Physics

Higher Level

Paper 2 — Mock Examination

Mock Exam 1

Calculator required

Time allowed: **2 hours 30 minutes**

Maximum mark: **90 marks**

Candidate information

Candidate name: ....

Session number: ....

Date: ....

Topic emphasis: mechanics, thermal physics, electricity, waves, fields, electromagnetic induction, quantum and nuclear physics, rotational dynamics, simple harmonic motion and relativity

Instructions to candidates

- Write your session number in the box on the cover.
- Do not open this examination paper until you are told to do so.
- Answer **all** questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

Where necessary, take the magnitude of the gravitational field strength at the Earth's surface to be $g = 9.81\,\mathrm{N\,kg^{-1}}$ and the speed of sound in air to be $340\,\mathrm{m\,s^{-1}}$. Values of all other constants are given in the data booklet.

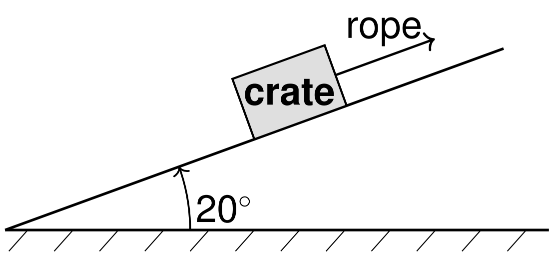
Working must be shown for all questions requiring calculation. Where a question asks you to ***show that*** *a quantity has a given value, full substitution must be seen and the answer should be given to at least one more significant figure than the value quoted.*

Mark allocation

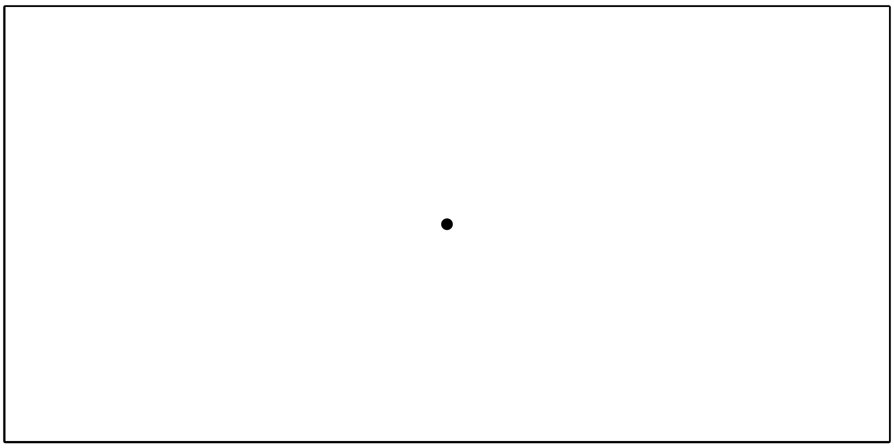
Question 1	[11 marks]	Question 5	[11 marks]
Question 2	[10 marks]	Question 6	[12 marks]
Question 3	[10 marks]	Question 7	[12 marks]
Question 4	[12 marks]	Question 8	[12 marks]

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A crate of mass 45 kg is pulled at a constant speed up a ramp inclined at 20° to the horizontal. The rope is parallel to the surface of the ramp. The coefficient of dynamic friction between the crate and the ramp is 0.25.



(a) Draw and label a free-body diagram showing the forces acting on the crate as it moves up the ramp. **[3]**



(b) **(i)** Show that the normal force acting on the crate is about 410 N. **[1]**

(ii) Calculate the tension in the rope. **[2]**

(c) The crate is pulled a distance of 8.0 m along the surface of the ramp. Calculate the work done on the crate by the tension in the rope. **[1]**

(d) Determine the energy transferred to thermal energy as the crate moves this distance. **[2]**

(e) At a later time the crate is moving up the ramp at $1.2\,\mathrm{m\,s^{-1}}$ when the rope suddenly breaks. Determine the further distance travelled by the crate up the ramp before it comes momentarily to rest. **[2]**

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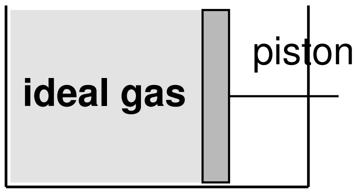
2. A sealed cylinder fitted with a frictionless piston contains 0.25 mol of an ideal monatomic gas. The volume of the gas is $6.2 \times 10^{-3}\,\text{m}^3$ and its temperature is 300 K.



(a) Show that the pressure of the gas is about 1.0×10^5 Pa. **[2]**

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(b) Calculate the average random kinetic energy of one molecule of the gas. **[2]**

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(c) The gas is now heated slowly to a temperature of 450 K at constant pressure.

(i) Calculate the new volume of the gas. **[1]**

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(ii) Calculate the work done by the gas during this change. **[2]**

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(iii) Determine the thermal energy transferred to the gas during this change. **[2]**

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(d) Outline the change, if any, in the entropy of the gas during this heating. **[1]**

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3. A student constructs a heater using a 2.5 m length of nichrome wire of uniform diameter 0.40 mm. The resistivity of nichrome is $1.1 \times 10^{-6}\,\Omega\,\text{m}$.

(a) Show that the resistance of the wire is about $22\,\Omega$. **[2]**

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(b) The wire is connected to a cell of emf 6.0 V and internal resistance $0.50\,\Omega$. Calculate the current in the circuit. **[2]**

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(c) Calculate the power dissipated in the nichrome wire. **[1]**

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(d) A second, identical, nichrome wire is now connected in parallel with the first.

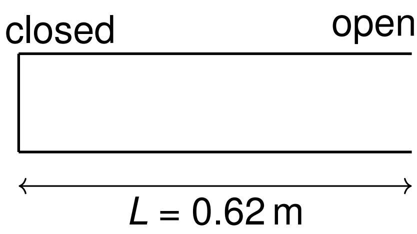
(i) Determine the current delivered by the cell. **[2]**

(ii) Explain why the terminal potential difference of the cell decreases when the second wire is connected. **[2]**

(e) State one assumption made in the calculation in (a). **[1]**

4. This question is about sound waves and about the diffraction of light.

(a) An organ pipe of length 0.62 m is closed at one end and open at the other.



(i) Show that the frequency of the first harmonic of the pipe is about 137 Hz. **[2]**

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(ii) State the frequency of the next possible harmonic of this pipe. **[1]**

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(b) An ambulance siren emits sound of constant frequency 850 Hz. The ambulance travels directly towards a stationary observer at a constant speed of $24\,\mathrm{m\,s^{-1}}$.

(i) Calculate the frequency of the sound received by the observer. **[2]**

(ii) The ambulance passes the observer and then travels directly away at the same speed. Determine the change in the frequency received by the observer. **[2]**

(c) Light of wavelength 589 nm is incident normally on a diffraction grating that has 600 lines per millimetre.

(i) Calculate the angle between the second-order maximum and the central maximum. **[2]**

(ii) Determine the highest order of maximum that can be observed with this grating. **[2]**

(d) Outline why the maxima produced by a diffraction grating are sharper than those produced by a double slit. **[1]**

5. A planet has a mass of 6.4×10^{23} kg and a radius of 3.4×10^{6} m. The planet has no atmosphere.

(a) Show that the gravitational field strength at the surface of the planet is about $3.7\,\mathrm{N\,kg^{-1}}$. **[2]**

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(b) Calculate the gravitational potential at the surface of the planet. **[1]**

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(c) A probe of mass 250 kg is placed in a circular orbit at a height of 500 km above the surface of the planet.

(i) Determine the orbital speed of the probe. **[2]**

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(ii) Determine the orbital period of the probe. **[1]**

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(iii) Show that the total energy of the probe in this orbit is about -1.4×10^9 J. **[2]**

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(d) Determine the minimum additional energy that must be supplied to the probe in this orbit for it to escape from the gravitational field of the planet. **[2]**

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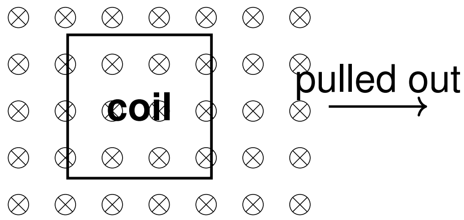
(e) State why the escape speed from the surface of the planet does not depend on the mass of the escaping object. **[1]**

6. This question is about electromagnetic induction and about magnetic forces.

(a) A square coil of 120 turns and side 8.0 cm is placed with its plane perpendicular to a uniform magnetic field of magnitude 0.35 T. The total resistance of the coil is 4.0 Ω. The coil is then pulled completely out of the field in a time of 0.15 s.



(i) Show that the initial flux linkage of the coil is about 0.27 Wb. **[2]**

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(ii) Calculate the average emf induced in the coil. **[1]**

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(iii) Calculate the average current in the coil. **[1]**

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(iv) Outline how Lenz's law determines the direction of the induced current in the coil. **[2]**

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(b) An electron enters a region of uniform magnetic field of magnitude 0.25 T with a speed of $2.0 \times 10^{6}\,\mathrm{m\,s^{-1}}$. The velocity of the electron is perpendicular to the direction of the field.

(i) Determine the radius of the circular path followed by the electron. **[2]**

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(ii) Explain why the speed of the electron remains constant in the field. **[1]**

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(c) Two long straight parallel wires are 0.15 m apart. The wires carry currents of 3.0 A and 5.0 A in the same direction. Determine the magnitude of the force per unit length acting on each wire, and state the direction of this force. **[3]**

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7. This question is about the photoelectric effect and about radioactive decay.

(a) Light of wavelength 450 nm is incident on a clean sodium surface. The work function of sodium is 2.3 eV.

(i) Show that the energy of an incident photon is about 2.8 eV. **[2]**

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(ii) Calculate, in J, the maximum kinetic energy of an emitted photoelectron. **[2]**

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(iii) Determine the stopping potential for this surface. **[1]**

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(iv) Explain why no photoelectrons are emitted from the sodium surface when it is illuminated with light of wavelength 600 nm, however intense that light is. **[2]**

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(b) Strontium-90 $\left({}^{90}_{38}\mathrm{Sr}\right)$ decays by β^- emission to a nuclide of yttrium (Y). The half-life of strontium-90 is 28.8 years.

(i) Write down the complete equation for this radioactive decay. **[2]**

$${}^{90}_{38}\mathrm{Sr} \longrightarrow$$

(ii) A sample of strontium-90 has an initial activity of 4.0×10^6 Bq. Determine the activity of the sample after 50 years. **[2]**

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(iii) Determine the number of strontium-90 nuclei present in the sample initially. **[1]**

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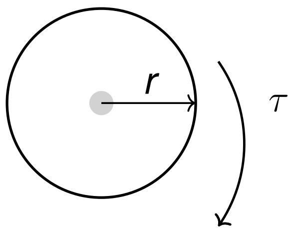
8. This question is about rotational motion, simple harmonic motion and special relativity.

(a) A flywheel is a uniform solid disc of mass 12 kg and radius 0.30 m, free to rotate about a horizontal axis through its centre. The moment of inertia of a uniform solid disc about this axis is $\frac{1}{2}mr^2$.



(i) Calculate the moment of inertia of the flywheel. **[1]**

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(ii) A constant resultant torque of 2.4 N m acts on the flywheel, which starts from rest. Determine the angular speed of the flywheel after 5.0 s. **[2]**

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(iii) Calculate the rotational kinetic energy of the flywheel at this angular speed. **[1]**

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(iv) State the magnitude of the angular momentum of the flywheel at this instant. **[1]**

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(b) A block of mass 0.40 kg is attached to a spring of spring constant $25\,\mathrm{N\,m^{-1}}$ and oscillates with simple harmonic motion of amplitude 0.060 m on a frictionless horizontal surface.

(i) Show that the angular frequency of the oscillation is about $7.9\,\mathrm{rad\,s^{-1}}$. **[1]**

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(ii) Calculate the maximum speed of the block. **[1]**

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(iii) Determine the speed of the block when its displacement from equilibrium is 0.030 m. **[2]**

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(c) An unstable particle has a lifetime of 2.2 μs when measured at rest. The particle travels at a constant speed of 0.95c relative to a laboratory.

(i) Calculate the lifetime of the particle as measured in the laboratory frame of reference. **[2]**

(ii) Determine, in the laboratory frame of reference, the distance travelled by the particle during its lifetime. **[1]**

End of examination.

Total: **90 marks**