2 A mass is supported by a single spring as shown.

The strain energy stored by the spring is *E*.

The mass is then supported by two springs, each identical to the first spring, as shown.

What is the total strain energy stored with two springs arranged in this way?

- ☐ **A** ¼ *E*
- ☐ **B** ½ *E*
- ☐ **C** *E*
- ☐ **D** 2*E*

(Total for Question 2 = 1 mark)

7 A star of diameter D and surface temperature T has luminosity L.

What is the luminosity of a star of diameter $\frac{D}{2}$ and surface temperature $2T$?

- ☒ **A** $\frac{L}{4}$
- ☒ **B** L
- ☒ **C** $4L$
- ☒ **D** $16L$

(Total for Question 7 = 1 mark)

8 An object of volume V made from a material of density ρ_1 is placed into a fluid of density ρ_2.

Which of the following gives the upthrust on the object?

- ☒ **A** $\rho_1 Vg$
- ☒ **B** $\rho_2 Vg$
- ☒ **C** $(\rho_2 - \rho_1)\, Vg$
- ☒ **D** $\frac{(\rho_2 + \rho_1)}{2} Vg$

(Total for Question 8 = 1 mark)

9 Electric and gravitational fields have a number of similarities and differences.

An electric field is produced by a point charge and a gravitational field is produced by a point mass.

Which of the following statements applies to both of these fields?

- ☒ **A** The field causes a force on all particles.
- ☒ **B** The force caused by the field can be attractive or repulsive.
- ☒ **C** At a distance x from the centre of the field, field strength is proportional to x^2.
- ☒ **D** At a distance x from the centre of the field, potential is proportional to $1/x$.

(Total for Question 9 = 1 mark)

3 When a force F is applied to a spring with stiffness k, the elastic potential energy stored is E.

What is the elastic potential energy stored when a force $2F$ is applied to a spring with stiffness $2k$?

☒ **A** $\frac{E}{2}$

☒ **B** E

☒ **C** $2E$

☒ **D** $8E$

(Total for Question 3 = 1 mark)

4 There are several different methods that can be used to determine the distance from our solar system to astronomical objects. These include the measurement of red shift, trigonometrical parallax and the use of standard candles.

Which row of the table shows a suitable method for each of the objects named?

	Nearby star	Nearby galaxy	Very distant galaxy
☒ **A**	parallax	red shift	standard candle
☒ **B**	red shift	standard candle	parallax
☒ **C**	parallax	standard candle	red shift
☒ **D**	red shift	parallax	standard candle

(Total for Question 4 = 1 mark)

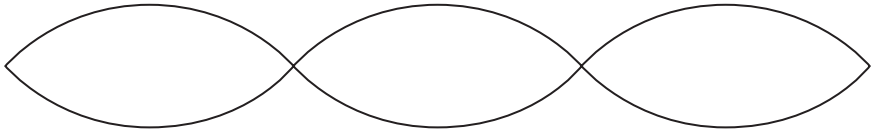
15 The photograph shows a guitar.

When a guitar string is plucked, a standing wave is created.

(a) Explain how a standing wave is created on the string.

(3)

(b) The diagram shows a standing wave on a guitar string.



The oscillating length of the guitar string is 66 cm.

(i) State the wavelength for this standing wave.

(1)

Wavelength = ...

(ii) Calculate the frequency of vibration for this standing wave.

tension in guitar string = 88.6 N

mass per unit length of guitar string = 4.47×10^{-3} kg m^{-1}

(3)

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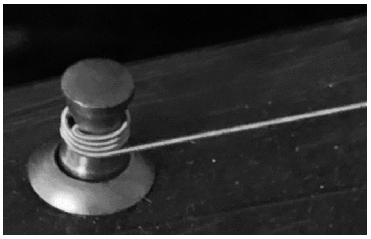
Frequency = ...

(c) One end of the guitar string is wrapped around a cylindrical tuning peg. Turning the peg changes the total length of the string and hence changes the tension in the string. This changes the frequency of vibration of the string.



(i) The length of one string is 68 cm.

Calculate the extension required to produce a tension of 93.4 N in the string.

Young modulus of string material = $1.8 \times 10^{9}\,\text{N m}^{-2}$

cross-sectional area of string = $6.6 \times 10^{-7}\,\text{m}^{2}$

(4)

Extension = ...

(ii) The vibrating length of string is unchanged by turning the tuning peg.

Explain the effect that tightening the string has on the frequency of the sound produced.

(2)

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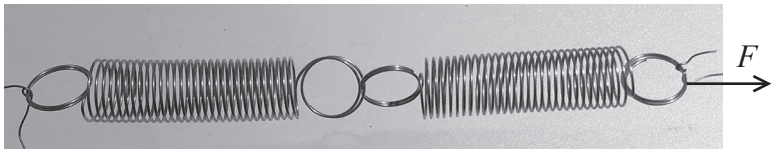
(Total for Question 15 = 13 marks)

Questions 3 and 4 refer to the following information.

A horizontal force F is applied to a horizontal spring, fixed at one end.

The stiffness of the spring is k and the elastic strain energy stored is E.

A second, identical spring is added and the same force is applied to the combination of springs, as shown.



3 What is the stiffness of the combination of springs?

- ☒ **A** $\frac{k}{2}$
- ☒ **B** k
- ☒ **C** $2k$
- ☒ **D** $4k$

(Total for Question 3 = 1 mark)

4 What is the elastic strain energy stored for the combination of springs?

- ☒ **A** $\frac{E}{2}$
- ☒ **B** E
- ☒ **C** $2E$
- ☒ **D** $8E$

(Total for Question 4 = 1 mark)

5 A mass of 24 kg is suspended from a steel wire of length 1.5 m. The wire has cross-sectional area $3.1 \times 10^{-6}\,m^2$.

The Young modulus of steel is 1.8×10^{11} Pa.

Which of the following gives the extension of the wire?

☒ **A** $\dfrac{24 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **B** $\dfrac{24 \times 9.81 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **C** $\dfrac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 1.5}$

☒ **D** $\dfrac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 9.81 \times 1.5}$

(Total for Question 5 = 1 mark)

6 The diagram shows a source of sound waves and an observer.

Which row of the table shows a situation which would result in a decrease in the frequency of sound observed?

	Source	Observer
☒ **A**	moves to the right at 20 m s^{-1}	moves to the left at 20 m s^{-1}
☒ **B**	moves to the right at 20 m s^{-1}	moves to the right at 20 m s^{-1}
☒ **C**	moves to the right at 20 m s^{-1}	stationary
☒ **D**	stationary	moves to the right at 20 m s^{-1}

(Total for Question 6 = 1 mark)

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A sphere of radius r is made from material of density ρ_M. The sphere is fully immersed in a liquid of density ρ_L.

Which of the following expressions gives the upthrust on the sphere?

☒ **A** $4\pi r^2 \rho_M$

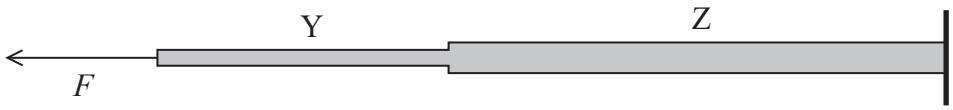
☒ **B** $\frac{4}{3}\pi r^3 \rho_M g$

☒ **C** $\frac{4}{3}\pi r^3 \rho_L g$

☒ **D** $4\pi r^2 \rho_L g$

(Total for Question 1 = 1 mark)

4 A wire Y of cross-sectional area A and length l is joined to a second wire Z of cross-sectional area $2A$ and length $2l$ as shown. Wire Z is fixed at one end and a force F is applied to the other end of wire Y.



The wires are made of the same material.

Wire Y extends by a distance x.

Which of the following is the extension of wire Z?

☒ **A** $4x$

☒ **B** $2x$

☒ **C** x

☒ **D** $\frac{x}{2}$

(Total for Question 4 = 1 mark)

5 A raindrop is falling through the air with an increasing velocity. The forces on the raindrop are weight W, upthrust U and viscous drag F.

Which of the following shows the relationship between these forces?

☒ **A** $F + U = W$

☒ **B** $F = W + U$

☒ **C** $F + W < U$

☒ **D** $F + U < W$

(Total for Question 5 = 1 mark)

16 The suspension system in a car includes a spring attached to each wheel as shown.

(Source: © Macrovector/Shutterstock)

The car, of mass 1100 kg, is stationary. Each spring is compressed by 152 mm due to a quarter of the weight of the car. Each spring is well within both the limit of proportionality and the elastic limit.

(a) State what is meant by within the elastic limit.

(1)

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(b) (i) Show that the stiffness of each spring is about 18 000 $N\,m^{-1}$.

(3)

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(ii) A force is applied to the car which results in a further small compression of each spring. The force is then removed, and the body of the car oscillates with simple harmonic motion.

Determine the frequency of the oscillations.

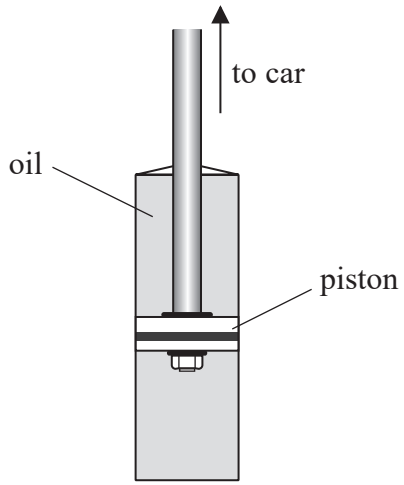
(3)

Frequency = ...

(c) State the conditions for simple harmonic motion.

(2)

(d) The oscillations are heavily damped by a piston in the suspension system. The piston moves within a cylinder filled with oil, as shown. The oil has a high viscosity.



Explain why using oil of high viscosity will produce heavy damping.

(3)

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(Total for Question 16 = 12 marks)