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** $\dfrac{(\rho_2 + \rho_1)}{2} Vg$

(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)

6 A proton can be considered to be both a point charge and a point mass. There is an electric field and a gravitational field associated with the proton.

Which of the following statements about the fields is **not** correct?

☒ **A** Field strength is a vector.

☒ **B** Potential is always less than 0.

☒ **C** Potential is proportional to $\frac{1}{\text{distance from proton}}$

☒ **D** Field strength is proportional to $\frac{1}{(\text{distance from proton})^2}$

(Total for Question 6 = 1 mark)

7 A pendulum of length l with a bob of mass m oscillates with frequency f.

What is the frequency of a pendulum of length $4l$ with a bob of mass $2m$?

☒ **A** $4f$

☒ **B** $2f$

☒ **C** f

☒ **D** $\frac{f}{2}$

(Total for Question 7 = 1 mark)

8 Which of the following lenses would produce a real image of an object placed 15 cm away from the lens?

☒ **A** converging, focal length = 10 cm

☒ **B** converging, focal length = 20 cm

☒ **C** diverging, focal length = 10 cm

☒ **D** diverging, focal length = 20 cm

(Total for Question 8 = 1 mark)

7 The photoelectric effect provides evidence for the particle nature of electromagnetic radiation.

Which of the following observations of the photoelectric effect could also be explained using the wave nature of electromagnetic radiation?

- ☒ **A** The emission of photoelectrons is instantaneous.
- ☒ **B** The maximum kinetic energy of photoelectrons depends on frequency.
- ☒ **C** The rate of emission of photoelectrons depends on intensity.
- ☒ **D** There is a minimum frequency for emission of photoelectrons to occur.

(Total for Question 7 = 1 mark)

8 The acceleration of free fall at the surface of the Earth is $9.81\,\text{m s}^{-2}$.
The mass of the Earth is M and the diameter of the Earth is D.

Which of the following gives the acceleration of free fall, in m s^{-2}, at the surface of a planet with diameter $\frac{D}{2}$ and mass $\frac{M}{9}$?

- ☒ **A** $\frac{9.81 \times 2}{9}$
- ☒ **B** $\frac{9.81 \times 4}{9}$
- ☒ **C** $\frac{9.81 \times 2}{3}$
- ☒ **D** $\frac{9.81 \times 9}{4}$

(Total for Question 8 = 1 mark)

17 Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

(a) Calculate the orbital period for a star in a circular orbit at a distance of 1.9×10^{14} m from a black hole of this mass.

(3)

Orbital period = ...

(b) The star S0-2 is in a highly elliptical orbit around the position of the black hole.

At its point of closest approach, S0-2 is at a distance of 1.8×10^{13} m from the centre of the black hole.

At the most distant point of its orbit, S0-2 is 2.7×10^{14} m from the black hole.

(i) Show that the change in gravitational potential between the closest and most distant points in this orbit is about 3×10^{13} J kg^{-1}.

(2)

(ii) At its point of closest approach, the star is travelling at a speed of $8.1 \times 10^6\,m\,s^{-1}$.

Calculate the speed of S0-2 at the furthest point in its orbit using the change in gravitational potential.

mass of S0-2 = 2.4×10^{31} kg

(3)

Speed = ...

(c) Trigonometric parallax and Hubble's law are two methods used to determine astronomical distances.
Explain whether either of these methods is suitable to determine the distance to S0-2.

(3)

(Total for Question 17 = 11 marks)

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 skydiver steps out of an aeroplane and falls from rest, towards the ground. Her parachute opens a short time after she reaches terminal velocity.

Which of the following statements is correct for the vertical acceleration a of the skydiver until her parachute opens?

☒ **A** a decreases to zero

☒ **B** a increases to a maximum

☒ **C** a is constant and equal to g

☒ **D** a is constant but less than g

(Total for Question 1 = 1 mark)

2 Light travelling in glass of refractive index n_g is incident at a boundary with water of refractive index n_w. The critical angle for the boundary is C.

Which of the following expressions is correct for this boundary?

☒ **A** $\sin C = \frac{1}{n_g}$

☒ **B** $\sin C = \frac{n_w}{n_g}$

☒ **C** $\sin C = \frac{n_g}{n_w}$

☒ **D** $\sin C = \frac{1}{n_w}$

(Total for Question 2 = 1 mark)

12 In February 2021 the spacecraft Perseverance Rover landed on Mars. When the spacecraft was 11.0 km above the surface of Mars, parachutes opened to slow the descent. The parachutes detached from the spacecraft when it was 2.1 km above the surface of Mars.

Calculate the change in gravitational potential energy of the spacecraft during the parachute section of its descent.

mass of spacecraft = 1030 kg
mass of Mars = 6.39×10^{23} kg
radius of Mars = 3390 km

Change in gravitational potential energy of the spacecraft = ...

(Total for Question 12 = 3 marks)