R SQUARED — ESAT PREPARATION
MOCK PAPER 1 – PHYSICS

Time: 40 minutes • 27 questions • 1 mark each • no penalty for incorrect answers

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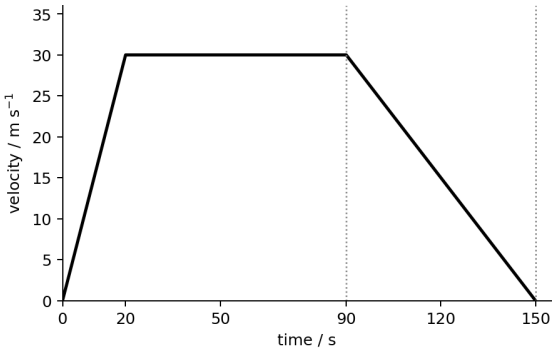
1. A car is travelling along a horizontal road in a straight line. The graph is a velocity–time graph for part of the car's journey.



During this part of the journey, what is the total distance that the car travels while it is decelerating?

A 400 m

B 500 m

C 550 m

D 600 m

E 750 m

F 900 m

G 1400 m

H 1800 m

2. Cosmologists sometimes model a hypothetical universe that is contracting rather than expanding. In such a universe, low-frequency radio radiation that originally filled the whole of space would gradually be compressed into shorter-wavelength radiation as the universe contracts. Which line of the table describes how the contraction of this universe would affect the frequency and wavelength of the radiation?

	effect on frequency	effect on wavelength
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase
E	no effect	decrease
F	no effect	increase

3. An unstable nucleus X becomes a stable nucleus Y after a succession of decays, during which a total of 5 alpha particles and 4 beta (β^-) particles are emitted. How many fewer protons does nucleus Y contain than nucleus X?

A 6

B 8

C 10

D 12

E 14

F 16

G 18

H 20

4. When a kettle of water is heated from below, convection currents form and transfer heat through the liquid. Here are three statements about the water as it is heated:

1. The mass of a fixed volume of the water increases.
2. The density of a fixed mass of the water decreases.
3. The volume of a fixed mass of the water increases.

Which of these statements help(s) to explain how convection currents are formed?

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

5. A nuclide $^{215}_{83}$Bi changes by radioactive decay into the nuclide $^{211}_{83}$Bi. Which combination of emissions produces this change?

A 3 alpha

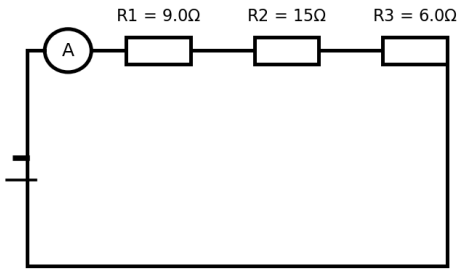
B 2 alpha and 1 beta

C 2 alpha and 2 beta

D 1 alpha and 2 beta

E 3 beta

6. The diagram shows three resistors R1, R2 and R3 connected in series with a battery of constant voltage. The resistance of each resistor and the corresponding current are also shown.



current = 0.40 A
Resistor R3 is now removed and the circuit is reconnected. What is the new current in the circuit?

A 0.40 A

B 0.44 A

C 0.50 A

D 0.60 A

E 0.75 A

F 3.0 A

G 9.0 A

7. Table 1 gives the approximate frequency ranges of sections of the electromagnetic spectrum.

type of wave	approx. frequency range / Hz
radio waves	$< 3.0 \times 10^9$
microwaves	3.0×10^9 to 3.0×10^{12}
infrared waves	3.0×10^{12} to 4.3×10^{14}
visible light	4.3×10^{14} to 7.5×10^{14}
ultraviolet waves	7.5×10^{14} to 3.0×10^{17}
X-rays	3.0×10^{17} to 3.0×10^{19}
gamma rays	$> 3.0 \times 10^{19}$

Table 2 gives information about six different waves in air. Waves 1 to 3 are longitudinal waves formed by an object vibrating. Waves 4 to 6 are electromagnetic waves. The speed of sound in air is 340 $\mathrm{m\,s^{-1}}$. The speed of light in air is 3.0×10^8 $\mathrm{m\,s^{-1}}$.

wave	type of wave	wavelength / m
1	longitudinal	2.0×10^{-5}
2	longitudinal	1.0×10^{-2}
3	longitudinal	2.0×10^{-1}
4	electromagnetic	6.0×10^{-7}
5	electromagnetic	6.0×10^{-1}
6	electromagnetic	2.0×10^{3}

A person detects only two of these waves unaided, using just their eyes and ears. Which two waves does the person detect?

A wave 1 and wave 4

B wave 1 and wave 5

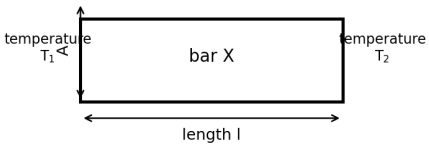
C wave 2 and wave 5

D wave 2 and wave 6

E wave 3 and wave 4

F wave 3 and wave 6

8. A cylindrical copper bar X of length l has a cross-sectional area A. The colder end of the bar is kept at temperature T_1 and the hotter end is kept at temperature T_2.



The curved surface of the bar is perfectly insulated and thermal energy is conducted from the hotter end of the bar to the colder end. Changes in l, A, T_1 and T_2 may alter the rate at which thermal energy is conducted along the copper bar. In which case is the rate of conduction of thermal energy along the insulated bar the same as for bar X?

	change in A	change in l	change in T_1	change in T_2
A	doubles	no change	no change	no change
B	halves	no change	no change	no change
C	no change	doubles	no change	no change
D	no change	halves	no change	no change
E	no change	no change	decreases by 15°C	increases by 15°C
F	no change	no change	decreases by 15°C	no change
G	no change	no change	increases by 15°C	decreases by 15°C
H	no change	no change	increases by 15°C	increases by 15°C

9. When travelling in a vacuum, visible light has a wavelength between 500 nm and 750 nm. The speed of light in a vacuum is 3.0×10^8 m s^{-1}. What can be concluded about ultraviolet radiation from this information?

A It has a maximum frequency of 2.7×10^{14} Hz

B It has a maximum frequency of 4.0×10^{14} Hz

C It has a maximum frequency of 6.0×10^{14} Hz

D It has a maximum frequency of 8.0×10^{14} Hz

E It has a minimum frequency of 2.7×10^{14} Hz

F It has a minimum frequency of 4.0×10^{14} Hz

G It has a minimum frequency of 6.0×10^{14} Hz

H It has a minimum frequency of 8.0×10^{14} Hz

10. A charge of 80 C passes through an electrical component when a steady voltage of 12 V is applied across it for 40 seconds. The resistance of the component remains constant throughout. What is the resistance of the component?

A 0.06 Ω

B 0.24 Ω

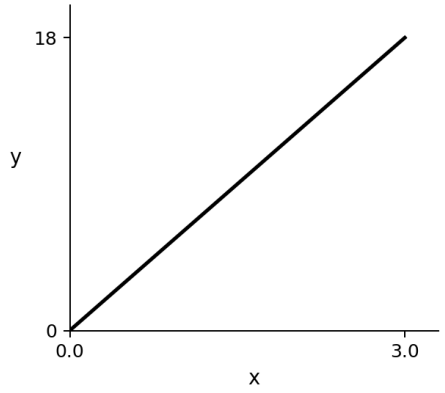
C 0.6 Ω

D 2.4 Ω

E 6.0 Ω

F 24 Ω

11. The graph shown of quantity y against quantity x represents the motion of a body.



(The scales on both axes are in the appropriate S.I. units, and the gravitational field strength g is 10 $\mathrm{N\,kg^{-1}}$.) Which two of the following could the graph represent?

1. kinetic energy against velocity for an object of mass 12 kg undergoing free-fall
2. potential energy against height for an object of mass 30 kg being lifted by a constant external force
3. velocity against time for an object of mass 20 kg being accelerated by a resultant force of 120 N
4. work done by an external force of 6.0 N against distance moved for an object of mass 15 kg being moved at constant speed by (and in the direction of) the external force

A 1 and 2

B 1 and 3

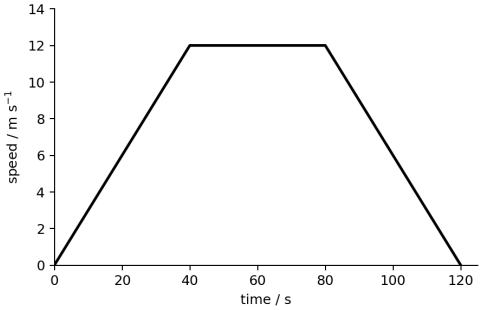
C 1 and 4

D 2 and 3

E 2 and 4

F 3 and 4

12. The graph is the speed–time graph for a bus travelling in a straight line between two stops.



What is the average speed of the bus during this time?

A 3.0 $\mathrm{m\,s^{-1}}$

B 4.5 $\mathrm{m\,s^{-1}}$

C 6.0 $\mathrm{m\,s^{-1}}$

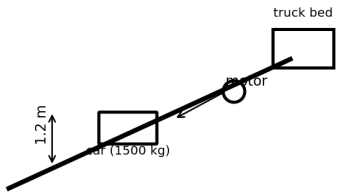
D 8.0 $\mathrm{m\,s^{-1}}$

E 9.0 $\mathrm{m\,s^{-1}}$

F 11 $\mathrm{m\,s^{-1}}$

G 12 $\mathrm{m\,s^{-1}}$

13. An electric motor is used to pull a broken-down car slowly from the road up a ramp on to the back of a breakdown truck.



The car has a mass of 1500 kg and is lifted through a vertical height of 1.2 m. The total input energy to the motor is 35 kJ and it is 70% efficient. In the process of lifting the car, energy is lost to the surroundings from the motor and from other causes. (gravitational field strength $= 10\ \mathrm{N\,kg^{-1}}$) What is the total energy lost to the surroundings?

A 9 kJ

B 11 kJ

C 14 kJ

D 17 kJ

E 23 kJ

F 29 kJ

14. A uranium-235 nucleus can undergo fission to produce two smaller nuclei, releasing neutrons. Three proposed reactions are shown below.
Diagram 1: ${}^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow 3\left({}^{1}_{0}n\right) + {}^{91}_{36}\mathrm{Kr} + {}^{142}_{56}\mathrm{Ba}$
Diagram 2: ${}^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow 2\left({}^{1}_{0}n\right) + {}^{94}_{38}\mathrm{Sr} + {}^{141}_{54}\mathrm{Xe}$
Diagram 3: ${}^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow 3\left({}^{1}_{0}n\right) + {}^{146}_{57}\mathrm{La} + {}^{87}_{36}\mathrm{Br}$
Which of the diagrams, if any, could represent a real fission process (i.e. correctly conserves both mass number and proton number)?

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

15. A filament lamp working at its operating voltage converts electrical energy at a rate of 125 W. The lamp has an efficiency of 4.0%. How much energy is wasted by the lamp in 10 minutes?

A 3000 J

B 4500 J

C 60 000 J

D 72 000 J

E 75 000 J

F 150 000 J

16. In one type of medical scanner a source is placed inside a patient's body. This source causes pairs of gamma-rays to be emitted simultaneously in opposite directions. Detectors on each side of the patient are used to detect the gamma-rays. The distance between the two detectors is 4.0 m. When the source is at Q, half-way between the detectors, the two gamma-rays arrive at the same time. In a particular scan the gamma-rays arrive at the two detectors with a time difference of 6.0×10^{-10} s. Assume that, inside the patient, the gamma-rays travel at a speed of 3.0×10^{8} m s^{-1}. How far from Q, half-way between the detectors, is the gamma-ray source?

A 4.5 mm

B 9.0 mm

C 18 mm

D 4.5 cm

E 9.0 cm

F 18 cm

17. A circuit consists of a 4.0 Ω resistor and a variable resistor connected in series with a 30 V battery. The variable resistor has a minimum resistance of 2.0 Ω and a maximum resistance of 20 Ω. The battery and the connecting wires have negligible resistance. What is the maximum power dissipated in the 4.0 Ω resistor?

A 16 W

B 40 W

C 64 W

D 100 W

E 120 W

F 150 W

18. A student is investigating heat flow along a solid uniform metal bar. The bar has length l, cross-sectional area A, and has its ends maintained at temperatures T_1 and T_2 (where $T_1 > T_2$). Which relationship represents the rate of heat flow P along the bar? (Assume that there is no heat transfer through the sides of the bar.)

A $P \propto \dfrac{(T_1 - T_2)}{Al}$

B $P \propto \dfrac{(T_1 + T_2)}{Al}$

C $P \propto \dfrac{A(T_1 - T_2)}{l}$

D $P \propto \dfrac{A(T_1 + T_2)}{l}$

E $P \propto \dfrac{A}{l(T_1 - T_2)}$

F $P \propto \dfrac{A}{l(T_1 + T_2)}$

19. When a plutonium-239 nucleus absorbs a neutron it undergoes nuclear fission. One particular fission reaction results in the creation of xenon and zirconium as daughter nuclei. The nuclear equation for this reaction is shown but with some non-zero integers replaced by letters:

$$^{239}_{94}\mathrm{Pu} + {}^{1}_{0}n \rightarrow {}^{w}_{54}\mathrm{Xe} + {}^{x}_{z}\mathrm{Zr} + y\left({}^{1}_{0}n\right)$$

Which equation relating w, x, y and z is correct?

A $w + y = 240$

B $x = 240 - (w + y)$

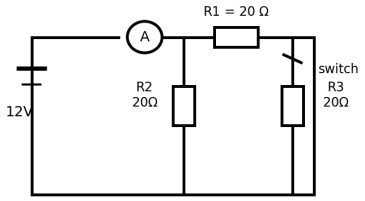
C $y = 40 - z$

D $94 = 54 + x + y$

E $240 = 54 + z$

F $94 = w + x + y$

20. The diagram shows a 12 V battery, a switch and three resistors, each of resistance 20 Ω. The ammeter reads the current leaving the battery.



Initially the switch is open. What happens to the reading on the ammeter when the switch is closed?

A It decreases by 0.05 A.

B It decreases by 0.10 A.

C It decreases by 0.15 A.

D It decreases by 0.20 A.

E It increases by 0.05 A.

F It increases by 0.10 A.

G It increases by 0.15 A.

H It increases by 0.20 A.

21. The potential difference across the motor in an electric car is 350 V and the current in the motor is 1000 A. The car accelerates along a horizontal road from rest for 5.0 s. The efficiency of the overall system is 40%. What is the kinetic energy of the car at the end of the 5.0 s? (Ignore energy losses due to air resistance and due to friction between the tyres and the road.)

A 175 000 J

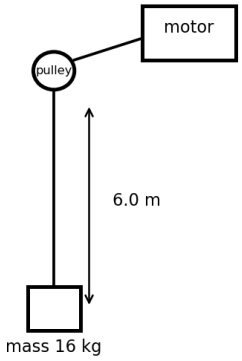
B 437 500 J

C 700 000 J

D 875 000 J

E 1 750 000 J

22. An electric motor is connected to a constant 12 V d.c. supply. The motor is used to lift a mass of 16 kg by means of a rope and pulley. The mass is lifted vertically through a height of 6.0 m in a time of 5.0 s. The complete lifting system (motor, rope and pulley) is 80% efficient.



What is the current in the electric motor? (gravitational field strength = 10 $\mathrm{N\,kg^{-1}}$)

A 1.6 A

B 2.0 A

C 2.5 A

D 16 A

E 20 A

F 25 A

23. The total power P radiated by a star is given by: $P = kR^2T^4$ where R is the radius of the star, T is its surface temperature and k is a constant. The power currently radiated by a certain star is 8.0×10^{25} W. Towards the end of the star's life its radius will increase by a factor of ten and its surface temperature will decrease by a factor of two. What will be the power radiated by the star when these changes have occurred?

A 1.25×10^{25} W

B 2.0×10^{25} W

C 5.0×10^{25} W

D 1.25×10^{26} W

E 2.0×10^{26} W

F 5.0×10^{26} W

G 1.25×10^{27} W

H 2.0×10^{27} W

24. The momentum of a small object moving in a straight line is 40 $\mathrm{kg\,m\,s^{-1}}$ and its kinetic energy is 100 J. What is the mass of the object?

A 2.0 kg

B 4.0 kg

C 6.0 kg

D 8.0 kg

E 16 kg

25. The nuclide ${}^{Q}_{P}\mathrm{X}$ decays to the stable nuclide Y. During this process five particles are emitted: an α-particle and four β^- particles. Which of the following is not a nuclide that could be formed at any stage during this process?

	atomic mass	atomic number
A	P	$Q-1$
B	P	$Q+1$
C	P	$Q+2$
D	P	$Q+4$
E	$P-4$	$Q-2$
F	$P-4$	$Q-1$
G	$P-4$	Q
H	$P-4$	$Q+2$

26. A transverse wave travelling through a medium has a frequency of 8.0 Hz, a wavelength of 5.0 cm and an amplitude of 2.5 cm. What is the total distance travelled by a particle of the medium in one minute?

A 800 cm

B 1200 cm

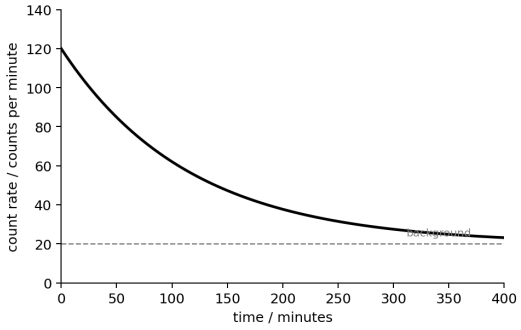
C 2400 cm

D 3600 cm

E 4800 cm

F 9600 cm

27. A radioactive isotope decays in a single step to a stable isotope. A radiation detector is placed very near to a sample of the radioactive isotope in a laboratory. The count rate on the detector changes as time elapses. The graph shows how the measured count rate changes with time.



What is the background count rate and what is the half-life of the isotope?

	background count rate / counts per minute	half-life of isotope / minutes
A	20	60
B	20	70
C	20	80
D	20	90
E	120	60
F	120	70
G	120	80
H	120	90