ALL SAINTS' COLLEGE

WACE PHYSICS Stage 3

Semester 1 Examination, 2015

Question/Answer Booklet

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer Booklet
Formulae and Constants Sheet

To be provided by the candidate

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters, mathaid

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum Standards Authority for this course

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	13	13	54	54	30
Section Two: Problem-solving	7	7	90	90	50
Section Three: Comprehension	2	2	36	36	20
				180	100

Raw exam score: _____

Marks removed for inappropriate significant figures = _____

Marks removed for inappropriate units = _____

Total = _____

_____%

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2015.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

3. You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.

4. Working or reasoning should be clearly shown when calculating or estimating answers. It is suggested that answers to calculations are given to 3 significant figures except when you are required to estimate. For estimation questions an appropriate number of significant figures must be stated.

5. Spare pages are included at the end of the booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

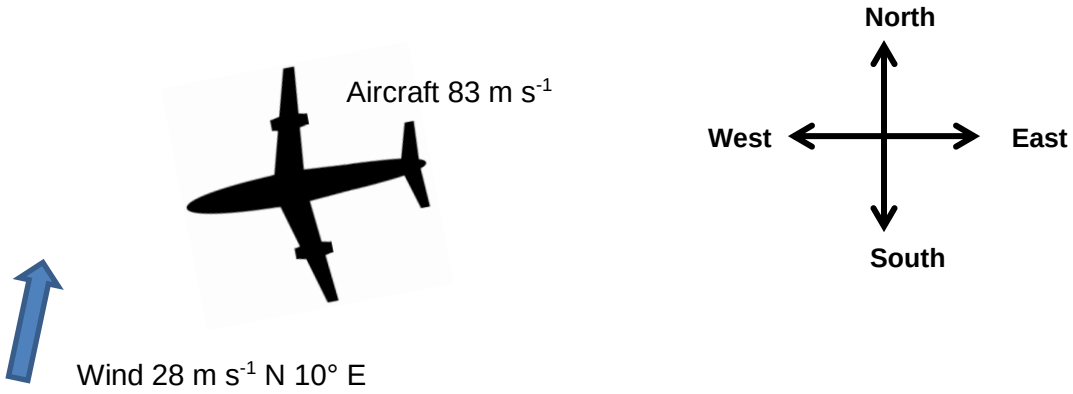
Section One: Short response **30% (54 Marks)**

This section has **13** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 54 minutes.

Question 1

An aircraft is travelling at 83 m s^{-1} and is attempting to land on a runway that is running due West. A strong wind is blowing at 28 m s^{-1} in a direction North 10° East (10° true). Calculate the direction that the aircraft must travel to ensure that its resultant velocity is due West. You must refer to a vector diagram in your solution.

(4)



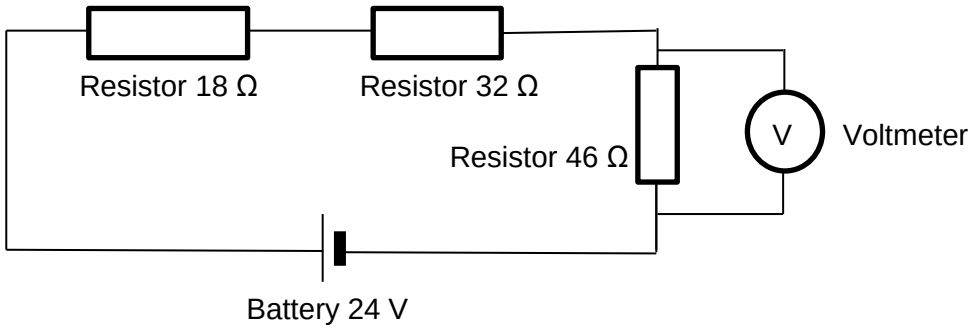
Question 2

A cross country runner is going around a circular segment of a curve at a constant speed of 18 km h^{-1} and with an acceleration of 1.40 m s^{-2} towards the centre. Determine the radius of the curve.

(3)

Question 3

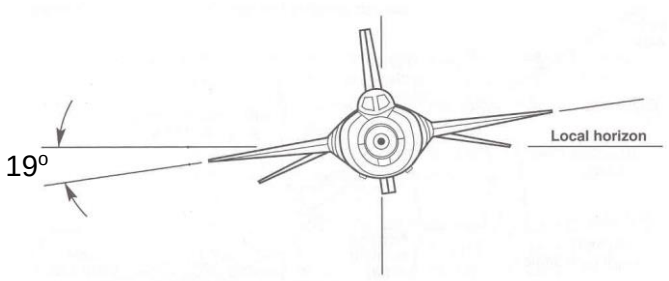
The diagram shows a simple electrical circuit which comprises a 24 V battery and an 18 Ω, 32 Ω and 46 Ω resistor. A voltmeter is connected across the 46 Ω resistor. Determine the reading on the voltmeter.



(3)

Question 4

A jet of mass 8000 kg is banking whilst making a turn at a constant altitude. It follows the segment of a circle and changes direction by 90° in a time of 12 seconds. The banking angle is 19.0°.



a) Draw a vector diagram showing the forces acting on the jet and the sum of the forces.

(1)

b) Calculate the horizontal turning radius of the jet.

(3)

Continued on next page

Question 5

An ideal transformer has 5200 turns on the primary coil and 130 turns on the secondary coil. If the voltage output of the secondary coil if 240 V calculate the voltage input to the primary coil.

(2)

Question 6

The picture shows an athlete training by pulling a truck tyre. A harness attached to her body is connected to the tyre with a strap.

The athlete has a mass of 65.0 kg and the truck tyre has a mass of 30.0 kg. The strap makes an angle of 27.0° with the ground and transmits a 400 N force by tension. The tyre is being pulled forwards at a constant speed of 1.50 m s^{-1}.

a) Calculate the horizontal force that her feet apply to the ground to pull the tyre forwards.

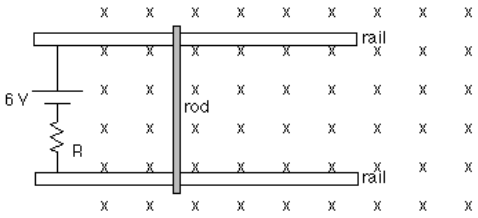
(2)

b) Calculate the normal reaction force from the ground to the athlete.

(2)

Question 7

The figure shows a 200 mm long metal rod which is free to move to the left and right across frictionless metal rails. The battery supplies 6.00 V to the circuit and the magnetic field strength is 20.0 mT into the page. The resistor has a resistance of 0.200 Ω and the rest of the assembly has negligible resistance.



a) Calculate the magnitude and direction of the electromagnetic force applied to the rod when the rod is stationary.

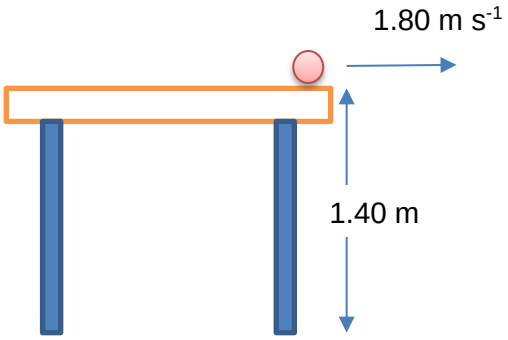
(3)

b) An ammeter was used to the measure current through the circuit. It was noticed that the current through the circuit decreases as the speed of the rod increases. Explain this observation.

(3)

Question 8

A marble rolls off a desk with a horizontal speed of 1.80 m s^{-1}. The top of the desk is 1.40 m above ground level. Calculate the horizontal distance that the marble will have travelled when it hits the ground.



(4)

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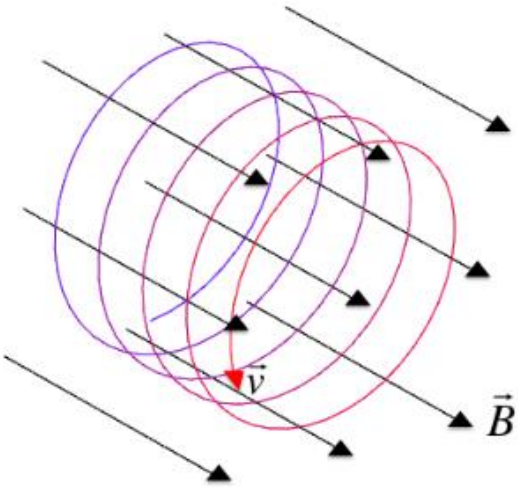
Question 9

A charged particle travelling at speed $\vec{v}$ enters a magnetic field of flux density $\vec{B}$ and takes the spiral trajectory shown in the diagram.



a) With reference to the diagram is the particle positively, negatively or neutrally charged or is it impossible to determine its charge? Circle your answer and explain your choice.

positive negative neutral impossible to determine

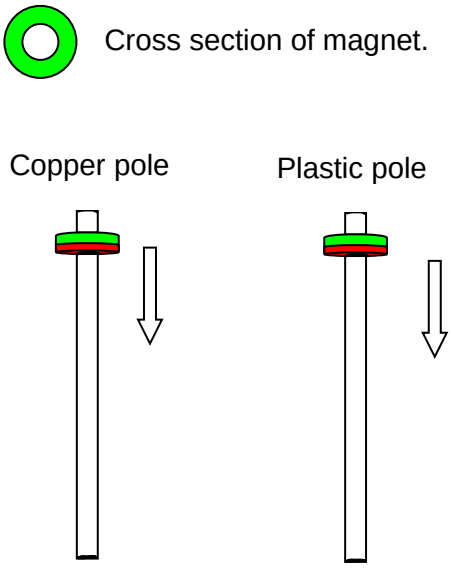
(3)

b) Another particle with a charge of $6.40 \times 10^{-19} C$ enters the magnetic field and undergoes a spiral trajectory. The component of the particle's velocity which is perpendicular to the magnetic field is $2 \times 10^{8}\ m\ s^{-1}$ and the magnetic flux density is $65.0\ \mu T$. Calculate the magnitude of the force applied to the particle.

(2)

Question 10

As shown in the figure, Ashley drops two identical, circular magnets down a frictionless copper pole and a frictionless plastic pole.



a) She notices that if both magnets are dropped at the same time, the magnet on the plastic pole reaches the ground first. Explain this observation.

(3)

b) If the flux density of the magnet sliding down the copper pole was doubled and its mass was also doubled, would the time it takes to reach the bottom of the pole increase, decrease or stay the same or is it impossible to determine how this would affect the time. Circle your answer and explain your choice.

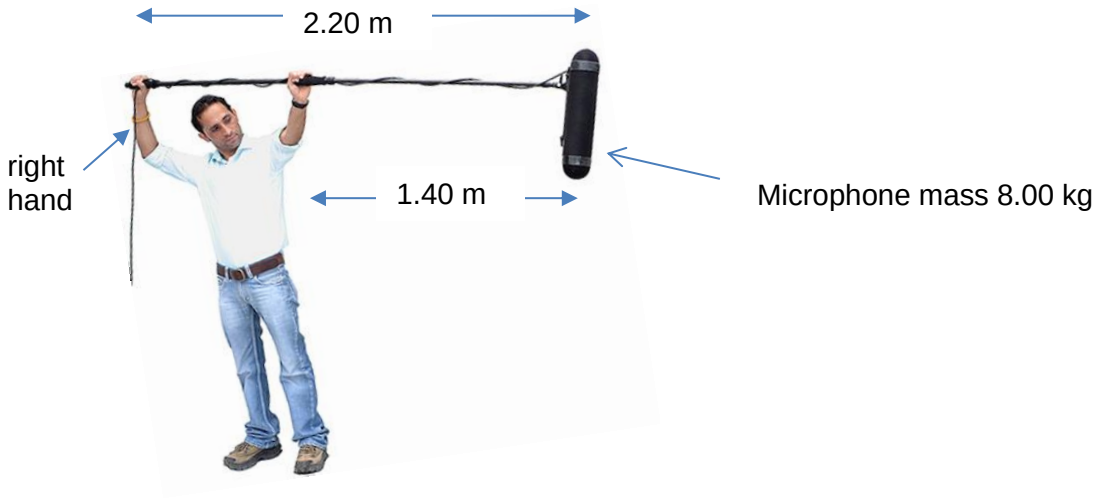
increase decrease stay the same impossible to determine

(3)

Continued on next page

Question 11

The diagram shows a sound engineer holding a microphone boom horizontally. The microphone has a mass of 8.00 kg and the boom arm has a length of 2.20 m and a mass of 1.40 kg. Dimensions are shown on the diagram. The sound engineer applies forces from his hands to the boom arm in a vertical direction.



a) Draw a free body diagram showing the forces acting on the boom.

(1)

b) Calculate the force acting on the sound engineer's left and right hands.

(4)

Question 12

A Boeing KC-135R Stratotanker, which has a wingspan of 39.9 m, takes off from Singapore airport which is near the equator. It then heads directly South. After taking off, the plane ascends at a speed of 237 m s^{-1} at 5.00° to the horizontal. The magnetic field lines at Singapore airport can be considered to be horizontal and the magnetic flux density is 4.70×10^{-5} T.

a) Calculate the potential difference between the wing tips of the Stratotanker as it ascends.

(2)

b) Which location on the wingspan will become positively charged? Circle your answer and explain your choice.

(2)

western wing middle of the wings eastern wing impossible to determine

Explanation:

Question 13

A porter is standing still and supporting a trolley that is loaded with boxes. The combined mass of the trolley and boxes is 84 kg. The trolley is free to rotate about frictionless wheels at its base. The porter applies a force vertically upwards on the handles to maintain equilibrium. The diagram on the right is to scale.

Estimate the net force that the porter applies to the trolley. You must provide reasonable estimates for all data required to answer the question and give your answer to 2 significant figures.

(4)

End of section A

Continued on next page

SECTION 2: Problem Solving

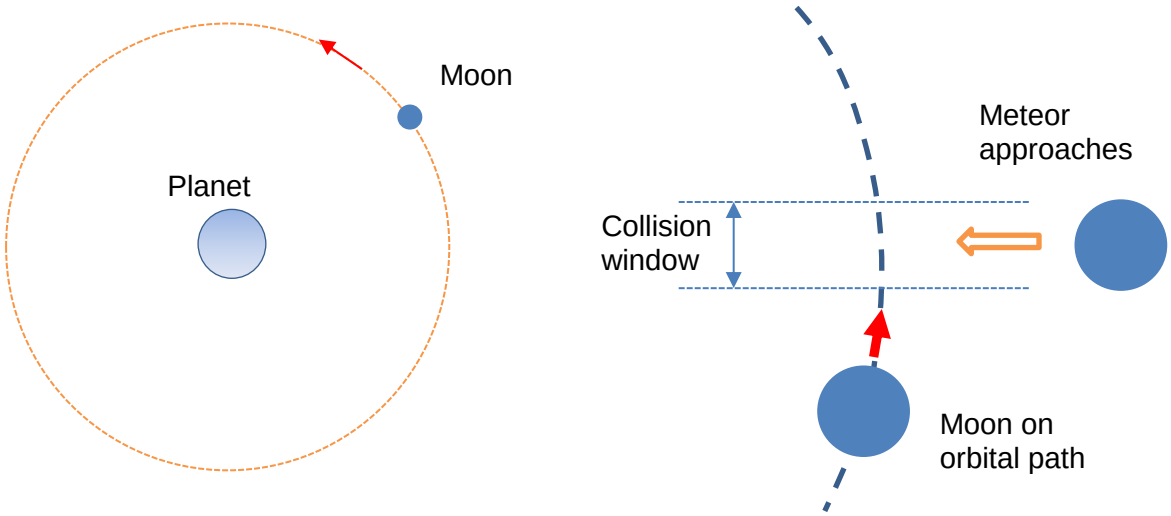
Marks Allotted: *90 marks out of total of 180 marks (50%)*

This section contains 7 questions. You should answer **ALL** of the questions and show **full working**.

Answer all questions in the spaces provided.

Question 1 [16 marks]

The diagram shows a planet of unknown mass. It has a moon of mass 9.23 x 10^{23} kg in a circular orbit. The orbital radius of the moon around the planet is 4.83 x 10^{9} m. It takes the moon 44 Earth days to go around the planet. The moon has a diameter of 14 700 km.



a) Calculate the gravitational field strength of the moon at an altitude of 7 000 km above its surface.

(3)

b) Calculate the orbital speed of the moon.

(3)

c) Derive an equation which expresses the mass of the planet (M) in terms of the orbital radius of the moon (r), the orbital period of the moon (T) and the universal gravitational constant (G). Use this expression to calculate the mass of the planet.

(4)

d) A meteor which is the same size as the moon is heading directly towards the planet from deep space. The meteor is on the same orbital plane as the moon. It is possible that it could collide with the moon if it passes through the moon's orbit at the same time that the moon is in that location (the "collision window" detailed on the diagram). Consider one complete orbital period and calculate the time in minutes that the moon is in this "collision window".

(4)

e) If the meteor "just misses" an impact with the moon it is possible that it will also miss an impact with the planet even though it was originally on a collision course with the planet. Explain why this is so.

(2)

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Question 2 [12 marks]

The Snowy Mountains Scheme is a 3950 megawatt (MW) hydro-electric power generation project located in Australia's Southern Alps. It comprises 7 main power stations and the Scheme produces on average around 4,500 gigawatt hours each year of clean renewable energy for the National Electricity Market. In doing so, the Scheme prevents around 4,500,000 tonnes of carbon dioxide being released each year. That's the equivalent of the exhaust from around 1 million cars.

a) The Tumut 1 power station is part of the Snowy Mountains Scheme. It produces 330 MW of power at 330 kV and supplies this energy to parts of Sydney. Calculate the current running through the electrical cables between Tumut 1 and Sydney (You may consider this situation as a simple series circuit).

(2)

b) Assuming that the resistance of the cables between Tumut 1 and Sydney is 10.00 Ω and the current through the cables is 1000 A, calculate the potential difference (voltage drop) across the cables.

(1)

c) Calculate the power transformed to heat in the cables if the current through the cables is 1000 A.

(2)

d) Determine the percentage of power lost while travelling through the cables.

(2)

e) Explain why voltage is stepped up and current stepped down by transformers before the power is transmitted over long distances.

(1)

f) The 330 kV voltage is stepped down to 66 kV by another transformer when it reaches a city. There are 5000 turns on the primary coil and 1000 turns on the secondary coil. This transformer is 100% efficient in terms of flux linkage but only 86.0% efficient in terms of power transfer from primary to secondary. The power on the primary side is 320 MW. Calculate the current in the secondary coils.

(2)

g) Explain why a transformer only operates with AC power and not DC power.

(2)

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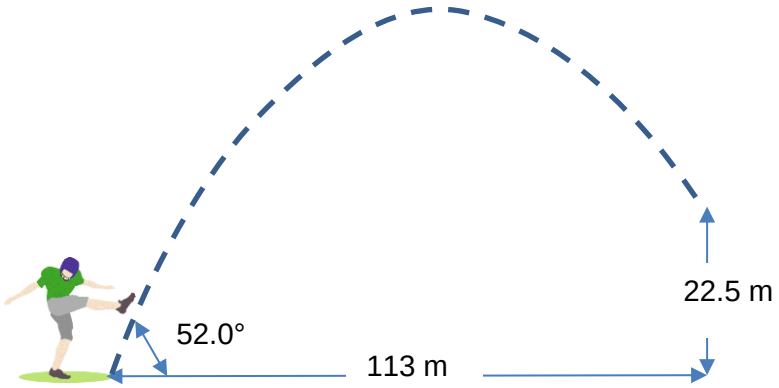
Question 3 [13 marks]

The diagram shows the AFL player Ben Graham as he kicks a goal for Geelong. The ball travels a horizontal distance of 113 m and crosses the goal posts at a vertical height of 22.5 m. The ball leaves his foot at ground level with an angle of elevation of 52.0°. You can ignore air resistance in this question.



a. Calculate the launch speed of the ball.

(7)

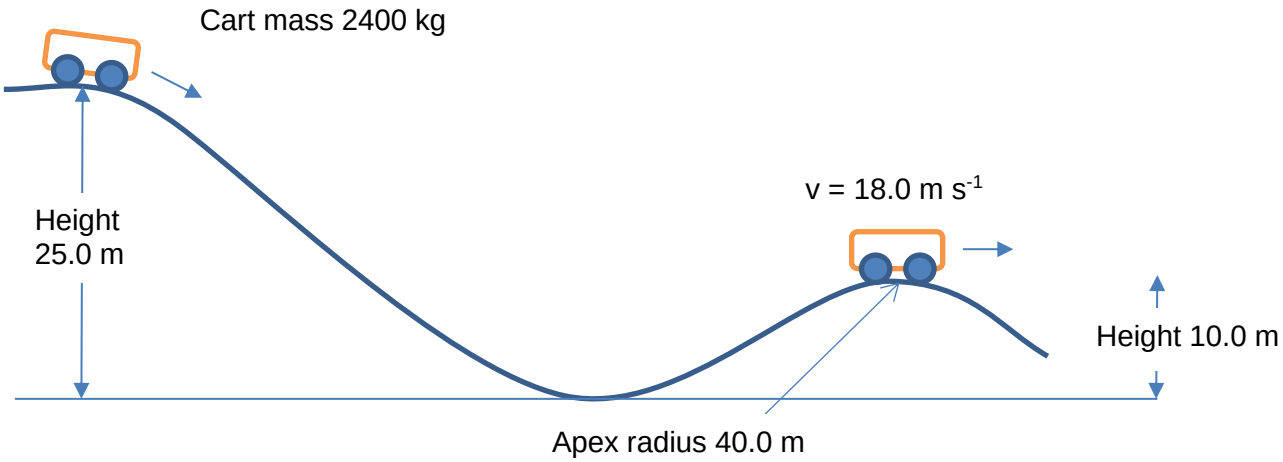
b. Calculate the amount of time that the ball will be above a height of 22.5 m. If you could not solve for the launch speed then use a value of 36.8 m s^{-1}.

(5)

Continued on next page

Question 4 [11 marks]

The diagram shows a cart on a roller coaster track. The cart of mass 2400 kg is already moving at a height of 25.0 m. It follows the track and goes over the apex at 18.0 m s^{-1}. The apex is a section of the track which is the arc of a circle of radius 40.0 m and is 10.0 m high. You can ignore friction and air resistance for this question.



a) Use the principle of conservation of mechanical energy to calculate the initial speed of the cart when it is at a height of 25.0 m.

(4)

b) Construct a vector diagram to show the forces acting on the cart at the apex. You must clearly indicate the sum of forces on this diagram.

(2)

c) Calculate the normal reaction force acting from the track onto the cart as it goes over the apex at a height of 10.0 m.

(3)

d) Explain what would happen to the magnitude of the normal reaction force if the radius of the circular arc on the apex was changed to 30.0 m.

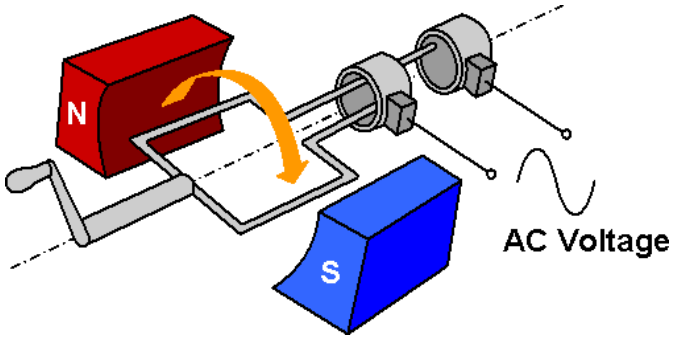
(2)

Continued on next page

Question 5 [13 marks]

The figure shows an AC generator where the mechanical torque is generated by turning a handle. At the instant shown the lengths of the coil are directly next to the poles of the magnets.

The coil is square and has a side length of 20.0 cm. It has 120 turns and is rototed at 90.0 rpm. The strength of the magnetic field is 920 mT.



a) Indicate on the diagram the direction of current flow at the instant shown. Explain your answer.

(2)

b) Calculate the speed of the length of coil beneath the north pole at the instant shown.

(3)

c) Assuming that the speed of the length of coil beneath the north pole is 0.943 m s^{-1}, calculate the maximum *emf* produced by the generator.

(2)

d) If the speed of rotation of the coil is increased would the torque required to turn the coil increase, decrease or stay the same. Circle your answer and explain your choice

(3)

increase decrease stay the same

Explanation:

e) On the graph below sketch the emf (% of maximum) versus time for one rotation from the start position shown in the diagram. Put appropriate numerical values and units on the time axis.

(3)

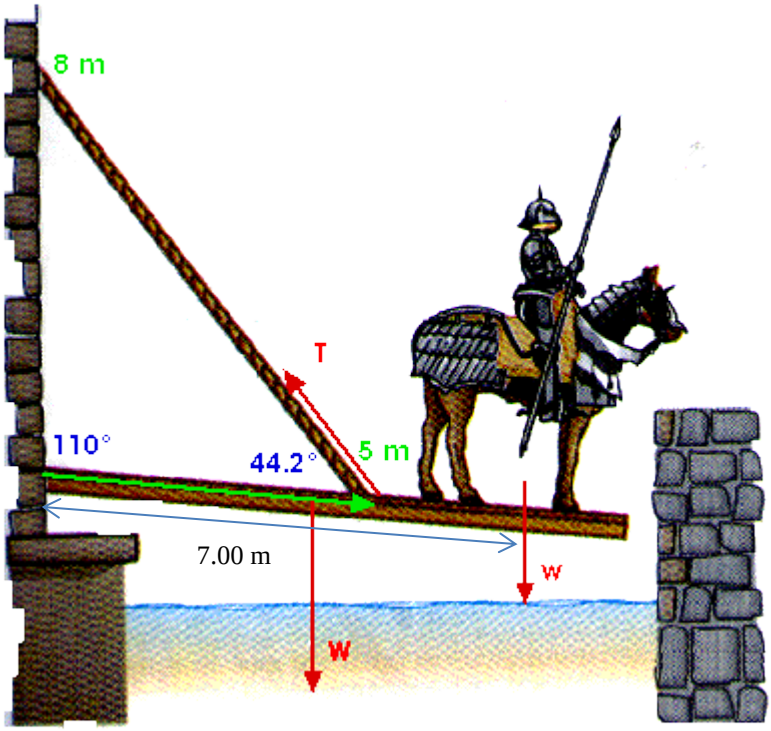
Continued on next page

Question 6 [11 marks]

The diagram shows a knight and horse on a drawbridge which is pivoted at the left hand edge. The drawbridge is 8.00 m long and has a uniform mass of 900 kg. It is not horizontal.

The knight and horse have a combined mass of 750 kg and their centre of mass acts on the drawbridge at a distance of 7.00 m from the pivot. A rope is attached to the drawbridge at a distance of 5.00 m from the pivot.

Important angles are shown on the diagram. The wall where the pivot is attached is vertical.



a) Calculate the tension in the rope.

(4)

b) Calculate the reaction force that the pivot exerts on the drawbridge. Note that this is a vector quantity that has magnitude and direction and it acts below the horizontal. If you could not solve for the tension in part a) then use a value of 23 380 N.

(5)

c) Explain what changes will occur to the tension in the rope if the horse walks backwards toward the castle.

(2)

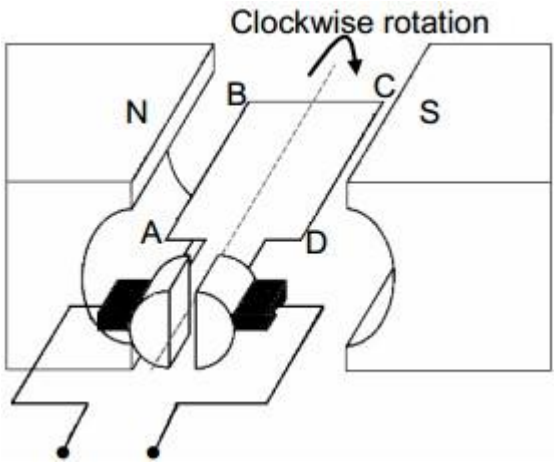
Continued on next page

Question 7 [14 marks]

The figure shows a simple DC motor used to power an electric car.

The parameters of the motor are as follows:

- Length of sides AB and CD = 4.00 cm
- Length of side CB = 3.00 cm
- Number of turns = 10
- Flux density of the magnets = 10.0 mT



a) Indicate on the diagram the direction of conventional current flow if the motor turns in the direction shown.

(1)

b) Explain how the motor produces torque in the position shown.

(3)

c) If the maximum torque applied by the motor is 1.20 Nm, calculate the current which runs through the coils.

(3)

d) If the coil rotates 30.0 ^{o} from the position shown, calculate the torque produced by the motor as a percentage of the maximum motor torque.

(1)

e) What would happen to the current in the coil as the car begins to travel uphill? Circle the correct answer and explain your choice.

(3)

increase decrease stay the same impossible to determine

f) Explain how the commutator and brush arrangement works and why it is necessary on a DC motor.

(3)

End of Section B

Continued on next page

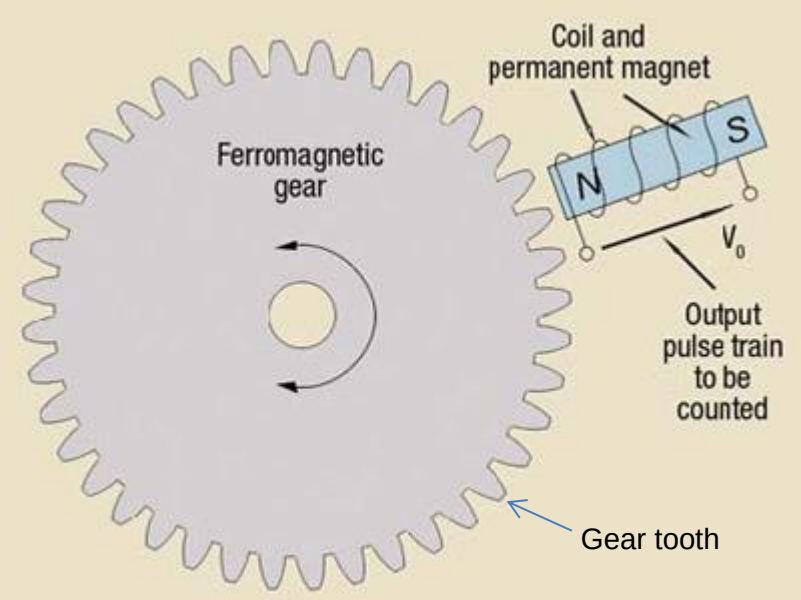
SECTION C: Comprehension and Interpretation

Marks Allotted: 36 marks out of total of 180 marks (20%)

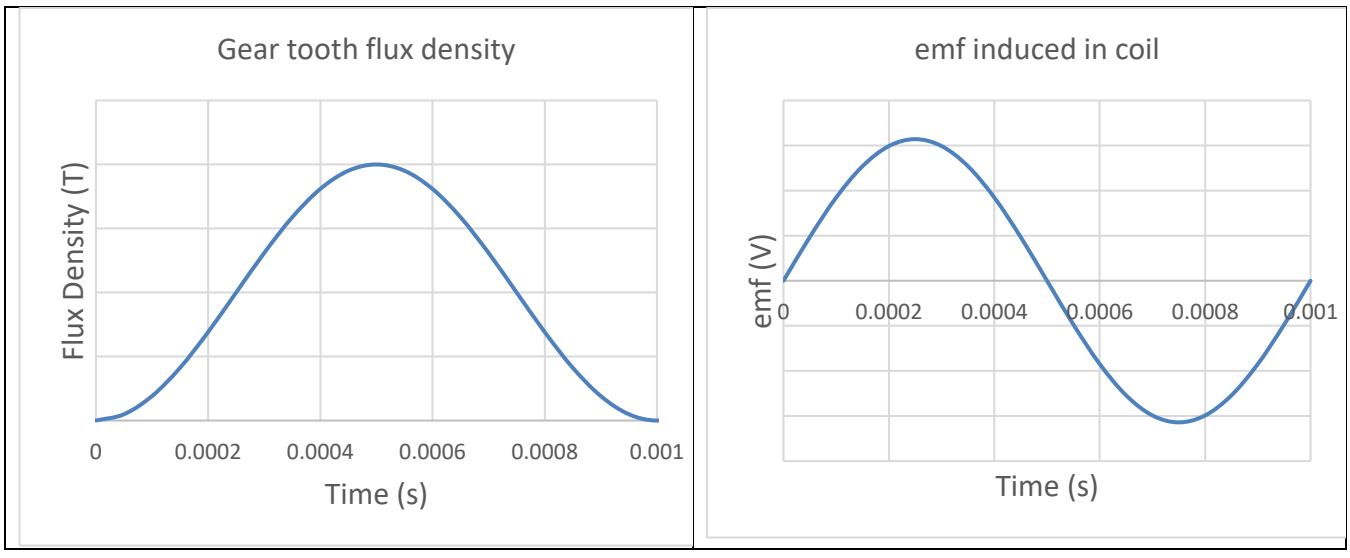
Question 1 [18 marks]

Rotary encoders are common instruments used to determine the angle of rotation and speed of a shaft or gear. They are used in many applications that require precise shaft and gear positions such as robotics, special purpose photographic lenses and rotating radar platforms.

A magnetic pickup (shown in the figure) is a type of encoder which uses a magnet wrapped by a coil and an irregular rotating ferromagnetic member (such as a gear) to determine the position of the gear. In the figure shown the north pole of the permanent magnet induces a south pole in a gear tooth tip as a gear tooth moves beneath the permanent magnet and coil.



The magnetic flux produced by the gear tooth changes the magnetic flux through the coil. The change in magnetic flux through the coil then induces an emf in the coil. The magnetic flux density produced by the gear tooth as it moves beneath the coil and the corresponding emf induced in the coil are shown in the figures below.



Consider a gear with a number of teeth denoted by N_G and a period of rotation denoted by T. During one revolution each gear tooth will be below the coil for the following time;

$$\Delta t_G = \frac{T}{N_G}$$

The time that it takes for the gear tooth flux density to increase from a minimum to a maximum is equal to half of the time that the gear tooth is below the coil.

$$\Delta \mathrm{t} = \frac{\Delta t_G}{2} = \frac{T}{2N_G}$$

To estimate the average emf induced in the coil we can approximate the rate of change of magnetic flux by the following equation;

$$emf_{avg} = -\frac{\Delta \Phi}{\Delta t} = \frac{NB_{max}A}{\Delta t} = \frac{NB_{max}\pi D^2}{4\Delta t}$$

where:

- B_{max} is the maximum magnetic flux density produced by the gear tooth (T)
- A is the cross sectional area of the coil (m^2)
- D is the diameter of the coil (m)
- N is the number of turns in the coil.

Combining the above equation with the time equation gives the following approximation for the average emf induced in the coil.

$$emf_{avg} = \frac{N.N_G.B_{max}.\pi.D^2}{2T}$$

Answer the following questions.

a) Explain why the emf induced in the coil reverses as a gear tooth tip passes underneath the coil.

(3)

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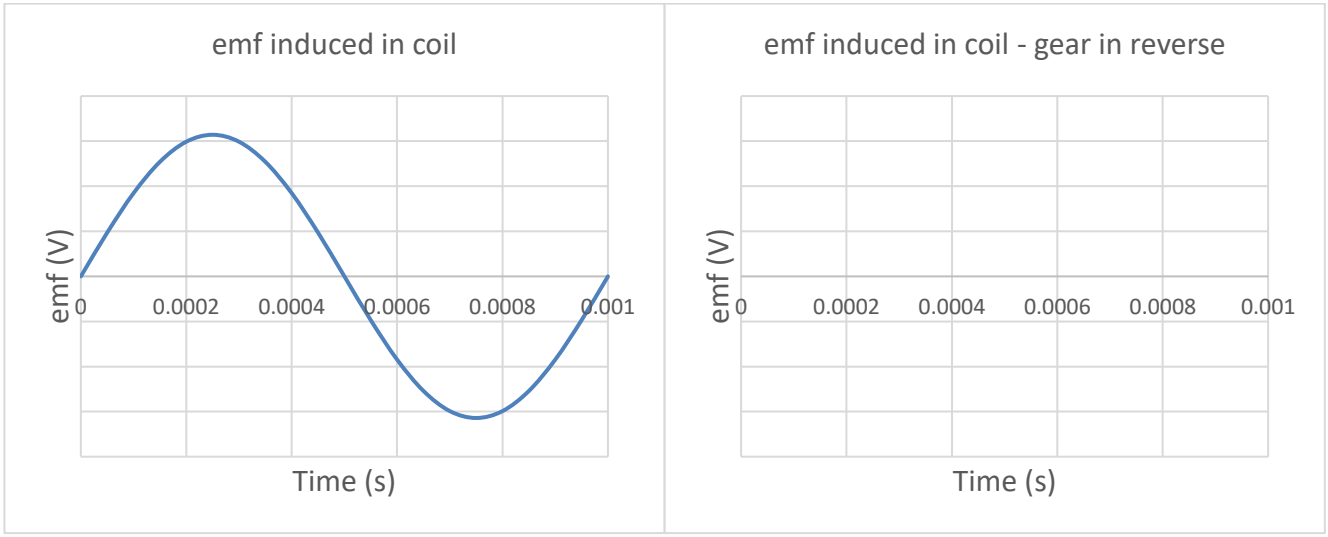
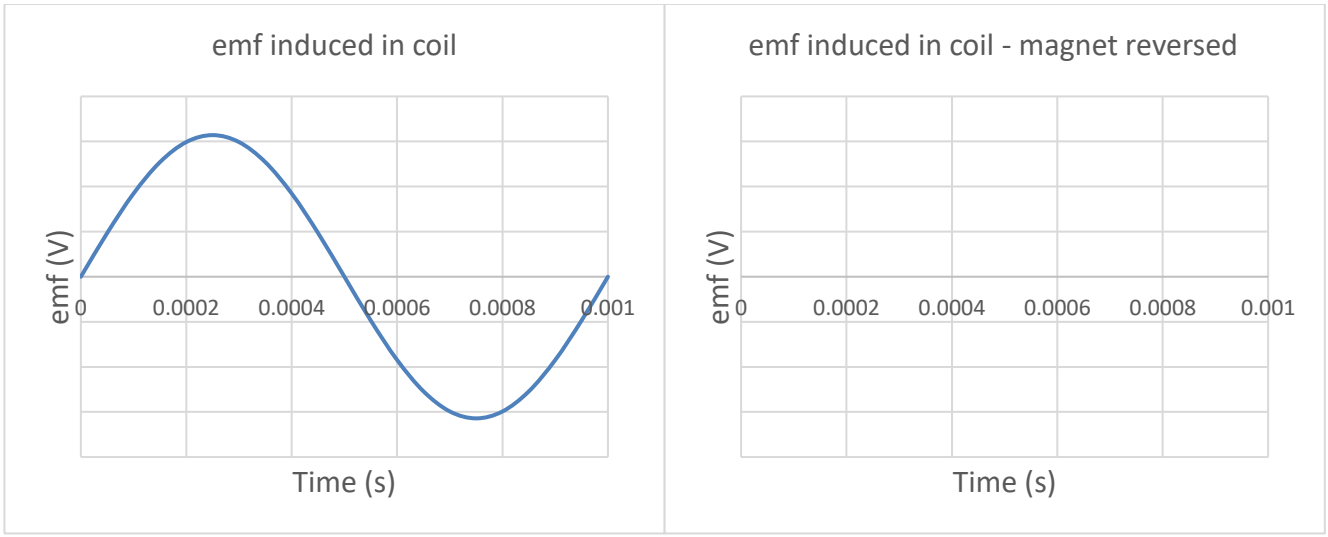
b) The first graph below shows the emf induced in the coil. On the second graph sketch the emf induced in the coil if the gear reverses its direction of rotation. Explain your response. (2)



Explanation:

c) The first graph below shows the emf induced in the coil. On the second graph sketch the emf induced in the coil if the permanent magnet is reversed so that the south pole faces the ferromagnetic gear. Explain your response. (3)



Explanation:

Consider a gear and magnetic pickup with the following values:

number of gear teeth:	$N_G = 60$
rotation rate:	$f(rpm) = 1000\, rpm$
maximum flux density:	$B_{max} = 0.2\, T$
coil diameter:	$D = 0.01\, m$

d) Demonstrate by calculation that the period of rotation is 0.0600 s.

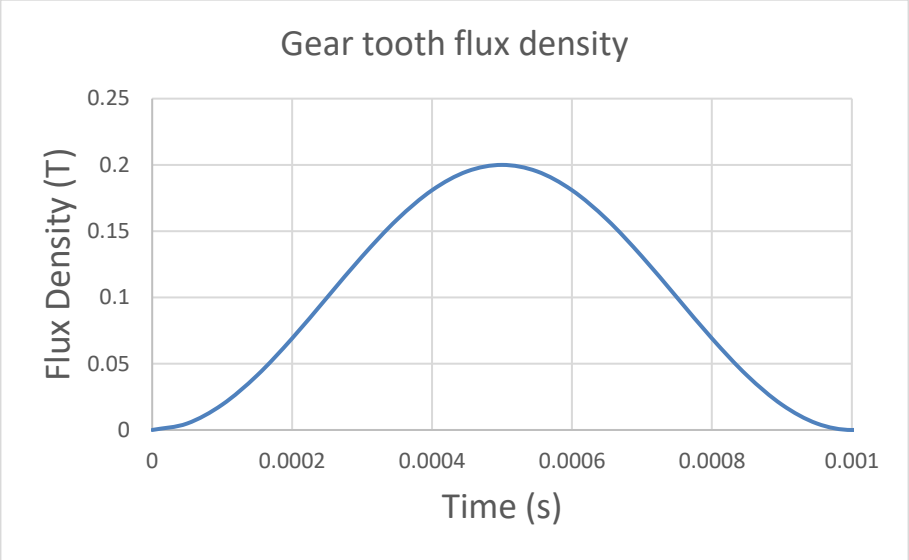
(2)

e) Calculate how many turns the coil should have to generate an emf of 3.77 V when the gear has a rotational period of 0.0600 s. Round your answer to the nearest whole number.

(2)

Continued on next page

The graph below gives the magnetic flux density in the coil produced by a single gear tooth. The time axis indicates the time that the gear tooth is exposed to the magnetic flux of the permanent magnet.



f) With reference to the graph state the magnetic flux density at a time of $6.50 \times 10^{-4} s$. The area of the coil is $3.14 \times 10^{-4}\ m^2$. Use the magnetic flux density value that you stated to calculate the flux through the coil.

(2)

g) Explain why the flux density produced by the gear tooth is a maximum when the gear tooth is beneath the coil-permanent magnet assembly.

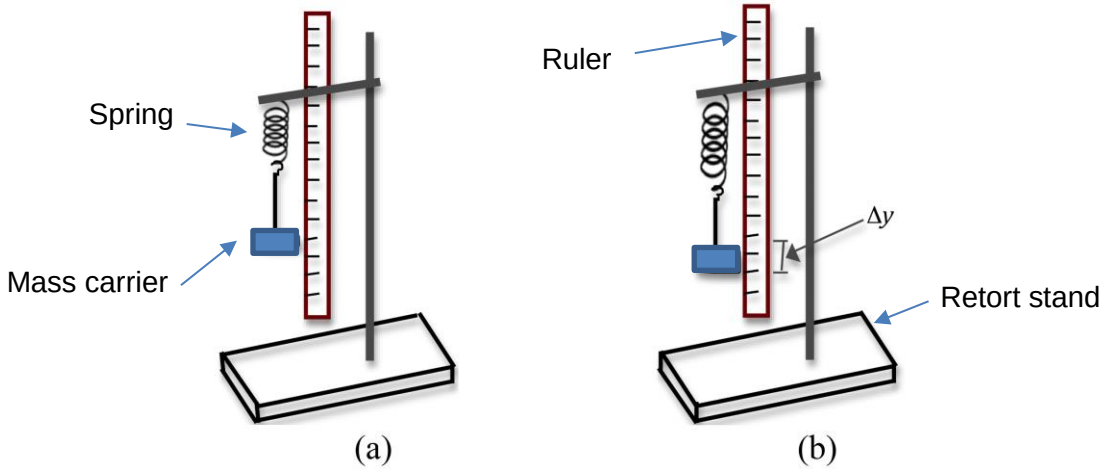
(2)

h) On the graph above place a cross where flux density increases at the fastest rate. Explain why this also corresponds to the maximum emf induced in the coil.

(2)

Question 2 [18 marks]

Students were investigating the simple harmonic motion of a mass oscillating on a spring. The purpose was to determine the value of the spring constant for that particular spring. The spring constant is a measure of the stiffness of a spring. The experimental set up is shown in the diagram below. A mass carrier was attached to the spring as in (a). The mass was pulled down by a displacement Δy as in (b). The mass was then released so that it oscillated up and down on the spring. The time for 20 oscillations was recorded with a stopwatch. This was repeated for a range of mass values. Results are shown in the table below.



It can be shown that the period of oscillation **T (s)**, is related to the other factors in this experiment by the following equation, where m is the **mass (kg)** of the mass carrier that is oscillating and **k (N m^{-1})** is the value of the spring constant.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Mass value (g)	Mass (kg)	Time for 20 oscillations (s)	Period T (s)	Period squared T^2 (s^2)
300		12.36	0.618 ± 0.031	0.382 ± 0.038
350		13.36		
400		14.08		
450		15.00		
500		16.08		
550		16.78	0.839 ± 0.042	0.704 ± 0.070

For this experiment the time values recorded with a stopwatch had an uncertainty of ± 5%

a. Manipulate the data in the table so that you can plot a straight line graph of period T^2 (s^2) versus mass (kg). You must indicate the absolute uncertainty of all time related values. Some of the values have been done for you.

(2)

b. You will be plotting **T^2** (s^2) on the vertical axis and **mass** (kg) on the horizontal axis to get a straight line graph of the general format y = m.x + c
The gradient of your graph will correspond to an average value of: (*circle the correct response)*

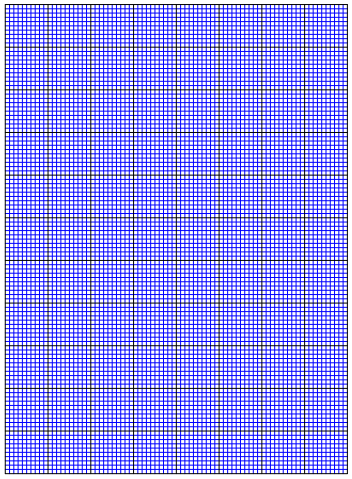
(1)

a. $\frac{2\pi}{\sqrt{k}}$ *b.* $\frac{4\pi^2}{k}$ *c.* $\frac{\sqrt{k}}{2\pi}$ *d.* $\frac{k}{4\pi^2}$

Continued on next page

c. Use the data to produce a graph below. *You must use error bars to indicate the accuracy of the period squared values. You should break your axes appropriately as no analysis of the vertical intercept is required.*

(5)



d. Calculate the gradient of your line of best fit from your graph. Clearly show the rise and run that you used on the graph.

(3)

e. Determine the units of the gradient from your graph axes.

(2)

f. From the gradient of your line of best fit, calculate of the spring constant (k) for the spring used in this experiment.

(3)

g. It was later discovered that the students had, by mistake, only recorded the time for 19 oscillations instead of 20. How would the spring constant that they calculated in part **f.** have been affected by this experimental error? Circle your answer and explain your choice.

The spring constant in part **f.** would have been:

too high not affected by this error too low

Explanation:

(2)

END OF EXAM

Spare pages for additional working.