed. A simplified diagram of the setup is shown below. The toothed cog has 720 teeth and rotates several hundred times per second.



a) At a rate of rotation of 283rps (rotations per second) extinction is observed. Speeding up the cog, extinction is next observed at 313 rps. Explain why the light is extinguished at a particular rate of rotation.

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____ [2]

b) Explain why there are two (or more) rates at which extinction is observed.

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____ [1]

c) If $n + ½$ teeth cross the beam at 283 rps, state how many teeth must cross the beam at 313 rps? Calculate the number of teeth that cross the beam per second at each of the two speeds, the difference in the number of teeth crossing per second, and thus the time interval for one extra tooth to cross. (This is the travel time of the light beam)

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____ [3]

d) Calculate the speed of light from these measurements.

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____ [1]

/7

Question 12.

A solid sphere of mass *m* rolls down a slope. The sphere gains kinetic energy in two forms: *rotational kinetic energy* and *translational kinetic energy* in which the centre of mass moves along at speed *v*. For the solid sphere, a fixed fraction, $\frac{2}{7}$, of the gravitational potential energy lost as it rolls down the slope appears as *rotational kinetic energy*.
If the sphere now rolls along a flat surface, moving at a speed of 4.0 ms^{-1} and then encounters a rising slope at 30^o to the horizontal, we can calculate how far up the slope the sphere will rise. We can take the mass of the sphere as 1 kg.

a) Calculate the translational KE of the sphere and hence the total energy of the rolling sphere.

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____ [3]

b) Describe the energy changes that take place as the sphere rolls up the slope.

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____ [3]

c) What is the vertical height reached by the sphere?

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____ [2]

d) How far up along the slope does this take the sphere?

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____ [2]

/10

Question 13.

The resistance of a wire is proportional to its length and inversely proportional to its cross sectional area. The resistance of a wire of length ℓ and cross sectional area A is given by $R = \frac{\rho\ell}{A}$ where ρ is a constant which depends upon the material of the wire. Some metals are ductile, which means that they can be drawn into long thin wires. In doing so, the volume V remains constant whilst the length increases and the cross sectional area of the wire decreases.

A wire of length 32 m has a resistance of 2.7 Ω. We wish to calculate the resistance of a wire formed from the same volume of metal, but which has a length of 120 m instead.

a) Write down the relation between V, A and ℓ. Obtain an expression to show how R depends upon the length ℓ of the wire and its volume V.

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____ [2]

b) Rewrite the equation with the constants ρ and V on one side and the variables we are changing, R and ℓ, on the other.

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____ [1]

c) Calculate the resistance of the longer wire.

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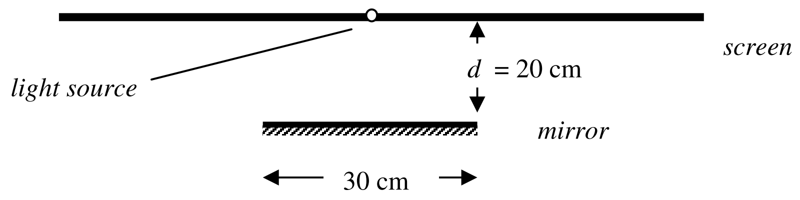
____ [3]

/6

Question 14.

A point source of light is embedded in a large screen. A circular mirror of diameter 30 cm is placed 20 cm in front of the screen, parallel to it and with the centre of the mirror lying along the normal to the screen which passes through the point light source.



a) Sketch the path of the light rays on the diagram above.

____ [2]

b) Calculate the area of illumination on the screen.

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____ [2]

c) If the distance from the screen to the mirror is now given by d, how does the area of illumination depend upon separation d?

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____ [2]

d) Describe qualitatively how the intensity of light reaching the screen depends upon the separation d for smaller and larger values of d.

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____ [3]

/9

Question 15.

In an experiment carried out in 1959 by Pound and Rebka at Harvard University, Einstein's General theory of Relativity was tested by measuring the change in frequency of a photon of the electromagnetic spectrum when it went downwards in the gravitational field of the earth. A 14 keV γ-ray is emitted downwards by a radioactive isotope of iron (Fe-57), and as it falls down in the gravitational field of the earth its energy and hence its frequency increases. A relatively simple classical calculation turns out to give the right result for the frequency change.

a) To determine the frequency of the initial 14 keV photon, convert the energy into joules and, using the relation between energy and frequency of photon $E = hf$, calculate the frequency.

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____ [2]

b) If we associate a fictitious mass m to the gamma ray photon, given by $m = \frac{E}{c^2}$ then the energy change of the photon as it falls in the earth's field through a distance d is given by the familiar potential energy change in a gravitational field, $\Delta E = mg\Delta d$. Express this as a change of frequency of the gamma ray photon Δf .

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____ [2]

c) If the distance the photon falls is 22.5 m, calculate both the change in frequency and the fractional change in frequency $\frac{\Delta f}{f}$ of the gamma ray photon.

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____ [3]

d) This small frequency change is detected by using the Doppler effect in which a moving source emits a wave whose frequency is modified by its motion. The fractional change of frequency emitted is given by the ratio v/c where v is the speed of the source required. Calculate v.

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____ [1]

speed of light, $c = 3.0 \times 10^8$ ms^{-1}
Planck's constant, $h = 6.6 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C

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